Republic of The Sudan

Ministry of Environment, Forestry and Physical Development

HCENR

Higher Council for Environment and Natural Resources

Technology Needs Assessment for Climate Change Adaptation

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Disclaimer

This document is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP Risoe Centre (URC) in collaboration with the Regional Centre, Environmental Development Action in the Third World (ENDA), for the benefit of the participating countries. The present report is the output of a fully country-led process and the views and information contained herein are products of the National TNA team, led by the Higher Council for the Environment and Natural resources, Ministry of Environment, Forestry and Physical Development

This document is composed of four parts namely:

Part 1: Technology Needs Assessment.

Part 2: Barrier Analysis and Enabling Framework.

Part 3: Technology Action Plan**.**

Part 4: Project Ideas.

Foreword

Technology Needs Assessment for Climate Change (TNA) is a project implemented by the Higher Council for Environment and Natural Resources (HCENR) in collaboration with the United Nations Environmental Program (UNEP) Risoe Centre (URC), Denmark, and supported by the Global Environmental Facility (GEF) grant financing. Project execution is assisted by a national team composed of eleven experts representing different government institutions, research centres and universities.

TNA is considered as a prospect for Sudan to prioritize technologies suitable for its local conditions and contribute to reducing Greenhouse Gases (GHGs) emissions and to moderate vulnerability to negative impacts of climate change; these technologies will go in line with the national development priorities of the country.

TNA also allows Sudan to come up with ideas for sound projects on appropriate technologies for both adaptation and mitigation. TNA will also contribute to the success of implementation of the United Nations Framework Convention on Climate Change (UNFCCC) as long as the developed countries take a leading role in providing financial assistance and facilitating technology transfer for developing countries.

TNA is a participatory process; it requires consultation of wide range of stakeholders during different steps of the process. Stakeholders participated in the groundwork of these studies will eventually add more to the preparation and success of the TNA as they have diverse views, background and experiences in climate change. Identified sectors and sub sectors for the TNA were built upon previous studies conducted earlier such as the National Adaptation Program of Actions and National Communications.

Environment and poverty alleviation have also been recognized as the cross-cutting issues in the Five-Years Strategic Plan of the country (2007 – 2011). Sound, environmentally benign technologies are needed to be incorporated in the environment conservation and poverty alleviation. The government exerts great emphasis on the improvement and development of mutual relations with international partners, and it is concerned by augmenting a mechanism for benefiting from the latest research, expertise and technologies to enable the country to achieve these goals. TNA in Sudan can go beyond prioritizing technologies to practical approach to spread the use of the technologies identified, as Sudan faces many barriers in the technology transfer such as limited resources, lack of training, poor dissemination tools. In conclusion, TNA will help to overcome these barriers.

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Republic of Sudan

Ministry of Environment, Forestry and Physical Development

Higher Council for Environment and Natural Resources

TECHNOLOGY NEEDS ASSESSMENT

PART 1

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Abbreviations

AIACC	Assessment of Impact and Adaptation to Climate Change
EGTT	Expert Group on Technology Transfer
COP	Conference of Parties
CTI	Climate Tecnology Initiative
FNC	Forests National Corporation
GDP	Growth Domestic Product
GHG	Greenhouse Gases
GoS	Government of Sudan
HCENR	Higher Council for Environment and Natural Resources
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
MDGs	Millennium Development Goals
MEA	MultiLateral- Environmental Agreements
MEPD	Ministry of Environment and Physical Development
MoST	Ministry of Science & Technology
NAPA	National Adaptation Programme of Action
NAPs	National Adaptation Plans
NGOs	Non Governmental Organizations
SNC	Second National Communication
TAP	Technology Action Plan
TNA	Technology Needs Assessment
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

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Executive Summary

Mitigating GHG emissions is only one aspect of climate policy. Equally important will be the need to reduce countries' vulnerability to climate change impacts, so that the livelihoods and ecosystem services on which people depend can be protected and sustainable. This will require adaptation measures in order to increase countries' resilience in areas like health and social systems, agriculture, biodiversity component and ecosystems; as well as production systems and physical infrastructure, including the energy grid. A number of least developed countries, among which is Sudan, are undertaking multiple assessments of vulnerability and adaptation needs to develop their National Adaptation Programme of Action (NAPA) and National Adaptation Plans (NAP). Adaptation is the first and overriding priority for developing countries to respond to climate change and achieve sustainable development.

The starting premise of this report is to present a systematic approach for Sudan to identify, evaluate and prioritize technologies for adaptation and achieving sustainable development objectives. The main outputs are portfolios of prioritized technologies in agriculture and water sectors which are selected among other sectors as the most important contributors to sustainable livelihood of local communities, particularly in the rural areas. Generally, the main sectors vulnerable to climate change and variability, as indicated in Sudan's First National Communication, are Agriculture, Water Resources and Public Health. Traditional rain-fed farmers, small scale farmers and pastoralists are typically the groups least able to cope with climate-related shocks in Sudan. Regarding Sudan's water sector, there is reduced groundwater recharge and drought threatening existing cultivation. Pastoral and nomadic groups in the semi-arid areas of Sudan are also affected by the fluctuations of rainfall. A trend of decreasing annual rainfall and increased rainfall variability is contributing to drought conditions in many parts of Sudan. The adverse impacts of climate change on the water and agriculture sectors already experienced worldwide are often projected to be most severe in resource-poor

countries. Therefore, it is necessary to have access to a diverse array of adaptation technologies that are appropriate and affordable in various contexts. The scale of these adaptation technologies should range from the individual household level, to the community scale, to large facilities that can benefit a city or a region. Within this overall development and climate policy context, a key step for countries is to select technologies that will enable them to achieve development equity and environmental sustainability, and to follow a low emissions and climate resilient development path.

Technology needs assessments (TNA) can serve as an important help for Sudan in formulating national development strategies at all levels. Technologies within such strategies are likely to form a key element contributing to long-term development goals and making the country more resilient to climate change.

In Sudan traditional subsistence agriculture accounts for nearly half of GDP; this sector is responsible for the vast majority of employment. Besides the sector's major contribution to domestic income, it is a main source of foreign currency and national food security. Eradicating poverty through improved agricultural production is among Sudan's primary development objectives. The main adaptation benefits drawn from the adoption of the selected technologies are exemplified in improvement of farms productivity for various agricultural crops, particularly at the traditional subsistence level of agriculture. The benefits that would be generated from the adoption of the selected technologies for the agriculture sector include (1) availability of food – through availability and access to crops, (2) access to food – through provision of infrastructure, (3) stability of food supply and (4) utilization of food. The adaptation technology options for the water sector are derived from the key adaptation activities in water resources management. In Sudan, rain-fed farmers and pastoralists have developed and implemented various low-technology forms of water harvesting to capture larger amounts of scarce rainfall. Projects of water harvesting have increased communities' access to reliable water, thereby increasing their capacity to cope with the impacts of reduced precipitation, increased temperature and drought - all of which has been integrated into the NAPA consultation process.

The methods employed for sectors selection for climate change adaptation started with identification of development priorities of the country in light of a changing climate. The main national strategies of Sudan were explored for the sake of identifying development priorities. This step was followed by preparation of a list of clustered development priorities to fully take into account climate change implications. The main development priorities of the country according to the national strategies are (1) poverty reduction (2) food security (3) public health and social systems (4) biodiversity and (5) sustainable livelihood. These development priorities were grouped under economic, environmental and social priorities from both a short and long term perspective to enhance selection of sectors and their prioritization. The main sectors falling under the umbrella of the development priorities were agriculture, water, land use change and forestry, and human health. In this case, the sectors were ranked according to their contribution to enhancing the resilience of local communities, as perceived by the stakeholders irrespective of the environmental, social and economical benefits.

Due to the short timeframe and limited resources available for the TNA Project, two sectors were selected; namely agriculture and water sectors. Two technologies were selected from each subsector. Improved crop varieties (breeding) and conservation agriculture (zero tillage) were selected for the agricultural sector, while seasonal forecasting and early warning system (monitoring system - automatic water level) and rain water harvesting techniques (*haffir*) technologies were selected for the water sector. Ranking of subsectors and selection of technologies were made according to sound methodology and stakeholders' consultation based on relevant criteria related to economic, social and environmental dimensions.

Chapter 1

Introduction

1.1 Background

Climate change is increasingly recognized as a critical challenge to ecological health, human well-being and future development, as underscored by award of the Nobel Peace Prize for 2007 to the Intergovernmental Panel on Climate Change (IPCC). The award recognizes the substantial advances in our shared understanding of climate change, its causes, consequences and remedies. This work has culminated in the unprecedented impact of the panel's most recent report, the Fourth Assessment Report (Leary et. al., 2008). The adverse impacts of climate change on the different sectors will be experienced worldwide and are often projected to be most severe in resource-poor countries. Therefore, it is necessary to have access to a diverse array of adaptation technologies that are appropriate and affordable in various contexts. The scale of these adaptation technologies should range from the individual household level, to the community scale, to large facilities that can benefit a city or region. Adaptation should not be understood as simply implementing the correct technology or practice; it should be part of a coherent, inter-sectoral strategy to ensure sustainable development. Therefore, tools for planning and decision-making for climate change adaptation in all the sectors are also considered (UNDP, 2010).

Article 4.5 of The United Nation Convention for Climate Change (UNFCCC) states that developed country Parties "shall take all practicable steps to promote, facilitate, and finance, as appropriate the transfer of, or access to, environmentally sound technologies and know-how to other parties, particularly developing country Parties, to enable them to implement the provisions of the Convention". Based on the request made by the Parties to the UNFCCC at the Fourth Conference of the Parties (COP.4), the UNFCCC Secretariat conducted a consultative process to help identify and define key elements of a framework for technology transfer under the UNFCCC

(UNFCC, 2006). Moreover, Article 4.7 of the convention alludes to the dependence of developing countries for financial support and technology transfer to enable them to effectively implement their obligations under the Convention. Decision 4/CP.7 of the UNFCCC adopted a Framework for meaningful and effective actions to enhance the implementation of Article 4.5 and also established an expert Group on Technology Transfer.

1.2 About Technology Need Assessment Project

The TNA Project is an outcome of an agreement signed between the Government of Sudan represented by the Higher Council for Environment and Natural Resources (HCENR) and the United Nations Environmental Program (UNEP) Risoe Centre (URC), Denmark, and supported by the Global Environmental Facility (GEF) grant financing. The Environmental Developmental Action in the Third World (ENDA) provides technical and process support to the participating countries in Africa.

1.3 TNA Project Objectives

The overall objective of the TNA is:

- To identify and prioritize, on the basis of country-driven participatory processes, technologies that can contribute to mitigation and adaptation goals of the participating countries, while meeting their national sustainable development goals and priorities (TNA);

- To identify barriers hindering the acquisition, deployment, and diffusion of prioritized technologies; and

- To develop Technology Action Plans (TAP) specifying prioritized technologies, overcome the barriers and facilitate the transfer, adoption, and diffusion of technologies.

TNA is one of the main components of the technology framework mentioned above, which is designed to enhance technology transfer to developing countries. While global climate change provides serious challenges to Sudan, opportunities to optimize progress towards more sustainable development lie in a growing awareness of the need to find more sustainable production and consumption processes in all the sectors, to respond to climate impacts through adaptation. The Climate Change TNA project has been undertaken to enable Sudan access technologies that could improve its developmental and environmental integrity.

Despite the small amount of GHGs emissions, Sudan is committed to contribute to achieving the objectives of the convention. Sudan signed the United Nation Convention on Climate Change (UNFCCC) in 1992 and ratified it in 1993 and the Kyoto Protocol in February 2005 (GoS, 2007); since then the country did its best to meet all the Convention's commitments. Sudan already submitted its First National Communication in the year 2003 and is about to submit its Second National Communication. In the year 2007 Sudan submitted its NAPA and it is now engaged in the implementation of the first 4 selected priorities that have emerged from the NAPA consultative process. They represent the highest priority interventions as determined through a structured multi-criteria assessment process that involved a broad range of stakeholders. Each project is briefly described regarding its rationale, objectives, activities, expected outcomes, implementation arrangements and budget. It is worth mentioning that in the NAPA four states were selected for the project and from each state the top priority project was selected for implementation. The selected projects were: (1) enhancing resilience to increasing rainfall variability through rangeland rehabilitation and water harvesting in the Butana area of Gedarif State (2) reducing the vulnerability of communities in drought-prone areas of Southern Darfur State through improved water harvesting practices (3) improving sustainable agricultural practices under increasing heat-stress in the River Nile State and (4) environmental conservation and biodiversity restoration in Northern Kordofan State as a coping mechanism for rangeland protection under conditions of increasing climate variability. Currently Sudan is also preparing a national adaptation plan in line with the UNFCCC Cancun agreement. In this context and in response to the request of the UNFCCC for countries to identify and submit their prioritized technology needs, and based on the GEF support made available through the UNEP, Sudan is undertaking this TNA to enhance its enabling environment and opportunity for technology transfer to support its work on climate change adaptation and mitigation. The TNA project has the following objectives: (1) assessing, identifying and finally submitting technology needs for adaptation to the COP of the UNFCCC based on national development needs and priorities, (2) enhancing public awareness on climate change and (3) capacity building in priority areas. The project is implemented by the HCENR in collaboration with the relevant governmental and non-governmental organizations.

1.4 Existing National Climate Change Adaptation and Development Priorities Policies

Sudan implemented several activities under multilateral environmental agreements (MEAs) which have direct relations to climate change adaptation and development priorities. The outcomes of these include a number of assessment reports, strategies and action plans to implement Sudan's obligations under the MEAs, in particular the UNFCCC, United Nations Framework Convention on Biological Diversity (UNCBD) and United Nations Framework Convention to Combat Desertification (UNCCD). The status of these three MEAs is outlined in Table 1.

Table 1: Status of Key MEAs Relevant to Climate Change Adaptation

	Communication
UNFCCC	Ratification 1993
	First National Communication, AIACC AF14 publications; Second National Communication, NAPA
UNCBD	Ratification 1995
	National Biodiversity Strategy & Action Plan
	(National reports (4 reports have been submitted to UNCBD

UNCCD	Ratification 1994
	National Action Programme to Combat Desertification
	National Report on the Implementation of the UNCCD
	The Second National Report on the Implementation of UNCCD/ NAP in Sudan

The NAPA process, under the UNFCCC, identifies specific initiatives that are considered urgent and immediate climate adaptation needs. This process enhanced local capacity in exploiting the range of positive synergies embedded in the national discourse for enhancing environmental quality.

Many of the issues concerning climate change adaptation – ecosystem resilience, reforestation, sustainable agriculture, and increased risk from drought – are also of central concern in the context of the UNCCD. Some of the potential areas of commonality are identified in Sudan's First National Communication under the UNFCCC, Sudan's National Biodiversity Action Plan, and the Second National Report on the UNCCD Implementation for Sudan. Implementing the various MEAs identified above have led to activities, either in place or in development, that are potentially relevant to climate change adaptation. The major types of initiatives are as follows:

* Government Policies and Strategies**:** these are country-driven policy responses to environmental challenges motivated by either commitments under MEAs or national sustainable development objectives;

* National Programs**:** these are specific measures designed to meet specific needs and objectives of national policies, to be funded by national budget and/or bilateral donors;

* Intergovernmental/Multilateral Processes: these are scoping studies that address critical areas affecting or impeding national development; and

* Other Multilateral Activities: these are assorted projects, largely funded through GEF and focused on capacity building and sectoral development priorities.

In Sudan there are several government policies and strategies that are complementary to climate change adaptation goals. The Environmental Protection Act was enacted in 2001 and provides a framework law for policies, legislation and executive action of federal and states organs (GoS, 2007). The objective of the Act is protection of the environment and conservation of natural resources through enhancing coordination between government and other national institutions including private sectors.

One of the most important strategies formulated in the country is the 25-Year Strategy which provides the policy directions to all economic and social sectors, and incorporates the country's environmental strategy. It states clearly that environmental issues must be embodied in all development projects (GoS, 2007). Examples of key national programs are adoption of terrace system for crop production and promotion of water harvesting (hand-dug depressions) for provision of drinking water for human beings and animals. Another key intergovernmental/ multilateral process that has relevant aims to those of climate change adaptation is the Poverty Reduction Strategy which is intimately linked to climate change adaptation. It is worth mentioning that in the Country Report to the World Summit on Sustainable Development, Government of Sudan tried to translate Rio messages into strategies, plans and institutional reforms. In this context, the country has initiated various sectoral strategies for biodiversity, water, agriculture, population, poverty reduction, etc. Along with these, appropriate policies were endorsed and supported by economic reforms. New coordinating institutions were created and serious efforts were made to mobilize the civil society organizations in a partnership to implement the set strategies. Policies and Strategies were reinforced by legislation based on Sudan's 1998 constitution, which specifies the role of the government in the protection of the environment and pursuance of sustainable development.

Chapter 2

Institutional Arrangement for the TNA and the Stakeholders' Involvement

The HCENR is a governmental institution that is mandated to conduct and coordinate activities related to national environmental initiatives and it is a focal point to several MEAs, of which UNFCCC and CBD are major. *Climate Change* has a unit within HCENR. Several ministries, national institutions, researchers, academia, the private sector, NGOs and others of relevance to climate issues are involved.

The implementation arrangement set by the HCENR for Sudan's TNA consists of a national coordinator, national team and core stakeholders. The national coordinator represents the *Climate Change* unit in HCENR and manages the overall process of technology need assessment. In TNA – Sudan project, steering Committee of the Second National Communication played the role of the TNA Project Steering Committee, based on their experiences, to provide strategic policy advice because the majority of the members of the national team and the project coordinator were members of the steering committee of the Second National Communication.

2.1 National TNA team

The formation of the national team was based on the relevant institutions and the familiarity of the member experts with climate change, national development objectives and sector policies. The national team consists of five members representing diverse related backgrounds. The national team acts as a technical task force to conduct the assessment process in Sudan and as a hub through which all activities are coordinated. The mandate of this team is to conduct technical analyses, review vulnerability assessments, to build public awareness and to strengthen national capacity through various workshops and seminars.

The TNA project capitalized on the experience and knowledge of the members of the national adaptation team to lead the process of identification of technologies and their prioritization, in close collaboration with stakeholders from related institutions. The project coordinator and the two team leaders (Adaption and Mitigation) have attended regional capacity building workshops organized by the UNEP Riso Center and ENDA in Naivasha, Kenya, in June 2011 and Fringilla, Zambia, in February 2012. The knowledge and experience gained from these workshops have been shared with the rest of the national team.

2.2 Stakeholder Engagement Process Followed in TNA

As TNA is a country driven approach, the TNA process was made through a consultative process that engaged relevant stakeholders. The stakeholders represent 45 different institutions (List is attached in Appendix II) related to technology development and transfer for climate change adaptation and mitigation in the country. Stakeholders were selected from different entities such as research institutions (University of Khartoum, Forest Research Centre, Agricultural Research Corporation and National Research Centre), NGOs (Practical Action Organization, Sudanese Society for Environment Conservation, and Nile Basin Initiative Discourse), national institutions/ ministries (Ministry of Agriculture & Irrigation and Forests National Corporation, Ministry of Water Resources and Electricity, Ministry of Science & Technology and Ministry of Health), media and labor unions (Farmers Union and Herders Union) and Meteorological Authority.

Two meetings were conducted to introduce the purpose of the project and to create initial awareness among stakeholders in order to facilitate the process of identification and prioritization of technologies. Two stakeholder workshops were organized at the national level. The inception workshop was held with the objective of scoping and discussing the priority sectors. It was attended by about 110 participants representing 45 related institutions (government, private sector, academia, research and technology institutes, NGOs, and the media). In the second stakeholders workshop about thirty five stakeholders contributed to the prioritization of the subsectors and the needed technologies. Figure 1 below shows the institutional organization of the TNA process in Sudan.

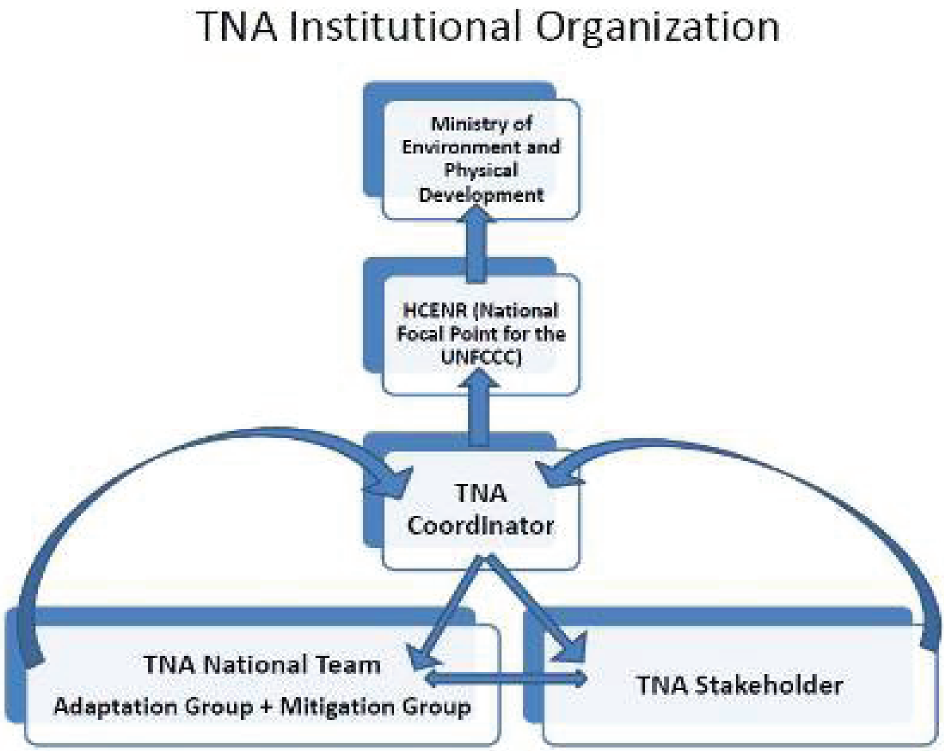

Figure 1. TNA Institutional Organization

Chapter 3

Sector Selection

3.1 An Overview of Expected Climate Change and Impact - Sectors Vulnerable to Climate Change

A changing climate may alter a country's development needs over time and this will affect the country's technology needs for adaptation. An analysis based only on current climate conditions is liable to fail to prioritize the relevant sectors affected by current and future changes in climate and the technologies that will be needed. It must be noted though that an assessment of climate change impacts is surrounded by large uncertainties which increase with a more disaggregated climate change analysis (UNDP, 2010). In Sudan, for the selection of sectors for climate change adaptation attempts were made to analyze the development priorities in light of a changing climate. Based on analyzing existing national development strategies the team identified the clusters of development priorities required in the TNA process. This process involved consultation of many publications related to national development in Sudan. The main national strategies consulted and explored were (1) Poverty Reduction Strategies (2) Sudan's First and Second National Communications to the UNFCCC (3) National Adaptation Programme of Action (NAPA) (4) Millennium Development Goals (MDG-Sudan) (5) Agriculture Revival, Prospective Working Plan Guidance (Ministry of Science and Technology) (6) Assessment of Impact and Adaptation to Climate Change (AIACC) (7) Presidential Decree No. 22 for 2010 (determination of the executive and presidential national systems and their priorities and specialization and (8) the current 25-years national strategy. Exploring the national development strategies revealed the following Sudan development priorities, namely:

1. Poverty Reduction
2. Food Security
3. Health and Social systems
3. Biodiversity

4. Sustainable Livelihood, and
5. Combating Desertification

3.1.1 Implications of Climate Change and Vulnerable Sectors in Sudan

The implications of climate change for Sudan are highlighted in short and long terms. In Sudan, which is characterized by different ecological zones, sub-continental warming is predicted to be greatest in the northern regions, particularly the desert and semi-desert regions. Climate scenario analyses conducted as part of the preparation of Sudan's FNC indicate that average temperatures are expected to rise significantly relative to the baseline scenario. By 2060, projected warming will range from 1.5°C to 3.1°C during August and1°C to 2.1°C during January. Projections of rainfall under climate change conditions also show sharp deviations from the baseline scenario. Results from some of the models show average rainfall decreases of about 6 mm/month during the rainy season. Therefore, the different sectors (agriculture, water, health, livestock, settlements and infrastructure) will be variously affected. A rise in average temperatures and drop in annual rainfall will affect the viability of current agricultural production systems and the efficacy of current water resource management strategies, while at the same time endangering public health. As such, climate change poses serious challenges to Sudan's overriding development priorites in agriculture, forestry, water resource management and energy development. Adaptation-related activities that build upon existing national processes, forge new linkages where possible and break new ground where needed, have the potential to lessen this climatic vulnerability. The key adaptation activities in agriculture, as pointed out by NAPA (2007) include (1) drought early warning systems for disaster preparedness (2) strengthening of extension services, including demonstration (3) extension services in agricultural capacity strengthening for small-scale farmers (4) water harvesting (5) introduction of drought-resistant seed varieties, poultry and fish production and (6) protection and/or rehabilitation of rangelands and construction of shelterbelts. The NAPA process, and the scoping, consultation and prioritization processes embedded therein, offer a framework for enabling the necessary adaptation action (HCENR, 2007).

3.1.2 Agriculture Sector Vulnerability to Climate Change

Agriculture is inherently sensitive to the climate and is therefore a vulnerable sector. The agricultural sector is the most important sector due to its direct contribution to enhance the resilience of local communities through food security and reduction of poverty. Agriculture's socio-economic importance magnifies the sector's vulnerability to climate change. The climate projections for Sudan indicated an increase in temperatures and a decrease in rainfall (GoS, 2007). Agriculture is projected to continue to be vulnerable under the current cropping, livestock and tree-growing regions. The commercial agriculture sectors have a relatively high autonomous adaptation due to their organized nature, relatively large scale (and thus access to expertise and capital) and have demonstrated a capacity to be very agile. However, traditional subsistence agriculture dominates Sudanese economy, with about 70% of the population dependent upon crop production and/or livestock husbandry to support their livelihoods. As small-scale farmers who employ largely rain-fed traditional practices dominate the agriculture sector, on which Sudan's food security and economy (especially foreign currency) are largely dependent high vulnerability to climate variability and change emerges as a vital national strategic concern. Indeed, eradicating poverty through improved agricultural production is among Sudan's primary development objectives. Sudan's diverse agro-ecological zones offer the potential to produce a fairly wide range of crops, as well as livestock products. Yet production is consistently quite low, due to the vulnerability of rain-fed agriculture to rainfall variability, prolonged drought and lack of appropriate development inputs including technologies. The situation is aggravated by prevailing conditions of poverty and other environmental factors that create a number of pressing challenges for Sudan. For example, land degradation has affected large areas and continues to threaten arable lands. Depletion of forests threatens species and human communities, reducing valuable services forests provide. Table 2 summarizes the types of extreme weather and climate events, vulnerable sectors and the observed negative impacts on community livelihoods in Sudan (NAPA, 2007).

Table 2. Extreme Climate Events in Sudan - Sectors Affected & Impact Categories

Event	*Sectors*	*Impacts*
Drought	Agriculture, livestock, water resources and health	Loss of crops and livestock, decline in the hydroelectric power, displacement wildfire
Floods	Agriculture, livestock, water resources and health	Loss of life, crops, livestock; insects and plant diseases, epidemic/vector diseases, decline in hydro power; damage to infrastructure and settlement areas
Dust Storms	Transport	Air and land traffic accidents and health
Thunder-storms	Aviation	Loss of lives and properties
Heat Waves	Health, agriculture & livestock	Loss of life, livestock and crops
Wind-storms	Settlements and service infrastructure	Loss in lives, property; damage to infrastructure (electricity and tele-(phone lines

Source: NAPA 2007

In Sudan's FNC, the Vulnerability and Adaptation Assessment identified key vulnerabilities in the country. The top priority sectors include: agriculture (small, medium and large scale), water resources (permanent, seasonal and ground water courses), and public health (with special emphasis on malaria transmission potential). A preliminary assessment of climate adaptation options indicates that in a number of cases, there are complementarities between these actions and the actions recommended in the context of the Biodiversity and Desertification Conventions. In response to these challenges, Sudan has been actively seeking to promote domestic sustainable development policies, engaging in international cooperation to access technology and financial support, facilitating strategic research, employing preventive measures and monitoring mechanisms, enabling ground-level development work, and strengthening its human and institutional capacity. Sudan is presently engaged in a range of projects and processes that support a sustainable development trajectory.

3.1.3 Water Resource Vulnerability to Climate Change

In addition to the River Nile, the primary water sources in Sudan are the seasonal non-Nilotic wadis and streams; groundwater and unconventional water. The River Nile is Sudan's primary source of water, which it shares with ten countries within the Nile Basin. The Wadis waters are shared with three countries and ground water is shared with three countries. The Nile River has exhibited extreme annual flow variations. These extremes motivated the construction of storage dams, including Sennar and Roseires on the Blue Nile, the Girba dam on Atbara, the Gebel Aulia dam on the White Nile, and the Marawi dam on the River Nile (Abdalla *et. al.*, 2011). Irrigated agriculture is by far the major user of water in Sudan, consuming more than 90% of the allocated water. Human and animal consumption together are estimated to be 5% of total consumption, while industrial and other uses make up only 1% (Abdalla *et. al*., 2011).The combined effects of the Inter tropical Convergence Zone (ITCZ) and the country's topography dominate Sudan's climate. The result is a wide spatial variation in rainfall. Sudan's ecological zones reflect this variation, ranging from high rainfall savanna vegetation in the south, to low rainfall savannah in the central areas, to vast semi-arid to desert areas in the north. The Nile water basin contributes most of Sudan's available surface water, transporting over 93 billion cubic meters (bcm) of water per year on average, though only a fifth of this may be used in accordance with a 1959 water use treaty with Egypt (NAPA, 2007).

Disastrous drought, an unpredictable and recurring climatic event, was experienced in Sudan at least five times during the last century. The weather systems which underlie the extreme variability of the rainfall in arid and semi-arid Africa are thought to be the result of displacement of wind (Nicholson, 1983). Through the use of climatic impact assessment technology using sophisticated and extensive application of satellite-based remote sensing, early warning of potential drought induced food shortages enables more careful review of actual field conditions and preemptive mobilization of drought relief efforts (Catterson et. al., *ibid* r, 1989). Desertification on the other hand is even a more serious problem than drought in that it represents a long-term, pervasive loss of productivity in a world where escalating populations can scarcely afford to lose it. FAO (*ibid* n), (1989b) showed that drought often exacerbates the impact of desertification but it is principally a result of man's inadequate stewardship of the land driven by the exponential demographic pressures.

3.1.4 Public Health

The evidence of anthropogenic climate change is now clear and convincing. The Earth's surface has warmed by more than 0.8 °C over the past century and by approximately 0.6 °C in the past three decades (NASA, 2007). This warming has been linked to more extreme weather conditions such as intense floods and droughts, heavier and more frequent storms, and a possible increase in frequency and intensity of the El Niño Southern Oscillation. These changes are largely caused by human activities, mainly the burning of fossil fuels releasing carbon dioxide (CO_2) that traps heat within the atmosphere. These CO_2 emissions continue to rise, and climate models project the average surface temperature will rise by 1.1 °C to 6.4 °C over the 21st century (ibid).

Since 1990, WHO (2004) has published a series of reports on climate change and has participated in review processes such as the Intergovernmental Panel on Climate Change. These activities have outlined four key characteristics of the health risks generated by a warming and a more variable climate. First, these hazards are diverse, global and probably irreversible over human time scales. They range from increased risks of extreme weather, such as fatal heat waves, floods and storms, to less dramatic but potentially more serious effects on infectious disease dynamics, shifts to long-term drought conditions in many regions, melting of glaciers that supply freshwater to large population centres, and sea level increases leading to salination of sources of agriculture and drinking water. Secondly, the health impacts of climate change are potentially huge. Many of the most important global killers are highly sensitive to climatic conditions. Malaria, diarrhea and protein-energy malnutrition together cause more than 3 million deaths each year.[3] Third, these risks are inequitable, in that the greenhouse gases that cause climate change originate mainly from developed countries, but the health risks are concentrated in the poorest nations, which have contributed least to the problem (Ja Patz, *et. al*., 2005). Finally, many of the projected impacts on health are avoidable, through a combination of public health interventions in the short term, support for adaptation measures in health-related sectors such as agriculture and water management, and a long-term strategy to reduce human impact on climate.

Communities in Sudan are likely to be exposed to a significantly increased risk of malaria under climate change (NAPA, 2007). Studies in Kordofan State, for example, have shown that the risk of transmission potential could increase substantially by 2060 (SFNC, 2002). This can put the already overburdened health care system under extreme stress and the disease would take a heavy toll (Zakieldeen, 2007). Previous studies in Sudan have confirmed the correlation between temperature and precipitation patterns and malaria, meningitis, and leishmaniasis, diseases that afflict millions throughout the country. While the NAPA consultation process confirmed that malaria is a major concern, the other diseases were also prioritized for adaptive measures. Adaptation activities will need to take into account the diversity of factors that influence the capacity to cope with health hazard outbreaks. Specifically, major adaptation activities and needs that have been identified across the five ecological zones are as follows (GOS, 2007):

* Improve community sanitation and medical services, including capacities for diagnosis and treatment;
* Building of community awareness regarding preventive measures for malaria, meningitis, and leishmaniasis;
* Introduction of preventive measures to restrict malaria transmission such as mosquito nets, treatment/drying up of breeding sites;
* Introduction of early disease diagnosis and treatment programmes for malaria, meningitis, and leishmaniasis;
* Improvement of irrigation system management so as to reduce breeding sites; and
* Provision of alternative water supply systems for domestic use that do not involve open standing water areas.

3.1.5 Livestock Breeding

Livestock have always been fundamental to life in some of the world's driest places. Able to travel, gathering water and energy from far and wide, grazing animals can support livelihoods where crops struggle to even survive. As climate changes and dry places become even drier, however, more livestock compete for less water, and rangelands fail to provide food through the year. The Butana region of Sudan is one such place and can be considered as a case study to represent the nomadic life in Sudan. The Butana Integrated Rural Development (IRD) Project is an attempt to help communities make the most of their small share of resources. Butana lies on a dry plateau east of the River Nile. While it sits outside the narrow band of fertility watered by the legendary river, the region is still considered relatively green - relative, that is, to other areas of Sudan, a drought-prone country straddling the Sahara. Butana has a reputation for prime grazing land, but the greenery is highly seasonal, with rainfall limited to only a brief period in the middle of the year (Masuad, 2010). The IFAD-Butana Integrated Rural Development Project (BIRDP) is an attempt to help communities make the most of their small share of resources.

As in other dry regions people cope with seasonal changes through transhumance, yearly migrations with their cattle, sheep or camels in search of water and forage. Butana is crossed by many such transhumance routes, which can make life difficult for the local people. After a few months of herds passing through, water supplies and plant cover regularly fall short well before the end of the long dry season. With the climate becoming drier by the year and concentrations of livestock continuing to grow, the shortfall is turning into a serious problem indeed for the people of the Butana. The reputation of Butana region for green pastures still holds true in the rainy season - for a short time; at least signs of rangeland degradation are most apparent in areas around sources of drinking water, which are extremely localised. The perennial rivers, streams and ponds are quickly drained after the rains, leaving livestock and people alike to rely on a variety of specialised man-made water sources; the most widely used being a very old technology: dugout reservoirs called *haffirs,* which harvest water from surrounding land during the rainy season. Hand-dug surface wells and newer boreholes also dot the landscape (ibid).

3.1.6 Settlements and Infrastructure

More frequent extreme events are likely to impact critical infrastructure. For example, transport infrastructure, such as roads and rail, may be damaged or rendered unusable as a result of extreme events, such as localized flooding, which in turn impacts on the access to settlements and economic productivity. Roads networks may also be threatened by increasing frequency of extreme hot days and increased temperatures, which may damage bitumen. Higher temperatures and more frequent heat waves may lead to greater energy demand for cooling, increasing the stress on energy distribution networks. While essential infrastructure and services across the State are vulnerable to the long-term impacts of climate change, low-lying coastal settlements will be particularly vulnerable now and over the medium to long-term.

Communities currently living in coastal local government areas are vulnerable to storm surge, coastal erosion and sea level rise. Increases in the frequency and extent of coastal flooding will also occur when combined with storm surge and high tide events. Rising sea levels can also cause significant erosion, especially to soft sandy beaches. Around half of Tasmania's open coasts are sandy shores vulnerable to significant erosion and many of these are already experiencing severe erosion. Tasmania has an estimated 6,100 houses located within 110 metres of soft sandy shorelines (Department of Climate Change, 2009).

Expansion of settlements and encroachment into vulnerable areas, such as land prone to bushfire, and/or flooding and/or sea level rise, increases the risks that are faced from climate change, and raises the need to further invest in climate-resilient planning and building design. An expected increase in fire risk also poses future challenges for human settlements which is recognized as being subject to the highest fire danger in the State (White *et. al*, 2010).

3.2 Process, Criteria, and Results of Sector Selection

The process of sectors selection was based on exploration of the national development strategies of the country, namely poverty reduction, food security, health and social systems, biodiversity, sustainable livelihood, and combating desertification. To facilitate the sectors and technology prioritization processes, the development priorities were grouped under economic, environmental and social priorities from both a short and long term perspective. Table 3 shows the development priorities in context of the different dimensions of environmental, economical and social development priorities, as perceived by the stakeholders in the second workshop.

Table 3: Clustering of Development Priorities

Development Priorities	Environmental Development Priorities	Economical Development Priorities	Social Development Priorities
Poverty reduction	Create healthy environment	Eradicate poverty	Social welfare
Food security	Reduced soil degradation	Ensure food security	Improve health
Health & Social Systems	Improve living ;conditions of slum areas improve water quality	Provide access to energy and power	Improve access of women to market
Biodiversity	Conserve biodiversity		
Sustainable livelihood	Healthy sanitation	Increase job opportunities	Social safety
Desertification resistance	Healthy environment for women and children	Accelerate growth for rural non – farm sector	Stability of local communities

A short list of the main sectors that contribute to the attainment of the development objectives was prepared by the national team. The listed sectors were agriculture (large, medium and small scale agriculture), water resource (supply and demand), land use and forestry, human health, settlement, infrastructure and livestock. The national team in their attempt to prioritize sectors, benefited from previous identification of sectors for adaptation to climate change existing in NAPA process and Sudan development priorities. The main sectors selected according to national development priorities are agriculture (large, medium and small scale), water resources (supply and demand), and human health. Accordingly, only the first two priority sectors were considered in full in the TNA process, because of the limited resources available for the TNA Project. This initial work of sectors selection was introduced to the stakeholders in the national inception workshop (listed in Appendix II). After thorough discussions a general consensus on the prioritized sectors and sub-sectors was arrived at by the national team and the stakeholders. Table 4 shows the final list of prioritized sectors and sub sectors. IPCC 2006 guidelines for categorization of (sub) sectors was useful in the process of prioritization of (sub) sectors/areas that provide the most effective actions for adaptation based on existing FNC, SNC and Sudan NAPA.

Table 4: Prioritization of Sectors - Baselines for Adaptation

Sector	Sub-sector
Agriculture (large, medium and small scale)	Irrigated Agriculture
	Rain fed
	Rangeland
Water Resources (Supply - Demand)	Permanent Water resources
	Seasonal Water resources
	Ground Water resources

After thorough discussions among the national team and consultation with the stakeholders, it was finally agreed that the agricultural sector is the most important sector due to its direct contribution enhancing the resilience of local communities through food security and reduction of poverty. The second sector of importance is the water resource sector. Three subsectors were identified for the agriculture sector and three subsectors for water resources sector (Table 4).

3.3 Current Status of Technologies in Agriculture and Water Sectors

Although agriculture and animal rearing are the main economic activities in the country, reliance on indigenous knowledge (accumulated experience) is the only vital means for enhancing income generation. Therefore, traditional methods are deployed for increasing the productivity of the agricultural land with the exception of the well-to-do farmers who have financial potential to adopt technologies on an individual basis. Moreover, government institutions, particularly research institutions, attempt to introduce some technologies that could contribute to the wellbeing of the local inhabitants.

For the agriculture sector, improved crop varieties (locally bred and introduced varieties), zero tillage, and livestock production are the most affordable technologies to mitigate the vulnerability of local communities in the face of climate change and variability. Zero tillage has been introduced in limited areas at Gadarif State since the year 2000. Training and skills development of state and federal staff, stakeholders and farmers in the application of technologies of zero tillage (planting, spraying and application of fertilizer) has taken place in this area and latter spread in most of mechanized rainfed agricultural schemes in the country. Moreover skilled operators (in maintenance and calibration) are available and nowadays the farmers are knowledgeable about the zero tillage system. Regarding improved crop varieties (imported and breeding), extensive training was launched for farmers, stakeholders, service providers, seed producers, women and farmer groups. Improved seed crop varieties covers only 10% of farmers' needs in Sudan. Famers in Sudan rely heavily on farm saved seeds and have little access to commercial improved seed. Although livestock production in Sudan plays a pivotal role in issues of national food security and hard currency earnings from export, there are no tangible official policy, strategies and programmers targeting the preservation and development of the subsector despite herders being subjected to frequent and wide ecological changes and environmental effects.

In the water sector, rain water harvesting technique is the most common technology for provision of drinking water for human beings and animals beside irrigation of agricultural lands. *Haffirs* (hand-dug or natural depressions) are wide spread in different areas of Sudan. The wide spread of the technology is attributed to its cheapness. Other technologies based on rain water harvesting are small dams, reservoirs in natural depressions, earth embankment, terraces and contour bunds. Earth dams are found in many areas and are implemented in large scale in several villages.

Automatic water logger is considered one of the modern technologies in the water sector. It was applied in Sudan in the mid 1990s and vanished and faded away shortly after its introduction due to technical reasons. The technology of connecting rural areas with a pipe line is not yet implemented in Sudan, and is now in the study phase.

Chapter 4

Technology Prioritization for the Agriculture Sector

4.1 Climate Change Vulnerability and Existing Technologies and Practices in the Agricultural Sector

Climate change from anthropogenic emissions of GHGs is among the most daunting environmental problems confronting the world today. The Fourth Assessment Report of the IPCC (IPCC, 2007) has confirmed earlier conclusions that no country and no region of the world will be unaffected and in many countries the consequences for all human activities will be profound unless action is taken urgently to reduce GHG emissions. The overall climate change has made clear that identification and development of technologies, practices, and policies, for adapting to the adverse physical impacts associated with climate change, are of key importance to avoid irreversible changes associated with dangerous levels of climate change. The increasing importance of technology issues has been reflected by the agenda of negotiations on a future climate policy regime. It is noteworthy that two of the five pillars of the Bali Action Plan (adopted at the thirteenth Conference of the Parties to the UNFCCC, COP13, December -2007) focus on enhanced actions on technology development and transfer and on the provision of financial resources to enable technology transfer. The need for enhanced action on technology transfer to developing countries has been recognized by Environmental Group on Technology Transfer (EGTT), 2009 as “not all countries have the technologies needed or the ability to innovate new technologies to mitigate and adapt to climate change”. Those countries that are lacking in the technologies or capacity, mainly the developing countries, need to be helped not merely to adopt the existing environmentally friendly technologies but also to develop the capacity to innovate new technologies and practices in cooperation with others.

4.2 Adaptation Technology Options for the Agricultural Sector and their Main Adaptation Benefits

In Sudan crop cultivation is divided between market-oriented sectors comprising mechanized, large-scale irrigated and rainfed farming and small-scale farming following traditional practices that are carried out in many parts of the country where rainfall or other water sources were sufficient for cultivation. Sudan has a large irrigated agriculture sector totaling more than 2 million hectares. Gravity flow is the main form of irrigation, but about one-third of the irrigated area is served by water pumps. Table 5 shows the main agricultural irrigation schemes in Sudan, their areas and years of establishments (Embassy of the Republic of Sudan, Washington. 2008).

Table 5: The Main Agricultural Irrigation Schemes in Sudan

Scheme	Year established	Area (hectare)
Qash and Baraka	1860	--
Gezira Scheme	1920	450,000
New Halfa Irrigation Scheme	1960	164,000
Managil Scheme	1990	400,000
Rahad Irrigation Scheme	1977	63,000
Khartoum Irrigation pumps	1920	--
Junaid Project	1955	36,000
Suki Project	1970	36,000
HajarAsalaya	1977	7,600
Kenanah Sugar Project	1977	16,200

Source: Abdul-Jalil *et.al*. (1998).

The Nile and its tributaries were the source of water for 93 percent of irrigated agriculture. Generally, at the traditional rain fed agriculture simple hand tools is the common method for production. Sometimes the productivity is enhanced through autonomous interventions like adoption of the terrace system and animal ploughing which represent management practices to cope with climate change and variability. These management practices have some requirements like use of indigenous knowledge, development of low-cost strategies with multiple benefits, inclusion of gender-sensitive strategies, encouragement of relevant national agricultural research, secure land and natural resource rights of groups and individuals, and promotion of multidisciplinary and multi-sectoral institutions and processes (FAO, 2008).

In eastern Sudan Practical Action Organization developed a new technology known as pond forming which facilitates the construction of terraces in a relatively short time compared to the traditional method. The pond former is tied on the back of tractors and while driving, the pond former raises the earth embankment on the edges of the farms. In the rainfed mechanized farming there are also other types of technologies used. Golder Associates Africa has introduced the first auto-steer tractor in Agadi farm in Blue Nile State in central Sudan. The tractor is fitted with a GPS satellite guidance system that takes control of tractor steering and can maintain a preset course accurate to within 10 cm. The auto-steer unit has already helped reduce the average planting time on the Agadi farm by 60% compared with the previous two seasons (Howcroft, 2006). Other techniques such as conservation and zero tillage have also been introduced to boost productivity in many parts of the country. Zero tillage has proved to be an ideal way of managing soil and weed problems. In the early 1990s agriculture and livestock rearing were the main sources of livelihood in Sudan securing about 61% of the working population. Approximately one-third of the total area of former Sudan, the largest country on the African continent is suitable for agricultural development and heavier rainfall in the south permits both agriculture and herding by nomadic tribes. Agricultural products in total account for about 95% of the country's exports. Sudan possesses substantial animal wealth (130 million heads) and camels' farming is particularly popular. Livestock rearing provides employment for so many people, modernization proposals have been based on improving existing practices and marketing for export, rather than moving toward the modern ranching that requires few workers (Embassy of the Republic of Sudan, Washington. 2008).

In TNA-Sudan, the adaptation technology options for the agriculture sector were also driven by exploring the most vulnerable groups to climate risks. Traditional rain-fed farmers, small scale farmers and pastoralists are typically the least able groups to cope with climate-related shocks in Sudan. Accordingly, the selection of adaptation technology options is consistent with the adaptation activities in the agriculture sector. The main adaptation benefits expected from the adoption of the selected technologies are exemplified in improvement of farms agricultural crops productivity, particularly in the traditional subsistence agriculture, and eradicating poverty through improved agricultural production which is among Sudan's primary development objectives. Sudan's diverse agro-ecological zones offer the potential to produce a fairly wide range of crops, as well as livestock products. The adaptation benefits that would be generated from the adoption of the selected technologies in the agriculture sector also include sufficient availability of food, greater access to food through provision of infrastructure, stability of food supply and consumption of food.

4.3 Criteria and Process of Technology Prioritization

After the process of subsectors prioritization, the team identified and listed technologies for selected subsectors to be prioritize by the stakeholders. Absolute weighing was made for the selected subsectors relying on certain criteria (relevance to climate change, alignment with national goals, market potential and skills and capacity building). The results of this prioritization revealed that the main subsectors in agriculture are irrigated agriculture, rain-fed agriculture and livestock breeding. While for the water sector the three main subsectors were permanent water resources, seasonal water resources and ground water resources.

The technology prioritization was made by giving relevant measures to criteria and weighing of these criteria. The criteria selected for prioritizing the technologies were vulnerability, strategies and targets, sustainability, costs and benefits, utilization scale and supportive sys-

tems. The criteria and technology, as well as the weighting for each, are summarized in Table (6).
The criteria are structured to contain a number of measures relevant to a particular criterion. Each technology is ranked on a scale of 0 to 3, with 0 indicating zero impact or a negative ranking, 1, low ranking, 2, medium and 3 high ranking. The prioritization of technology options was done in phases. First, the relevance to climate change of the technology was considered. Only options where commercialization has not yet occurred on a large scale in Sudan and where technology transfer from developed countries is required were selected for the prioritization matrix. Each technology selected was then weighed on a scale of 1 to 3. As stated supra weight 1 means the technology has low importance, 2 (medium importance), while 3 is really critical. These absolute weights were converted into relative weights. For each selected technology option, scores were allocated for every technology and standardized. Each standardized score was multiplied by the relative weight and a total was calculated for each technology. In the next phase of the prioritization, technology options were arranged in a hierarchical order from the prioritization matrix. Table 6 shows that improved crop varieties ranked first, zero tillage 2nd, improved crop varieties (imported) 3rd, genetically modified crops 4th and livestock breeding ranked at the bottom of the list.

Table 6: Evaluation Matrix for the Agriculture Sector

Technology Option	Strategies & Targets	*Sustainability*	*Costs/benefit*	Vulnerability	Utilization scale	Supportive systems	Total	Ranking
Weight-absolute	3	3	3	3	2	2	16	
Weight - relative	0.1875	0.1875	0.1875	0.1875	0.125	0.125		
Improve crop variety	1	1	0.667	1	1	1	0.94	1st
	0.1875	0.1875	0.125	0.1875	0.125	0.125		
Zero tillage	1	1	1	0	1	0.333	0.73	2nd
	0.1875	0.1875	0.188	0	0.125	0.042		
Improve crops (im-(ported	0.667	0	0.330	1	0	0	0.646	3rd
	0.125	0	0.333	0.19	0	0		
Genetically modified crops	0.333	0	0.333	1	0.50	0.333	0.42	4rth
	0.062	0	0.062	0.19	0.06	0.042		
Livestock breeding	0	0.333	0	1	0.50	0.667	0.396	5th
	0	0.062	0	0.19	0.06	0.08		

Annex III shows the multi-criteria analysis for agriculture and water sector including, scoring of stakeholders, standardization and ranking of technologies.

4.4 Results of Technology Prioritization for Agriculture Sector

The result of the technology prioritization revealed almost a general consensus on improved crop varieties and zero tillage technology. In the agriculture sector evaluation matrix the two technologies scored the highest percentages compared to other technologies (0.94 and 0.73, respectively). Improved crops varieties (imported) was ranked third (0.646) followed by genetically modified crops (0.42). Livestock breeding was ranked on the bottom of the list with 0.396.

Chapter 5

Technology Prioritization for Water Sector

5.1 Climate Change Vulnerability and Existing Technologies and Practices in Water Sector

Life in Sudan revolves around water. The total amount of fresh water from internal and external sources is around $30\times10^{9}m^{3}$/year, bringing the per capita water availability below the water stress limit of 1 000 m^{3}. If these resources were devoted to agriculture alone, they would irrigate an area of less than 5% of the irrigable land of the country (Abdalla et. al., 2011). However, agriculture has to compete with other municipal and industrial uses. The latter are increasing with the expansion in urbanization and industrialization, and they present a higher marginal value for water. Some of the issues and problems faced associated with water are the physical constraints, such as the limitation in the availability of water, the inadequate storage facilities, sedimentation in reservoirs and canals, and difficulties in harvesting the flow of seasonal streams and abstracting groundwater. The environmental issue is felt through the growth of aquatic weeds in canals and pollution of water bodies through the application of agricultural chemicals.

Regarding climate change vulnerability for Sudan's water sector, the reduced groundwater recharge has grave repercussions for Sudan. National studies have shown that soil moisture could decline under future climate change. When coupled with increased water consumption, population growth, high variation in rainfall and the high rate of evaporation, a looming water crisis appears likely; and indeed, chronic drought is one of the most important climate risks facing Sudan. Drought is threatening the existing cultivation of about 12 million hectares of rain-fed, mechanized farming and 6.6 million hectares of traditional rain-fed lands. Pastoral and nomadic groups in the semi-arid areas of Sudan are also affected (Elawad, 1991). A trend of decreasing annual rainfall and increased rainfall variability is contributing to drought conditions in many parts of Sudan.

Rainfall patterns in Sudan show two important trends. First, average annual rainfall has declined from about 425 mm/ year to about 360 mm/ year. Secondly, the coefficient of variability of rainfall shows an overall increasing trend, suggesting greater rainfall unreliability. These rainfall patterns have led to serious drought episodes throughout the country (Hamid, 2009). Moreover, Sudan has experienced many devastating floods during the past several decades. These events have led to widespread losses of property, damage to irrigation facilities and water services and the spread of waterborne diseases. The discharge levels from the Ethiopian Plateau are highly variable. During exceptional wet periods, the rivers in the country can give rise to large-scale flooding, particularly in the flood plain areas of south-eastern Sudan (Mohamed, 2005). There are two major types of flood events that regularly plague Sudan. The first occurs during torrential rains when high levels of water overflow the Nile River and its tributaries, while the other type is flash flooding, which occurs from heavy localized rainfall during the rainy summer season or over the Red Sea area in winter season due to mountain runoff.

Traditional dugouts fed by rainwater and run-off (called *Haffirs*) have played a critical role for centuries in some parts of Sudan in supplying water for domestic use in villages and to pastoralists in remote areas vulnerable to erratic rainfall variations. However, increasing siltation from topsoil erosion and drifting sands as well as poor maintenance have led either to a serious decline in the water storage capacity or to the outright loss of many *Haffirs*. Due to increasing competition over limited water supplies, many *Haffirs* have become 'flashpoints' between pastoralists and farmers (GoS, 2012). The major problem that faces the rain fed farmers is drinking water after the rainy season, especially during the harvest time. Water harvesting techniques constitute the most important technologies and practices in the water sector**.** In the rain fed areas water harvest structures like *Haffirs*, small dams, and depression reservoirs are highly needed for drinking water and to some extent for irrigated agriculture. Water harvesting techniques have been implemented in several states in Sudan. The main influencing factors in water harvesting potentials are rainfall characteristics, runoff and catchment characteristics. Runoff depends upon the area and type of the catchment over which it falls as well as surface features (*ibid*). For the permanent water sources, there are different techniques and management practices like monitoring and gauging systems of permanent and seasonal water courses; communication and information systems to involve stakeholders and create a link with internationally related bodies, on farm irrigation water management and irrigation practices in irrigation schemes. Among the management practices are selection of pumping sites, sediment monitoring and hydrographic surveys on reservoirs which include river bank protection; also water resource management, irrigation water and sediment management, flood management and sediment monitoring.

5.2. Adaptation Technology Options for the Water Sector and their Main Adaptation Benefits

Adaptation technology options for the water sector are derived from the key adaptation activities in water resource management. In Sudan, rain-fed farmers and pastoralists have developed and implemented various low-technology forms of water harvesting to capture larger amounts of scarce rainfall. Such practices, however, are not currently widespread throughout Sudan. The NAPA consultation process confirmed great interest in expanding this and other practices to communities. The priority adaptation activities and needs that have been identified by NAPA (2007) are:

- Promotion of greater use of effective traditional water conservation practices;
- Rehabilitation of existing dams and improvements in water basin infrastructure;
- Introduction of new water harvesting/spreading techniques;
- Construction of dams and water storage facilities in some of water valleys;
- Introduction of water-conserving agricultural land management

practices;
- Improvement of access to groundwater supplies (water pumps);
- Enhancement of capabilities of regional meteorological stations;
- Introduction of a revolving micro-credit fund to support implementation of small water harvesting projects; and
- Extension services in water capture and storage techniques for small-scale farmers.

Therefore, the adaptation technology options for the water sector are in line with the key adaptation activities. Flood preparedness and early warning system and water harvesting are the selected technologies for the water sector. The main adaptation benefits by adoption of such technologies can be summarized in projects of water harvesting in some parts of the country increasing community access to reliable water and increasing their capacity to cope with the impacts of reduced precipitation; all of which has been integrated into the NAPA consultation process. Accordingly, these benefits can be attained in new locations where the intervention was not introduced. Moreover, adoption of family tanks for drinking water, as a water harvesting technique, guaranteed adequate and healthy supply of drinking water. Construction of dams, *haffir* and earth embankment contributed to alleviation of poverty through the increase of agricultural and livestock productivity. In general, further adaption benefits can be summarized in:
- Fighting poverty by creating an enabling environment for settlement and enhanced livelihood prospects;
- Promoting peace and stability by lessening conflict over water;
- Enhanced animal and agricultural production through improved water access; and
- Environment conservation and protection.

Water harvesting is the capture, diversion, and storage of rain water for different uses, though mainly for drinking; and in irrigation where water becomes available to the crop and thereby permits economic agricultural production. The current status of the technology in the country reveals that *haffirs* are widespread in different areas of

Sudan. Rain water harvesting is one of the priority programs for rural socio-economic development in the country. Rain water is not only important for drinking, it is also important for agriculture and pasture as most of the livelihood of the rural people depends on farming and animal rearing. Compared to other means of development, rain water harvesting is cheap to develop with high socio-economic returns. After thorough investigations, technical experts in the country have come to the conclusion that many water harvesting techniques can be used to avail water for drinking and farming on a small scale all over the targeted area. *Haffirs*, small dams, reservoirs in natural depressions and contour bunds, inter alia, can be used.

Remote Sensing technology for the receipt and processing of Satellite images are used for estimating daily rainfall quantities over the catchments of the Blue Nile and Atbara rivers in Ethiopia and Sudan. A communication system for real-time transmission of water levels in the Blue Nile, Atbara River and Main Nile in Sudan is linked to the Flood Warning Center in Khartoum providing a modern telemetry system and monitoring network (Automatic water level).

A computerized Flood Forecast System, consisting of a set of mathematical models with an appropriate user interface allows smooth and rapid data processing and forecasting.

Timely information during flood season is highly requested and will prevent loss of life and houses. Installation of automatic loggers and its management require expertise and institutional organization. This technology needs to be implemented in 14 key locations in Sudan. Training and skills development of State staff and local communities for operation and maintenance of the automatic loggers is very important for sustainability of this technology. Automatic water logging was applied in Sudan in the mid-1990s; however, this technology no longer exists due to technical reasons. Development of flood forecasting systems for Sudan is an important measure that should build upon existing forecasting systems and capacity. Key elements of flood forecasting and warning systems include data acquisition networks and data transmission; data processing and archiving; operational forecast modeling systems; flood warning, dissemination and communications. With respect to flood warnings, essential is effective delivery of relevant information that is readily understood and useful to intended users ranging from government agencies to flood plain dwellers.

5.3 Criteria and Process of Technology Prioritization for Water Sector

The same criteria and process of technology prioritization applied to the agriculture sector were used for the water sector. Table 7 shows the evaluation matrix for the water sector, in which rain water harvesting and seasonal forecasting in tandem with early warning were ranked as top priorities with 0.94 and 0.89, respectively. Seasonal forecasting and early warning (telemetry system) was ranked 3rd, rain water harvesting (earth dam) 4th, water pipeline for fresh water supply 5th, water quality technology 6th, ground water recharge 7th and desalinization technology ranked at the bottom of the list.

Table 7: Evaluation matrix for the Water Sector

Technology option	**Strategies & targets**	***Sustainability***	***Costs/benefits***	**Vulnerability**	**Utilization scale**	**Supportive systems**	**Total**	**Ranking**
Weight-absolute	3	3	3	3	2	2	16	
Weight - relative	0.188	0.188	0.188	0.188	0.125	0.125		
Rain water harvesting ((haffir	1	1	1	1	0.5	1	0.94	1st
	0.188	0.188	0.188	0.188	0.063	0.125		
Seasonal forecasting and Early warning (Automatic water (level	1	1	1	0.75	1	0.5		2nd
	0.188	0.188	0.188	0.141	0.125	0.063	0.89	
Seasonal forecasting and Early warning ((Telemetry System	1	1	0.75	0.75	1	0.5		3rd
	0.188	0.188	0.140	0.140	0.125	0.063	0.84	

Rain water harvesting ((earth dam	1	0.333	0.5	0.5	1	0.25		4rth
	0.188	0.062	0.094	0.094	0.125	0	0.563	
Water pipeline for fresh water supply	0.5	1	1	0	0	0.5		5th
	0.094	0.188	0.188	0	0	0.063	0.531	
Water quality technology	1	0.333	0	0.5	1	0.5		6th
	0.188	0	0	0	0.125	0	0.531	
Ground water recharge	0.65	0	0	1	0.5	0		7th
	0.122	0.000	0.000	0.188	0.063	0	0.37	
Desalinization	0	0.333	0	0.5	0.5	0		8th
	0	0.062	0.000	0.094	0.063	0	0.22	

For the water sector, results of technology prioritization revealed the preference of rain water harvesting (*haffir*) and seasonal forecasting and early warning system (Automatic water level).

5.4 Results of Technology Prioritization for Water Sector

The result of the technology prioritization revealed almost a general consensus on rain water harvesting (*haffir*) and seasonal forecasting and early warning (Automatic water level). In the water sector evaluation matrix the two technologies scored the highest percentages compared to other technologies (0.94 and 0.89, respectively).

5.4.1 Rain water harvesting (*haffir*)

There are many types of catchment rainwater harvesting, namely micro–catchment water harvesting (roof top or a farm plot and storing it in a tank or in the root zone of the farm soil in the case of a farm), medium sized catchment water harvesting (water harvesting from long slopes), and large catchment water harvesting (dams, distribution network, etc.). The main design criteria for water harvesting structures are small dams and reservoirs, natural depressions; *haffirs* and contour bunds. Different types of water harvesting techniques are used in Sudan; simple embankments for cultivation, embankments on *khor* or stream beds for agriculture/drinking, embankments on *khors* or streams to increase infiltration rates for ground water recharge, small surface impoundments (*haffirs*) for drinking, small dams and embankments with some structures for drinking/agriculture/flood protection/ground water recharge (GoS, 2012).

Rain water harvesting is one of the priority programs for rural socio-economic development in the country. Rain water is not only important for drinking, it is also important in agriculture and pasture as most of the livelihood of the rural people depends on farming and animal rearing. Compared to other means of development, rain water harvesting is cheap to develop with high socio-economic returns. It is also important for drinking, as well as for agriculture and pasture. The objectives of the rain water harvesting development, therefore, are the following:

- Enhance availability and access to water;
- Improve living conditions of both pastoralists and farmers;
- Promote peace and stability; and
- Strengthen the resilience of the local communities to climate change

5.4.2 Seasonal Forecasting and Early Warning (monitoring system-Automatic water level)

The development objective of seasonal forecasting and early warning is to reduce human suffering and damages while capturing the benefits of flooding. Through this technology it is possible to manage flood risks including floodplain management and flood mitigation planning; flood forecasting and warning; and emergency response and preparedness at regional, national, local and community levels. This will contribute to the longer term goal of establishing a comprehensive approach to flood management that integrates watershed, river and floodplain management while incorporating a suite of structural and non-structural flood mitigation measures within a broad multipurpose framework. The outcomes expected from the seasonal forecasting and early warning includes:

- Assessment of the flood risk to support flood management planning and investment planning;
- Improved flood plain management for major urban centers vulnerable to flood damage and for flood-prone rural communities;

- Operational flood forecasting systems with appropriate compatibility and mechanisms for exchange of information and data;
- Improved emergency response by governments and enhanced community preparedness; and
- Enhanced regional collaboration and cooperation during flood events.

Chapter 6

Summary and Conclusions

The Climate Change TNA project has been undertaken to introduce technologies for adaptation to climate change that could improve Sudan's resilience to climate change impact while progressing on national developmental priorities and ensuring environmental integrity. In Sudan there are national policy concerns about climate change adaptation for attaining development in the different aspects of life. Most, if not all, of Sudan national policies in the field of climate change were undertaken through MEAs. There is high concern about the three keys of MEAs, namely: UNFCCC, UNCBD and UNCCD which are strengthened by NAPA.

The TNA process started with the formulation of the institutional arrangements in which the HCENR under the auspices of the Ministry of Environment, Forestry and Physical Development is the responsible body for TNA in Sudan. The process was carried out by three operational entities: the national coordinator, national team and stakeholders. The national coordinator (HCENR staff) played a major role in leading a small national assessment team that is familiar with national development objectives and sector polices as well as potential climate change impacts in the Sudan and adaptation needs. The adaptation national team consists of 5 members from related ministries, research institutions and academia. The tasks of the national team are twofold: first, administrative tasks in terms of organization and facilitation of the workshops and secondly provision of content-wise support. The stakeholders were selected to lead transfer of new knowledge and insights on specific technology challenges and opportunities that might otherwise have been missed. Two workshops were organized; the first was the inception workshop with the objective of scoping and sensitizing about the project. The second workshop was organized for the sake of prioritizing technologies for adaptation options in which the stakeholders played a substantial role.

To select sectors for climate change adaptation attempts were made to identify development priorities in light of a changing climate, to obtain a list of clustered development priorities fully taking into account climate change implications. The main national strategies of Sudan were explored for sake of identifying development priorities. Poverty reduction, food security, health and social systems, biodiversity, sustainable livelihood and desertification containment were the main development priorities. These development priorities were grouped under economic, environmental and social priorities from both a short and long term perspective to enhance selection of sectors and their prioritization.

The main sectors vulnerable to climate change and variability, as indicated in Sudan NAPA, are: Agriculture, Water Resources, Public Health, Built Environment and Infrastructure (Climate-sensitive building design), Land use Management and Forestry (afforestation and reforestation). Due to the short timeframe and limited resources available for the TNA Project two sectors were selected, namely agriculture [with 8 subsectors] and water [with 3 subsectors]. Ranking of subsectors was made according to vulnerability reduction potential and national development priorities. Two technologies were selected from each subsector: for the agricultural sector improved crop species and cultivars and Zero tillage; for the water sector early warning system and water harvesting techniques. In determining priority areas for which technologies will be identified ranking of subsectors and selection of technologies was made by considering all sub sectors with a score of 4 or higher on vulnerability reduction and a total score of 12 or higher on delivery of development benefits. The prioritization of subsectors was followed by scoring the performance of subsectors in terms of coping strategy that lead to improvements in these subsectors.

As far as criteria and process of technology prioritization are concerned, after the process of subsectors prioritization, technologies for winning subsectors were listed for prioritization by the stakeholders using agreed upon criteria. It was decided earlier by the national team that two technologies should be selected from each sector (agriculture and water sectors). In the next phase of the prioritisation, technology options were arranged in a hierarchical order. The result of technology prioritization for the agriculture sector revealed almost a general consensus on improved crop varieties and zero tillage technology.

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Annex I

Technology Fact Sheets

A.1 Technology: Conservative Agriculture (zero tillage)
Sector: Agriculture
Subsector: Rain-fed Agriculture

A.1.1 Introduction

Zero tillage is a method of plowing or tilling a field in which the soil is disturbed as little as possible – the plant seed is sown directly into the seed bed which has not been tilled since harvest of the previous crop. In Sudan there are three major farming systems: the irrigated agricultural system, semi-mechanized system and traditional rain fed production system. Subjected to intensive and repeated tillage, rain-fed areas degenerate with reduced organic matter at a high rate, resulting in diminishing crop yield (non- sustainable agric production system). Production costs increase due to soil degradation whereby both farmer input and soil output capacities diminish, a low yield predicament aggravated by lack of technologies. Zero tillage aims at making better use of agricultural resources through the integrated management of soil, water and biological inputs. It contributes to environmental conservation and to sustainable agricultural production by increasing rural farmers' productivity and incomes and thereby reducing poverty.

A.1.2 Technology Characteristics

Zero Tillage improves the soil, increases production and decreases the cost of production. It consists of improved agricultural packages:
- Crop residue from previous crop and crop rotation;
- Application of herbicide for control of emerging and non emerging weeds (pre- post emergence herbicides);
- Planting in rows and application of fertilizer in one operation by a special planter; and
- Agricultural operation started after the soil has received 110 mm of

rain fall.

A.1.3 Country Specific Applicability and Potential

Application of the zero tillage production system requires knowledge and skills and also necessitates that farmers be organized in groups or societies under the umbrella of agricultural service providers. All these elements are available in Sudan and accordingly the applicability of the technology is feasible beyond doubt.

A.1.4 Status of Technology in Country

Zero tillage has been introduced in limited area in Sudan (Gadarif State) since the year 2000. Training and skills development of state and federal staff, stakeholders and farmers in application of technologies of zero tillage (planting, spraying and application of fertilizer) has taken place in Gadarif. Moreover, skilled operators (in maintenance and calibration) are available and the farmers are knowledgeable about the zero tillage system.

A.1.5 Opportunities and Barriers

- Most of the existing vast areas (in different parts of the country) where zero tillage has not yet been applied though suitable for the application of zero tillage, have suffered from soil degradation attributable to various climatic and non-climatic factors and are now experiencing agricultural production decline.
- Opportunities for investment in zero tillage in the rain fed areas are important for reversal of declining unit area productivity.
- Application of Zero Tillage has minimized weeds and improved soil structure over long periods, leading to a decrease in the cost of production.
- The application cost of zero tillage is high.
- In most part of Sudan there is lack of awareness and know how to apply and use zero tillage.
- Social and cultural opposition [might represent a barrier].

A.1.6 Benefits to Economic/Social and Environmental Development

The economic benefits of the intervention are represented in the creation of new job opportunities, increase of farmers' incomes, increased food production and encouragement of private sector investments in production of agricultural crops. In this connection there is need for data on approximately how many farmers are going to benefit from the technology besides information on the area which will be cultivated. The social benefits of zero tillage are improvement of living standards, upgrading the livelihood skills of farmers and enhancing their resilience to climatic and external economic shocks.

A.1.7 Climate Change Adaptation Benefits

Zero tillage can improve the productivity in rain-fed and irrigated farming areas. The targeted area for transfer and application of the zero tillage system is geographically large, covering one third of the cultivated land in Sudan. A fundamental criterion is that annual rain fall must exceed 600 mm. The targeted area extends from south Gadarif, Sennar, South White Nile, Blue Nile and South Kordofan, covering the Savannah Belt Zone. The aggregate number of rain-fed farmers in these areas exceeds a million. Adoption of this intervention promises to occasion attainment of farmers' needs as well as the development priorities of the country, particularly food security and poverty alleviation.

A.1.8 Financial Requirements and Costs

Cost to implement zero tillage as adaptation technology:
Cost of establishing one unit with Zero Tillage equipment: Tractor, 90HP+planter+ sprayer = 31,600 USD.
Cost of cultivation of one hectare by Zero Tillage =154 USD
The production of one hectare by Zero Tillage= 23 sacks (1 sack of crop = 100kg)
Additional cost to implement adaptation technology compared to "business as usual" cost of cultivating one hectare [by traditional method] = 40 USD
The production of one hectare using traditional system = 7 sacks (1 sack of crop = 100kg).

A.2 Technology: Improved Crop Varieties [Breeding]
Sector: Agriculture
Subsector: Irrigated and Rain-fed

A.2.1 Introduction

Plant breeding provides new improved crop varieties with unique characteristics that are beneficial, profitable and adapted for many growing environments. The farming sector in Sudan includes a diverse mix of farmers from small holder farmers, to large scale producers in both irrigated and rain-fed areas. The production per unit area is very low due to the lack of agricultural technologies, including improved varieties. Rain fall fluctuation, pests and diseases also drag down the productivity.

A.2.2 Technology Characteristics

The technology of breeding new improved crop varieties depends on genetic crop diversity and crop gene resources adapted to the targeted areas. The process is composed of the following:
- Selection of the areas and local varieties adapted to the area;
- Breeding process for tolerance to adverse environmental conditions such as drought, flooding and heat;
- Resistance to diseases and pests;
- Agronomic traits affecting yield quality competition against weeds;
- Evaluation starts during the breeding process and continues through variety release;
- Testing process for environmental adaptation and farmer acceptance;
- Breeding seeds production for released improved variety; and
- Foundation seed production for multiplication by seed companies, farmer groups and private and public sectors.

A.2.3 Country Specific Applicability and Potential

To apply this technology in the rain-fed area the following requirements are needed:
- Technical skills and institutional organization;

- Consultancy with national and international organizations in designing the breeding programs of improved varieties;
- Technical training for researchers, as well as state and federal staff who are working with the agriculture extension programme; and
- Establishment and rehabilitation of research units.

The potential covers the main rain-fed areas in South Gadarif, South White Nile and Blue Nile and can be extended from east to central and west of Sudan.

A.2.4 Status of Technology in Country

Training for farmers, stakeholders, service providers (private sector), seed producers, women and farmer groups are all included in the activity of improved crop varieties. Availability of Improved seed crop varieties covers only 10% of farmer needs in Sudan. Large scale production of improved seed varieties by public or private sector concerns would strengthen the capacities of research, extension and private sector operators in the development, dissemination and adoption of improved seed varieties. This would substantially enhance Sudan's quest for sustainable crop production intensity and food security, as well as agriculture commodity export capacity. This technology may reach hundreds of thousands farmers, depending on dissemination of information, adoption and the availability of improved seeds.

A.2.5 Opportunities and Barriers

Opportunities:
- Presence of a large number of plant breeding research institutions, programmes and experts in the country;
- Availability of infrastructures that could be built on; and
- Lack of funds for agricultural research is a big constraint to development. Reform is essential for more sustainable research with appropriate integration of technology adaptation and for strengthening seed research companies, extension agents and policy makers.

A.2.6 Benefits to Economic /Social and Environmental Development

Economic Benefits:

- Increased crop production encourages the private sector to investment in improved crop seed production;
- Multiplication of improved seeds;
- Increased income generation
- New jobs for research workers, seed production technicians and service providers; and
- Increased production per unit area.

Social Benefits:

- Training of different stakeholders who become skillful;
- Guaranteed food security and enhanced resilience of local people;
- Sustainability of livelihoods; and
- Discourage migration from production areas.

Environmental Benefits:

- Cessation of crop failure [as a result of utilization of more adapted crop varieties] will reduce environmental degradation;
- As local communities become technologically adapted they are more likely to contribute to environmental rehabilitation (e.g. become involved in tree planting);
- Decrease the expansion of agriculture into new areas, maintaining forest green covers and decreasing GHG emissions; and
- Minimize the demand for water needed for irrigation.

A.2.7 Climate Change Adaptation Benefits

The technology contributes to the stability of local communities under the ever changing climate through enhancing their coping mechanisms:

- Strengthen the resilience of the rural farmers to climate change;

and
- Tolerant crops to withstand adverse climatic condition.

A.2.8 Financial Requirements and Costs

Cost to Implement Adaptation Technology:

Cost of establishing and rehabilitating research units
One unit = 6 million USD (A unit composed of 2 offices, meeting room, laboratory, rest house and toilets)
Laboratory equipments cost= 1.5 million USD
Three units are needed in the targeted areas.
- Cost of capacity building and training = 500,000 USD
- Running cost = 750,000 USD
- Unforeseen cost = 540,000 USD

A.3. Technology: Improved Crop Varieties [Imported]
Sector: Agriculture
Subsector: Irrigated and Rain-fed

A.3.1 Introduction

Agricultural researchers and extension agents can help farmers identify new imported varieties that may be better adapted to changing climatic conditions and facilitate farmers comparing these new varieties with those they already produce. In some cases farmers may participate in selection of imported improved crop varieties that demonstrate the qualities they seek and new varieties with the characteristics they desire. The average productivity of traditional farming systems in Sudan has declined steadily over the past twenty years. The capacity of farmers to produce food in an efficient and sustainable manner is severely limited by technological constraints that are climate variability related and economic limitations rooted. Among the most significant constraints are bad management of plant resources and volatility of rainfall contributing to low productivity, poverty and food insecurity in the traditional rain-fed farming areas. Cyclic poverty deprives farmers of modern inputs such as certified seeds and fertilizer and limits their access to knowledge as well as acquisition of improved production techniques. Shortage of trained manpower reflects the socio-economic development challenges facing Sudan's marginal famer communities. Poor soils, pests and diseases contribute to the marginal farmer communities' predicament, aggravating the degraded natural resource base. Moreover, marketing system access is hindered by various factors, most significant among them infrastructural [such as deficient transport], produce quality and cost.

A.3.2 Technology Characteristics

Imported new improved crop varieties depend on genetic crop diversity and crop gene resources adapted to the targeted areas. The process is composed of the following:

- Selection of the areas for testing the new imported improved crop varieties;
- Testing for tolerance to adverse environmental condition such as drought, flooding and heat;
- Resistance to diseases and pests;
- Agronomic traits affecting yield quality, competences against weeds;
- Meeting the needs of farmers and end users;
- Evaluation started during the research testing on farmers' fields;
- Testing process for environmental adaptation and farmers' acceptance; and
- Seed production for multiplication by seed companies, farmer groups, private and public sectors.

A.3.3 Country Specific Applicability and Potential

This technology can be applied in Sudan depending on the following conditions:
- Institutional arrangements including establishment of farmers' committees in order to synchronize diversification on neighboring farms or plots that share common ecosystems.
- Consultancy in designing the testing programs of improved varieties with national stakeholders and international organizations. Technical training for researchers' as well as states' and federal staff working in the extension areas.
- Improvement of knowledge and skills at all levels including training for farmers, stakeholders, service providers (private sector), seed producers, women and farmer groups.

Sudan's rain-fed sector comprises large areas with considerable rainfall and fertile soil that have the potential for growing a diversity of crops.

A.3.4 Status of Technology in Country

Famers in Sudan rely heavily on farm saved seeds and have little access to commercial improved seed. Improved crop varieties seeds meet only 10% of farmer requirements in Sudan's. Large scale production of improved seed varieties by public or private sectors will strengthen the capacity of research and extension services; and equally strengthen the private sector in the development, dissemination and adoption of improved seed varieties, a prospect that is linked to food security and sustainable crop production intensity. Hundreds of thousands farmers would be beneficiaries when this win-win situation is attained; but dissemination of information and adoption as well as availability of improved seeds remain prerequisites.

A.3.5. Opportunities and Barriers

Improved crop variety breeding affords the opportunity of increasing production per unit area by 2-3 tones/hectare, in addition to alleviating poverty among rural farmers and maintaining food security.
Limited funds and budget for agricultural research impedes research development and consequently research output is inadequate. Specific measures are essential to develop more sustainable research with appropriate integration of technology adaptation which would strengthen farmers, seed companies, researchers, extension agents and policy makers.

A.3.6 Benefits to Economic/Social and Environmental Development

Economic Benefits

This may include**:**

- Increased crop production and decreased cost of production; and
- Encouraging private sector investment in improved crop seeds production.

Social Benefits

- Improved livelihood of local farmers and the population; and
- Creation of new jobs for research workers, seed production technicians and increase service providers.

Environmental Benefits

- Decreased expansion of agriculture into new areas and maintaining forest green cover in tandem with decreased GHG emission; and
- Minimize demand for water needed for irrigation.

A.3.7 Climate Change Adaptation Benefits

Introducing improved crop varieties will strengthen the resilience of rural farmers to climate change, as well as enhance cultivation of crops in some areas that were not cultivated.

A.3.8 Financial Requirements and Costs

Cost to implement adaptation technology**:** Cost of establishing and rehabilitating 3 research substation units in South Gadarif, South White Nile and Blue Nile to cover rain-fed areas that extend from east to central and west of Sudan.
One unit = 6 million USD
Laboratory equipments = 1.5 million USD
Additional cost to implement adaptation technology, compared to "business as usual"**:** Improved seed varieties that result in increasing the productivity per unit area = 1 million US dollars. The imported improved crop varieties cost 750,000 USD

A.4 Technology: Livestock Breeding
Sector: Agriculture
Subsector: Rangeland

A.4.1 Introduction

Sudan possesses a large number of animal species, breeds, strains and types of indigenous animals which results in high emission of methane (CH_4). Methane is produced primarily by enteric fermentation and manure management voided by eructation. All livestock generate N_2O emission from manure as a result of excretion of Nitrogen in urine and feces.

A.4.2 Technology Characteristics

The technology: improved animal breeding includes artificial insemination, improved feeding practices and dietary additives.

A.4.3 Country Specific Applicability and Potential

Animal breeding requires improved bulls, artificial insemination units at veterinary centers and high density of livestock. The veterinary staff needs to be trained and to develop skills in the area of insemination. Improvement of animal production departments and local communities are also identified. Moreover, proper maintenance of the artificial insemination apparatus is essential.

A.4.4 Status of Technology in Country

Livestock production in Sudan plays a pivotal role in national food security, farming operations, animal traction, rural and suburban transport and recreational shows attractions in addition to hard currency earnings from export. With the exception of some incidental efforts there are no tangible official policy strategies and programmes targeting the preservation of animals, market value improvement and herd development by genetic breeding. On the other hand, herders subjected to frequent and wide spread ecological changes and environmental effects (desertification, drought, famine, rainfall failure, pasture shortages etc) were obliged to adopt new strategies to cope with large discrepancies between rising demands for livestock products and the slow growth of this sector in Sudan. Adverse impact and long term dismal implications of this livestock sector predicament has prompted recent changes of policies. Technology intervention in the sector is now a recognized imperative.

A.4.5. Opportunities and Barriers

In recent years, a great proportion of animal herders have realized the importance of the quality of livestock, no longer simply focused on quantity. Animal rearing in Sudan has traditionally aimed at big herds for social prestige and herders are rarely attracted by market demand. Veterinary services provide vaccination free of charge and try to change the attitudes of nomads through awareness development. Eighty percent (80%) of Sudan's livestock is under the traditional production system. Nonetheless, the livestock sector provides all the meat required and is a major contributor to the country's exports. There are several production systems in the country, mainly: (1) the Nomadic agro-pastoral system or transhumance system (2) migratory agro-pastoral system (3) sedentary and (4) semi-sedentary system. Commercial farming systems include: dairy farming, feedlot and fattening systems, commercial poultry farming system, and the backyard system. Thus, government policies have to be structured to include all these systems.

A.4.6 Benefits to Economic/Social and Environmental Development

Economic Benefits: Providing more jobs and increased incomes of the east, west and central communities

A.4.7 Climate Change Adaptation Benefits

Resilience of the local communities to climate change is strengthened through improved economic conditions.

* Construction of a new water PVC pipeline network from the River Nile and its tributaries across the country's states to provide clean water for people and irrigation to agriculture in East and West Sudan.
* Simple pipeline design of reachable technology input.

A.4.8 Financial Requirements and Costs

Cost to implement adaptation technology:
The cost of establishing one center for artificial insemination is equal to 2 million US dollars

A.5 Technology: Genetically Modified Crops [GMCs]
Sector: Agriculture
Subsector: rain fed

A.5. 1 Introduction

GM crop varieties developed by biotechnology allows scientists to select specific genes from one organism and assimilate into another to confer desired traits. This technology can be used to produce new varieties of crops or animals more quickly than conventional breeding methods and to introduce traits not possible through traditional techniques. GM crops contain specific characteristics such as resistance to pests/herbicides/drought tolerance, whereby quality is improved in tandem with reduction of greenhouse gas emission.
The average productivity of traditional farming systems in Sudan has declined steadily over the past twenty years. The capacity of farmers to produce food in an efficient and sustainable manner is severely limited by technological constraints, among which the most significant is lack of capacity to offset the impact of rainfall volatility that invariably drags down productivity. Lack of modern inputs such as certified seeds and fertilizer result in farmers being menaced by poor soils, pests and diseases. Poverty and food insecurity in the traditional rain-fed farming areas aggravate the predicament. Hence, Sudan’s natural resource base is degraded.

A.5.2 Technology Characteristics

The process of Genetic Modification (GM) is composed of the following:
- Define the desired traits;
- Identification of the gene controlling the trait;
- Marking the gene for detection;
- Isolation of the desired gene, multiplication of the gene and introducing this desired gene into cells of the plant to be enhanced;
- Identify the plant cells that now contain the desired gene;

and
- Use tissue culture/traditional plant breeding techniques to transfer the trait into usable variety.

This process requires adequately equipped biotechnology laboratories.

A.5.3 Country Specific Applicability and Potential

- Developing GM crop varieties requires knowledge and skills in tandem with institutional organization.
- Establishing equipped biotechnology laboratories is a basic material perquisite.
- Consultancy and cooperation with international organizations and seed companies is normative.
- Technical training for researchers and technicians is essential.

A.5.4 Status of Technology in Country

Famers in Sudan rely heavily on farm saved seeds typically yielding low productivity per unit area. GM crop varieties may increase their production per unit area by 2- 3 tones /hectare; therefore, while productivity would be increased, production costs would decrease and the food security situation improved.

A.5.5. Opportunities and Barriers

Lack of financial resources supporting agricultural research leads to inadequate spending on research and development, the corollary of which is inefficiency of research output. Reform is essential to develop more sustainable research with appropriate integration of technology adaptation, whereby strengthening would also accrue to farmers, seed companies, researchers, extension agents and policy makers.
Currently, improved crop varieties seeds meet only 10% of farmer production in Sudan. The proposition of large scale GM crop varieties production in Sudan implies substantial improvement of research and development capacity, information dissemination about GM crops and adoption as policy; all of which imply sustainable crop

production intensity and dramatic food security improvement. The beneficiaries in rain-fed areas could receive hundreds of GM crop seed varieties that heighten resilience against the unpredictable rain fall variable.

A.5.6 Benefits to Economic/Social and Environmental Development

- Increased crop production
- Decreased cost of production
- Improved crop quality
- Increased farmer's income
- New jobs for research workers and seed production technicians, as well as increased number of service providers
- Improve livelihood and strengthen resilience of rural farmers to climate change

A.5.7 Climate Change Adaptation Benefits

Fits well, both for present and expected climate change

A.5.8 Financial Requirements and Costs

Cost to Implement Adaptation Technology: Cost of establishing and rehabilitating 3 research substation units in south Gadarif, south White Nile and Blue Nile to cover rain fed areas. This extended from east to central and west of Sudan.
One unit = 6 million U.S. dollars for establishing, including 3 offices /lab/rest house/training center/ toilets.
Operation cost=750,000 US dollars
Laboratory equipments = 2 million dollars
Additional cost to implement adaptation technology, compared to "business as usual":
Long term cost without adaptation: 2,000,000 US dollars
Long term cost with adaptation: 5,000,000 US dollars
GM crop varieties result in increasing the productivity per unit area/ one million US dollars.

B.1. Technology: Rain Water Harvesting (Haffir)
Sector: Water Resources
Subsector: Seasonal Water Resources

B.1.1 Introduction

Water harvesting is the capture, diversion, and storage of rain water for different uses, mainly for drinking and in irrigation where water becomes available to the crop and thereby enables economic agricultural production.

B.1.2 Technology Characteristics

Haffir are manmade ground reservoirs in the earth at suitable locations to store water for drinking purposes for both human and livestock uses. The concept is that water running in natural streams during the rainy season is diverted at certain suitable locations into these haffir. The size of the haffir ranges from 100,000 m^3 for large ones to 30,000 m^3 for small ones. Guide bunds are required to divert the water into the haffir. As water in the haffir is used for human drinking, filters are always associated with the haffir for clean potable water.

B.1.3 Country Specific Applicability and Potential

- Construction of haffir and their management requires skill and institutional organization.
- Consultancy in design of the haffir and its implementations is necessary.
- Training and skills development of state staff and local communities for the operation and maintenance of the water harvesting projects represents one of the core elements for sustainably.

B.1.4 Status of Technology in Country

Haffir are wide spread in different areas of Sudan. Rain water harvesting is one of the priority programs for rural socio-economic development in the country. Rain water is not only important for drinking, it is also important in agriculture and pasture as most of the livelihood of the rural people depend on farming and animal rearing. Compared to other means of development, rain water harvesting is cheap to develop with high socio-economic returns. After thorough investigations, technical experts in the country have come to the conclusion that many water harvesting techniques can be used to avail water for drinking and farming on small scale all over the targeted area. Haffir, small dams, reservoirs in natural depressions and contour bunds, inter alia, can be used.

B.1.5 Opportunities and Barriers

Financing constraints constitute one of the significant impediments facing socio-economic development in the country. This is particularly so for rainwater harvesting development. Despite the difficulties facing Sudan's economy in the short run, broad indications such as stringent austerity measures, revival of the agriculture sector, gold mining and significant inflow of direct Arab and foreign investments suggest that the economy will improve gradually in the long run. Improvement of the economy will lead to better livelihood prospects and services for the people of Sudan and in particular water supply and augmentation.

Rainfall characteristics (intensity, duration, distribution) are the most unpredictable variable. Regarding the cost, haffir cost much less than dams.

B.1.6 Benefits to Economic/Social and Environmental Development

Economic Benefits:

- Increase the income of farmers
- Increase food production and productivity generally

Social Benefits:

- Enhanced availability of and access to water
- Improved living conditions of both pastoralists and farmers
- Promote peace and stability

- Enhance settlements and reduces the competition for water between farmers and pastoralists

B.1.7 Climate Change Mitigation Benefits

Haffir strengthen the resilience of local communities to climate change

B.1.8 Financial Requirements and Costs

Construction of haffir: 20-25 Sudanese pounds (9-11 USD) per unit (M^3)
The capacity of designed Haffir range from 30,000 M^3- 200,000 M^3
Average cost 0.75-1 Million Sudanese Pounds (370,000 – 450,000 USD)

Additional Costs to Implement Adaptation Technology compared to "business as usual":

For human water consumption, the water stored in haffirs needs to be treated. For this purpose slow sand filtration techniques are usually adopted. However, filter costs (slow sand filter/rapid sand filter/pressure sand filter) are not estimated. An elevated tank with a reasonable capacity is usually provided to withdraw clean water.

B.2. Technology: Seasonal Forecasting and Early Warning System (Automatic Water Level)
Sector: Water Resources
Subsector: Permanent Water Resources

B.2.1 Introduction

Remote Sensing technology for the receipt and processing of satellite images are used to estimate daily rainfall quantities over the catchments of the Blue Nile and Atbara rivers in Ethiopia and Sudan. A communication system transmits water levels in the Blue Nile, Atbara River and Main Nile in Sudan to the Flood Warning Center in Khartoum. A computerized Flood Forecast System, consisting of a set of mathematical models with an appropriate user interface allows smooth and rapid data processing and forecasting.

B.2.2 Technology Characteristics

The Automatic Water Level is a data logger and submersible pressure transducer combination designed for remote monitoring and recording of water level or pressure data. The water level logger can record over 81,000 readings and has four unique recording options, fast (10 samples per second), programmable interval (1 second to multiple years), logarithmic, and exception. Multiple depth ranges are available from 3 to 500 feet of water level change. A 25 ft vented cable is standard on all water level loggers.

B.2.3 Country Specific Applicability and Potential

Timely information during flood season is vitally requested and will prevent loss of life and houses. Installation of automatic loggers and management of them require expert and institutional organization. This technology needs to be implemented in 14 key locations in Sudan

- Training and skills development of state staff and local communities for operation and maintenance of the automatic loggers is very important for sustainability.

B.2.4 Status of Technology in Country

Automatic water logger was applied in Sudan in the mid-1990s, yet, this technology has not been operational owing to technical reasons.

Development of flood forecasting systems for Sudan is an important measure that should build upon existing forecasting systems and capacity. Key elements of flood forecasting and warning systems include: (1) data acquisition networks and data transmission (2) data processing and archiving (3) operational forecast modeling systems (4) flood warning and (5) dissemination and communications. With respect to flood warnings, effective delivery of relevant information in a form readily understood by and useful to intended users, from government agencies to floodplain dwellers, is essential.

B.2.5 Opportunities and Barriers

- It is sensitive and easy to be broken; therefore special care should be taken to its location.
- High costs compared to normal gauges.

B.2.6 Benefits to Economic/Social and Environmental Development

Economic Benefits:

- Prevents the losses of the communities' resources due to floods

Social Benefits:

- Prevents life loss in some areas prone to flooding

Environmental:

- Allows forecasting extreme weather events

B.2.7 Climate Change Mitigation Benefits

Strengthens resilience of the local communities to climate change

B.2.8 Financial Requirements and Costs

Cost to Implement Adaptation Technology: Automatic Water Level (Pressure Type - SEBA) 4,000 USD. To implement this technology in 14 locations 56,000 USD is required.

B.3. Technology: Water Harvesting (Earth Dam)
Sector: Water Resources
Subsector: Seasonal Water Resources

B.3.1 Introduction

Water harvesting is the capture, diversion, and storage of rain water for different uses, mainly for drinking and in irrigation where water becomes available to crops and thereby permits economic agricultural production. In rural areas all over Sudan, people living in villages or those living a nomadic life, suffer from drinking water shortage for themselves and their livestock. They get their water during the rainy season only. Thereafter, they lack water due to the absence of water storage facilities. Rain-fed farmers need drinking water at their farms during the harvest time which usually occurs during the dry season. Lack of water very much affects the socio-economic life of the rural people and compels many of them to migrate to urban centers.

B.3.2 Technology Characteristics

- Wadi is a seasonal rain drainage (fig. 2). It is a system wherein the catchment is many square kilometers in area. Runoff flows through a major stream of Wadi and complex hydraulic structures are needed (dams, distribution network etc.) to harness the rain water.
- The concept of a small dam is to construct a dam across the course of a Khor (seasonal small drainage) or natural stream at a suitable location which suits topographical, foundation, and hydrological requirements.
- The dam reservoir capacity is governed by catchment areas of the stream, evaporation and releases.

B.3.3 Country Specific Applicability and Potential

In the rain-fed areas water harvesting structures like earth dams, *haffirs* and depression reservoirs are vitally needed for drinking water and to some extent for irrigated agriculture.
This technology can be successfully applied in Sudan if the follow-

ing requirements are set:
- Construction of small earth dams and their management requires skills and institutional organization.
- Consultancy in design of the dam and its implementations.
- Operation of sluice gate and spillway, etc.
- Training and skills development of state staff and local communities for operation and maintenance of the water harvesting projects is a core requisite for sustainably..

B.3.4 Status of Technology in the Country

Earth dams are found in many areas of Sudan, are implemented in large scale and serve numbers of villages. Rain water harvesting is one of the priority programs for rural socio-economic development in the country. Rain water is not only important for drinking, it is also important for agriculture and pasture as most of the livelihood of the rural people depends on farming and animal rearing. Compared to other means of development, rain water harvesting is cheap to develop with high socio-economic returns. After thorough investigations, technical experts in the country have come to the conclusion that many water harvesting techniques can be used to avail water for drinking and farming on small scale all over the targeted area. Small dams, haffir, reservoirs in natural depressions and contour bunds, inter alia, can be used. Priority regions that are targeted for establishing the earth dam are:
(i) Southern parts of Sudan;

(ii) Regions with known history of competition over natural resources, particularly water and land, that lead to or have potential to develop into conflict, and

(iii) Regions that received little or no water harvesting projects. The targeted rural communities are of course pastoralists and sedentary farmers.

B.3.5 Opportunities and Barriers

Financing constraints constitute a major impediment to socio-economic development in the country. This is particularly the case for rainwater harvesting development. Despite the difficulties facing Sudan's economy in the short run, the economy will improve gradually in the long run. Improvement of the economy will lead to better livelihood prospects and services for the people of Sudan and in particular water supply. Many barriers may face the implementation of this technology:

- Rainfall is a most unpredictable variable.
- This method has high costs compared with haffir.
- Inadequate funding
- Lack of basic information
- Weak infrastructures
- Lack of security in certain regions

B.3.6 Benefits to Economic/Social and Environmental Development

Economic Benefits:

- Increases the income of farmers.
- Increases food and livestock production and productivity generally

Social Benefits:

- Enhances availability and access to water
- Improves living conditions of both pastoralists and farmers
- Promotes peace and stability

Environmental Benefits

- Strengthens the resilience of the local communities to climate change
- Enhances settlement of local people,
- Alleviates the competition between farmers and pastoralists

B.3.7 Climate Change Adaptation Benefits

- Fits well, both for present and expected climate change
- Strengthens the resilience of the local communities to climate change

B.3.8 Financial Requirements and Costs

An average dam cost 6 Million Sudanese Pounds (3 Million USD). The water stored in the reservoirs needs to be treated if the water is used for human consumption. Therefore, slow sand filtration techniques should be adopted for the earth dams. Additional costs are hence needed (0.5 million USD) as well as maintenance costs of the earth dams.

B.4. Technology: Pipeline for Fresh Water Supply

Sector: Water Resources.
Subsector: Permanent Water Resources

B.4.1 Introduction

The pipe line technology/project could be adopted for drinking water production right away from the River Nile and its attributes to supply those who live in remote areas and suffer from droughts and insufficient drinking water, such as west and east Sudan. Drinking water scarcity has been identified as one of the most urgent needs to climate change adaptation. Farmers could adapt to current and expected changes in climate which affect the fresh water supply by adopting a pipeline network.

B.4.2 Technology Characteristics

- Low cost technology and maintenance.

B.4.3 Country Specific Applicability and Potential

For the adoption of this technology, the following steps are to be taken:
- Development of a technical and economic feasibility study for Sudan water pipeline project.
- Design of a national pipeline network running from the Nile to the targeted areas.
- Construction of regional water tanks and pumping stations for water storage and distribution.
- Coordination with the African pipeline projects application of capacity building programs
- International cooperation to benefit from Chinese pipeline technology *i.e.,* cost-effective and sufficient expertise, minimum capacity building requirements, easy to operate with minimum training requirements for local technical personnel
- Easy to maintain

B.4.4 Status of Technology in Country

The technology of connecting rural areas with a water pipe line has not yet implemented in Sudan, and is now under study phase.

B.4.5 Opportunities and Barriers

Sudan possesses many sources of fresh water in addition to its plane topography. This facilitates the establishment of connecting remote areas with a pipeline network to provide water for domestic and animal uses. The application of this technology is challenging due to the following factors:

- Special technical requirements
- Water extension to different locations in the same area may become difficult and costly to maintain
- Nile basin agreement may be in conflict with the pipeline project
- High initial costs

B.4.6 Benefits to Economic/Social and Environmental Development

Economical benefits:

- Perpetual accessibility of drinking water for both human and animals population
- Secure food productivity
- Offers job opportunities
- Reduction of water-borne diseases
- Income generation

Environmental Benefits

- Provision of fresh drinking water
- Reduction of water-borne diseases

Social Benefits:

- Improvement of livelihoods
- Elimination of tribal conflicts over water issues
- Improvement of know-how and capacity building

B.4.7 Climate Change Adaptation Benefits

Beside water scarcity in these areas, Sudan is subjected to desertification due to climate change. Hence, there is a crucial need for this technology to minimize current and future effects of climate change. This technology allows different systems to adapt to expected drought due to climate change and prevention of severe desertification.

B.4.8 Financial Requirements and Costs

Cost to implement adaptation technology:

The application of this technology in Sudan in the presence of the River Nile and its tributaries will cut down the costs to the minimum. This is because there is no need for submarine pipeline and desalination plants. The costs of implementing this technology are not estimated yet in Sudan. However, hereunder are estimated costs of implementing pipe line projects:

- The initial cost of a 40-mile long upgraded PVC pipeline in South United States, with initial capacity of about 16,000 barrels of water a day, is $2.1 million for start-up. However, the labor cost in US compared to that of Sudan is fairly high.
- Construction of a major water supply pipeline to a group of Islands in Abu Dhabi cost US$27bn; with capacity for 76 million gallon of water a day the pipeline project started in 2008 and will be completed in 2018. In this case, the high cost is due to the marine pipeline and water desalination costs.
- A 600 mile subsea pipeline for fresh water in Chile will cost about US$3.85bn, planned for three construction phases over five years.

B.5. Technology: Seasonal Forecasting and Early Warning (Telemetry Systems)

Sector: Water Resources.

Subsector: Permanent Water Resources

B.5.1. Introduction

Telemetry monitoring is often thought to be too expensive and complex for many applications. However, wireless telemetry wherever you are, wherever your equipment is, using the latest radio, GPRS, and GSM data logger telemetry technology is now possible. Wireless telemetry systems are able to address the data acquisition needs of the water, environmental, industrial and meteorological communities with intelligent telemetry applications that can provide network monitoring for any parameter or signal. The type of low-cost telemetry monitoring system required depends on many factors such as the location of the site/sites of measurement and the number and distribution of sites.

B.5.2 Technology Characteristics

A radio frequency (RF) telemetry system with a shape memory alloy microelectrode was designed and fabricated. The total size and weight are 15 mm×8 mm and 0.1 g, respectively. Since the telemeter is small and light enough to be loaded on a small animal such as an insect, the system can be used for the neural recording of freely moving insects. The RF-telemeter can transmit signals by frequency modulation transmission at 80-90 MHz. The transmitted signals can be received up to about 16 meters away from the telemeter with a high signal-to-noise ratio. The neural activity can be detected without attenuation by using an instrumentation amplifier with its input impedance set to 2 MΩ at 1kHz. The telemeter was loaded on a cockroach and the neural activity during a free-walk was successfully measured through this telemetry system.

B.5.3 Country Specific Applicability and Potential

Telemetry systems will have to be operated and managed by the Ministry of Water Resources which is responsible for the generation and compilation of hydrological data. Operation and maintenance will involve electrical and electronic systems of specialized equipments and this will involve some prior training of the staff responsible to operate and maintain the system. Developments in the wireless communication services and the data logging systems have made telemetry systems a necessity for many organizations.

B.5.4 Status of Technology in Country

These systems are not readily available on the market. They will have to be ordered and necessary infrastructural arrangements must be made before they are installed and commissioned for use. Easy to accept for all involved stakeholders, there is also the possibility of sharing data amongst institutions concerned. Wireless telemetry systems are gaining wide importance and they are contributing significantly towards sustainable development of water resources.

B.5.5 Opportunities and Barriers

Opportunities for investment in telemetry systems are greatest as it can lead to time and cost savings, in addition to improved management of water resources. Conditions most favorable for its implementation are improvement in the network of hydrological data collection, collection of hydrological data on a more regular basis and at a lower cost.

Barriers to implementation include lack of such systems available locally, lack of skilled personnel to operate and maintain the system.

B.5.6 Benefits to Economic/Social and Environmental Development

Economical Benefits:

- Creation of jobs to set up, operate and maintain the system
- Creation of opportunities in the commercial area where organizations will be able to market such products with an operation and maintenance contract
- Reduction of expenses associated with mobilization of staff in hydrological data collection

Social Benefits

- Improvement in monitoring of the hydrologic network will result in improvement in water resource management and this can eventually result in more water being made available for development opportunities on both small and large scale.
- Training elements from capacity building for staff who will be involved in the operation of the system and at the same time education elements for the public who will be made aware of the need for optimization of water resources
- Increases per capita water availability. Lack of water can have serious health effects and allow for the spread of disease and illness if the reductions continues, even for a modest lengths of time
- Improved monitoring systems will help towards a more efficient use of water resources and will also lead to reduction in wastage.

B.5.7 Climate Change Adaptation Benefits

Sudan suffers from severe floods and seasonal forecasting. Therefore, early warning systems are much needed to eliminate the damage to lives and properties; inevitably provision will have to be made for robust systems and security.

B.5.8 Financial Requirements and Costs

Costs to implement adaptation options are 160 thousands Euro for the 16 key stations. Additional costs to implement adaptation option are needed, compared to "business as usual" (extra storage capacity). These would involve regular training of staff, operation and maintenance costs.

ANNEX II

List of Stakeholders Participating in the Inception and the Second Workshop

Name	Institute	Position
Somaya Alsayid	Ahfad University for Women	Lecturer
Nawal Hussain	Sudan Academy for Communication Sciences	Researcher
Nazik Hassan Ali Alawad	Ministry of Electricity and Dams	Deputy Director
Nuraldin Ahmed Abdalla	Meteorological Authority	Staff member
NourallaYassin Ahmed	National Energy Research Center	Researcher
Iman Alrashid Diab	National center for Research	Researcher
Sawsan Abdalla Ali	Forests National corporation	Deputy director
Issam Aldin Ibrahim Abdalla	Ministry of Agriculutre	Staff member
Haythum Kamal Aldin	Kenana Sugar Company	Employee
Almothana Saad Mohamed	Kenana Sugar Company	Employee
Igbal Salah Mohamed Ali	Ministry of Water Resurces	Researcher
Widad Motwakil Saadalla	Ministry of Water Resurces	Researcher
Tarig Algamri Atta Almanan	National Center for Research	Researcher
Hassan Wardi Hassan	Ahlia University	Lecturer
Mona Mahjoub Mohamed	Institute of Environmental Studies	Lecturer
Aboubaida Alboukhari	Sudanese Industerial Chamber Association	Staff member
Abdelrahman Altahir Ahmed	Kenana Sugar Company	Head Deparment
Salah Aldin Ali Mohamed	Mininstry of Petrollium	Staff member
Abdelazim Widaa	Mininstry of Petrollium	Staff member
Alrabia Mohamed Altahir	Mininstry of Petrollium	Head Deparment
Mostafa Mohamed Altahir	Ministry of Electricity and Dams	Staff member
Ikhlas Abdelaziz	Industerial Research Center	Researcher
Sayed Hajalnour Ahmed	Ministry of Environment , Forestry & Physical Development	Head Deparment
Thuraya Najib	Practical Acion	Employee
Ahmed Sulaiman Alwakeel	Free Lance	Environemtnal Consultant
Arig Jaafar Mohamed	National Energy Research Center	Researcher

Taghrid Abdelrahim	Ministry of Water Resurces	Staff member
Alwalid Abas Mohamed	National Energy Research Center	Researcher
Ali Omer Ahmed	National Energy Research Center	Researcher
Hanadi Attaalfadil Mohamed	Ministry of Industry	Staff member
Amani Abdelmahmoud Ali	Ministry of Environment , Forestry & Physical Development	Staff member
Ismail Fadlalmoula	Sudanese Meteorological Society	Staff member
Quosay Awad Ahmed	University of Khartoum, Petroleum Department	Lecturer
Mohamed Saad Ibrahim	Ministry of Animal Wealth	Staff member
Najla Mahgoub Hamadain	Forests National corporation	Staff member
Awatif Abdalla Mohamed	Ministry of Animal Wealth	Staff member
Salah Awadel-Karim	Cartoneel Printing and Packaging Company	Consultant Prof.
Nagla A. A. Dawelbait	National Centre for Research NCR	Assistant Prof
Suad Ibrahim Jalalaldin	Ministry of Agriculutre	Staff member
Naima Abedlgadir Hilal	Industrial Research Center	Researcher
Farough Ismail Abdeljalil	Ministry of Industry	Staff member
Salah Yousif Mohamed	Forests National corporation	Staff member
Amira Hasan Alam	Salam Company for Cement Production	Staff member
Ahmed Amer Mohamed	Shamal Company for Cement Production	Staff member
Abdelazim Yasin Abdelgadir	UofK, Faculty of Forestry	Lecturer
Alyas Ahmed Alyas Ahmed	UofK, Faculty of Forestry	Lecturer
Mohamed Ali Hamed	United Nations Development Program	Staff member
Osman TahaAlzaki	National Center for Research	Researcher
Hayfa Hasan Fadul	Ministry of Science and Technology	Staff member
Omayma Mohamed Ahmed	Ministry of Agriculutre	Staff member
Donya Hasan Khalafala	Ministry of Agriculutre	Staff member
Somaya Ahmed Alzaki	Institute of Environmental Studies	Lecturer
Asya Adlan Mohamed	Institute of Environmental Studies	Lecturer
Ali Mohamed Korak	Sudanese Association for Rural Afforestation	Staff member

Mohamed Yousif Mohamed	Institute for Water Harvesting Research	Lecturer
Sawsan Khair Alsid Abdel-rahim	Range and Pasture Administration	Staff member
Alamin Sanjak Mohamed	UofK, Faculty of Forestry	Lecturer
Mirghani Abnauf	Free Lance	Staff member
Dawoud Abbas Osman	Sduanese Industerial Union	Staff member
Imadaldin Ahmed Ali Babiker	Agriculutral Researh Authority	Staff member
Abedlrahman Khidir Osman	Free Lance	Staff member
Mawahib Altayeb Ahmed	National Center for Research	Researcher
Alfadil Biryma Hamed	National Energy Research Center	Research
Salah AldinHasab Aljabir	Ministry of Electricity and Dams	Staff member
Adam Musa Mohamed	Uinversity of Neelain	Lecturer
Adel Abdalla Rabih	Ministry of Electricity and Dams	Staff member
Osama Salah Mohamed	Ministry of Electricity and Dams	Staff member
Zuhair Mohamed Alsheikh	Ministry of Electricity and Dams	Staff member
SamyaYousifIdrisHabani	National Council	Staff member
AmiralElnour	Ministry of Industry	Staff member
AbdelrahmanAltahir Ahmed	Kenana Sugar Company	Staff member
Mustafa Mohamed Salih	Ministry of Electricity and Dams	Staff member
DirarHasan Nasr	University of Red Sea	Lecturer
Ali Mohamed Ali	HCENR	Project Coordi-nator
Mutasim Bashir Nimir	HCENR	NAPA Project Coordinator
Amal Abdelgadir Hasan	Ministry of Agriculutre	Staff member
Mahasin Balla Ahmed	Ministry of Agriculutre	Staff member
Alawiya Yousif Mohamed	Ministry of Agriculutre	Staff member
Maha Ali Mohamed	Ministry of Agriculutre	Staff member
Ayman Mohamed Abdin	Ministry of Agriculutre	Staff member
Dirar Ibrahim Dirar	Ministry of Agriculutre	Staff member
Khalid Ahmed Ali	Ministry of Agriculutre	Staff member
Asma Abobakr Ismail	HCENR	Staff member
Adel Mohamed Ali	HCENR	Staff member
Yasir Alzain Ahmed	HCENR	Staff member
Mohamed Ahmed Yousif	HCENR	Staff member

Mohamed Yousif Mohamed	Technology Transfer and Agricultural Extension	Staff member
Amani Abdelmahmoud Ali	Ministry of Environment , Forestry & Physical Development	Staff member
Nadir Mohamed	Sudanese Environmental Conservation Society	Environmental Consultant
Taysir Ismail Idris	Ministry of Agriculutre	Staff member
Howida Mirghani Almrdi	Ministry of Agriculutre	Staff member
Wigdan Mohamed Ibrahim	HCENR	Staff member
KhadijaYounis Abdelmawla	University of Bahri	Lecturer
Hasan Bashir Nimir	University of Khartoum, Petroleum Department	Lecturer
Nagmaldin Goutbi Alhassan	HCENR	Staff member
Ahmed Mohamed	Meteorological Authority	Staff member
Hiba Mahjoub Hassan	HCENR	Staff member
Mohamed Altahir Mohamed	HCENR	Staff member
Dinan Babiker Elkhalil	HCENR	Staff member
Mahjoub Hassan	Ministry of Environment , Forestry & Physical Development	Staff member
Ahmed Ibrahim Ahmed	Ministry of Transportation	Staff member
Abdelrahmen Elamin	EWASCO Company	Staff member
Hana Hamadalla Mohamed	HCENR	Staff member
Fathalrahman Ahmed	Ministry of Agriculture	Staff member
Daoud Abbas	Sudanese Industerial Chamber Association	Staff member
Mohamed Aljak Sulaiman	Industrial Research Center	Research
Seif Eldin Abdalmageed	Ministry of Labour	Staff member
Alam Sighayroun Mohamed	Sudanese Industerial Chamber Association	Member
Yasir Abdelkarim Abdelaziz	Sudanese Industerial Chamber Association	Member
Salwa Hamza Ali	Sudani Newspaper	Journalist
Ishraga Alhilo	Sahafa Newspaper	Journalist
Shaza Alrhma	Alray Ala'am News Paper	Journalist

ANNEX III

A. Multi Criteria Analysis for Agriculture Sector

Scoring

Technology option	Strategies & targets	*Sustainability*	*Costs/benefits*	Vulnerability	Utilization scale	Supportive systems
Improve crop variety	3	3	2.5	3	3	3
Zero tillage	3	3	3	2.5	3	2
Genetically modified crops	2	1.5	2	3	2.5	2
(Improve crops (imported	2.5	1.5	2	3	2	1.5
Livestock breeding	1.5	2	1.5	3	2.5	2.5

Standardization

Technology option	Strategies & targets	*Sustainabil-ity*	*Costs/ben-efit*	Vulnerabil-ity	Utilization scale	Supportive systems
Improve crop variety	3	3	2.5	3	3	3
	1	1	0.667	1	1	1
Zero tillage	3	3	3	2.5	3	2
	1	1	1	0.667	1	0.333
Genetically modified crops	2	1.5	2	3	2.5	2
	0.333	0	0.333	1	0.667	0.333
(Improve crops (imported	2.5	1.5	2	3	2	1.5
	0.667	0	0.333	1	0.333	0
Livestock breeding	1.5	2	1.5	3	2.5	2.5
	0	0.333	0	1	0.667	0.667

Weighting

Technology option	Strategies & targets	*Sustainability*	*Costs/benefits*	Vulnerability	Utilization scale	Supportive systems	Total	Ranking
Weight-absolute	3	3	3	3	2	2	16	
Weight - relative	0.1875	0.1875	0.1875	0.1875	0.125	0.125		
Improve crop variety	1	1	0.667	1	1	1	0.94	1st
	0.1875	0.1875	0.125	0.1875	0.125	0.125		
Zero tillage	1	1	1	0	1	0.333	0.73	2nd
	0.1875	0.1875	0.188	0	0.125	0.042		
Improve crops ((imported	0.667	0	0.330	1	0	0	0.646	3rd
	0.125	0	0.333	0.19	0	0		
Genetically modified crops	0.333	0	0.333	1	0.50	0.333	0.42	4rth
	0.062	0	0.062	0.19	0.06	0.042		
Livestock breed-ing	0	0.333	0	1	0.50	0.667	0.396	5th
	0	0.062	0	0.19	0.06	0.08		

"

B. Multi Criteria Analysis for Water Sector
Scoring

Technology option	Strategies & targets	*Sustainability*	*Costs/benefits*	Vulnerability	Utilization scale	Supportive systems
Rain water harvesting haffir	3	3	3	3	2	2
Seasonal forecasting and early warning ((Automatic water level	3	3	3	2.5	2	2
Seasonal forecasting and early warning ((Telemetry system	3	3	2.5	2.5	2	2
(Rain water harvesting (earth dam	3	2	2	2	3	1.5
Water pipeline for fresh water supply	3	3	3	1	1	2
Water quality technology	2	2	2	2	3	2
Ground water recharge	2.3	1.5	2	3	2	1
Desalinization	1	2	2	2	2	1

Standardization

Technology option	Strategies & targets	*Sustainability*	*Costs/benefits*	Vulnerability	Utilization scale	Supportive systems
(Rain water harvesting (haffir	**3**	**3**	**3**	**3**	**2**	**3**
	1	**1**	**1**	**1**	**0.5**	**1**
Seasonal forecasting and Early (warning (Automatic water level	**3**	**3**	**3**	**2.5**	**3**	**2**
	1	**1**	**1**	**0.75**	**1**	**0.5**
Seasonal forecasting and Early (warning (Telemetry system	**3**	**3**	**2.5**	**2.5**	**3**	**2**
	1	**1**	**0.75**	**0.75**	**1**	**0.5**
(Rain water harvesting (earth dam	**3**	**2**	**2**	**2**	**3**	**1.5**
	1	**0.333**	**0**	**0.5**	**1**	**0.25**
Water pipeline for fresh water supply	**3**	**3**	**3**	**1**	**1**	**2**
	1	**1**	**1**	**0**	**0**	**0.5**
Water quality technology	**2**	**2**	**2**	**2**	**3**	**2**
	0.5	**0.333**	**0**	**0.5**	**1**	**0.5**
Ground water recharge	**2.3**	**1.5**	**2**	**3**	**2**	**1**
	0.65	**0**	**0**	**1**	**0.5**	**0**
Desalinization	**1**	**2**	**2**	**2**	**2**	**1**
	0	**0.333**	**0**	**0.5**	**0.5**	**0**

Weighting

Technology option	Strategies & targets	*Sustainability*	*Costs/benefits*	Vulnerability	Utilization scale	Supportive systems	Total	Ranking
Weight-absolute	3	3	3	3	2	2	16	
Weight - relative	0.188	0.188	0.188	0.188	0.125	0.125		
Rain water harvest-(ing (haffir	1	1	1	1	0.5	1	0.94	1st
	0.188	0.188	0.188	0.188	0.063	0.125		
Seasonal forecasting and Early warning (Automatic water (level	1	1	1	0.75	1	0.5		2nd
	0.188	0.188	0.188	0.141	0.125	0.063	0.89	
Seasonal forecasting and Early warning ((Telemetry System	1	1	0.75	0.75	1	0.5		3rd
	0.188	0.188	0.140	0.140	0.125	0.063	0.84	
Rain water harvest-(ing (earth dam	1	0.333	0.5	0.5	1	0.25		4rth
	0.188	0.062	0.094	0.094	0.125	0	0.563	
Water pipeline for fresh water supply	0.5	1	1	0	0	0.5		5th
	0.094	0.188	0.188	0	0	0.063	0.531	
Water quality technology	1	0.333	0	0.5	1	0.5		6th
	0.188	0	0	0	0.125	0	0.531	
Ground water recharge	0.65	0	0	1	0.5	0		7th
	0.122	0.0000	0.0000	0.188	0.063	0	0.37	
Desalinization	0	0.333	0	0.5	0.5	0		8th
	0	0.062	0.0000	0.094	0.063	0	0.22	

Republic of Sudan

Ministry of Environment, Forestry and Physical Development

Higher Council for Environment and Natural Resources

BARRIER ANALYSIS AND ENABLING FRAMEWORK

PART 2

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Abbreviations

AIACC	Assessment of Impact and Adaptation to Climate Change
EGTT	Expert Group on Technology Transfer
COP	Conference of Parties
CTI	Climate Technology Initiative
FNC	Forests National Corporation
GDP	Growth Domestic Product
GHG	Greenhouse Gases
GoS	Government of Sudan
HCENR	Higher Council for Environment and Natural Resources
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
MDGs	Millennium Development Goals
MEA	Multilateral- Environmental Agreements
MEPD	Ministry of Environment and Physical Development
MoST	Ministry of Science & Technology
NAPA	National Adaptation Programm of Action
NAPs	National Adaptation Plans
NGOs	Non Governmental Organizations
SNC	Second National Communication
TAP	Technology Action Plan
TNA	Technology Needs Assessment
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

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Chapter I

Agriculture Sector

1.1 Preliminary Targets for Improved Crop Varieties Transfer and Diffusion

The rate of adoption of a new technology is subject to its profitability, degree of associated risks, capital requirements, agricultural policies, and socioeconomic characteristics of farmers. Producers benefit from the adoption of new technologies through opportunities to lower their production costs, either by increasing outputs from the same inputs or by maintaining the same output from reduced inputs. One of the short-term, impacts of a new agricultural technology is an increase in the incomes of farmers adopting the technology.

For the improved crop varieties technology, all the farmers of the country, rain-fed and irrigated agriculture, are preliminary targets for the transfer and diffusion of the improved crop varieties. The estimated number of the two categories is 800,000 farmers, of which 150,000 are small-scale farmers and 650,000 are large-scale farmers. The project of Sudan's TNA focuses on small-scale farmers (150,000 farmers) as large-scale farmers are believed to be financially capable of adopting the technology at their own expense. Therefore, Sudan's TNA focuses on those who are financially incapable of adopting the technology at their own expense mainly due to their vulnerability to climate change and acute poverty. The majority of this group (small-scale farmers) is practicing farming for subsistence needs. More specifically, this includes all rain-fed agriculture in Gedarif, Kassala, North Kordofan, North Darfur, White Nile and Sinnar states. These states are stretching from the border with Ethiopia in the east to the border with Chad in the west, falling within the semi-arid and low rain savannah zones. It is true that the proposed area covered in the project is incredible and covering six states, but widespread adoption of new production technology is expected to have important market-level effects. This means that widespread adoption of a new technology is likely to have economic implications beyond the production system. The following figure presents a visible productivity improvement for watermelon in Sudan. Since the number of the target group is relatively big (150,000 farmers), it is expectted to cover all the areas within ten years following the implementation of a pilot project in a selected state. In the following years different extension methods, including field days, tours and demonstrations of results and methods will be deployed to disseminate the information regarding improved crop varieties in order to enhance the transfer and diffusion of technologies in the six states. Since the Ministry of Agriculture is the responsible institution to secure satisfactory crop production, it is the responsible body for sensitizing and mobilizing small-scale farmers to adopt the technology of improved crop varieties to reduce their vulnerability.

Figure 1: Productivity Improvement of Watermelon

As far as zero tillage is concerned, the preliminary target group includes all small-scale farmers in areas characterized by 600mm rainfall per year because this is a prerequisite for the application of zero tillage. The plan covers 5,000 small-scale farmers in the following areas: South Sinnar State, Blue Nile State, South Kordofan State, Southern parts of North Kordofan State and Gedarif State. Within ten years it is expected that this technology would be adopted by all the small-scale farmers. The Ministry of Agriculture is responsible for information dissemination about zero tillage and also skills training for zero tillage in all the above mentioned areas.

1.2 Barrier Analysis and Possible Enabling Measures for Improved Crop Varieties

This section provides an analysis of barriers that impede the uptake and diffusion of the improved crop varieties technology by small-scale farmers in the semi-arid zone of Sudan. The step of identifying barriers for improved crop varieties was followed by screening classifying the barriers into key versus non-key barriers, and barriers that cannot be removed or resolved. The national team through consensus arrived at determination of the final set of key barriers. Furthermore, four levels of decomposition were deployed to identify barriers that include key barriers within broad barriers, elements of barriers and dimensions of barriers. The process involved regular discussion meetings by the national team and sporadic interviews with the stakeholders according to their availability. The stakeholders represent experts from the two selected sectors, from different affiliations, i.e. governmental institutions, higher education, civil society, and private sector.

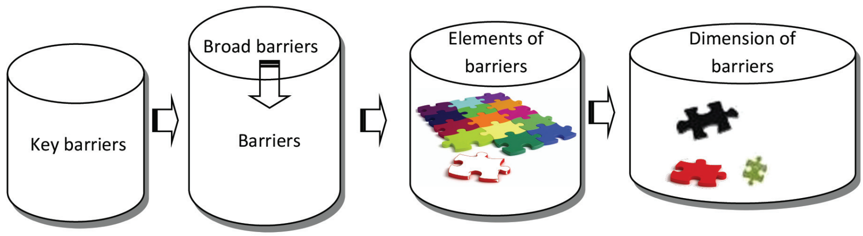

Figure 2: Identification of Barriers

The problem tree of improved crop varieties in appendix I show the decomposition of barriers. Although a wide array of adaptation options are available more extensive adaptation options are required to reduce vulnerability to climate change. There are barriers, limits and costs that are not fully understood. There is high confidence that there are viable adaptation options which can be implemented in the agriculture sector at low costs and/or with high cost-benefit ratios. Empirical research also suggests that higher cost-benefit ratios can be achieved by implementing some adaptation measures at an early stage rather than retrofitting long-lived infrastructure at a later date. In brief, it is very important to identify the barriers and analyze them to enhance the proper selection of the technology based on sound arguments.

1.2.1 General Description of Improved Crop Variety Technology

The new improved varieties of crop embody a technology aimed at enhancing plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses. Plant breeding provides new improved crop varieties with unique characteristic that are beneficial, profitable and adaptable for many growing environments. The farming sector in Sudan includes a diverse mix of farmers from small holder farmers, to large-scale producers in irrigated and rain-fed areas. The production per unit area is very low due to the lack of agricultural technologies including improved varieties. Rainfall fluctuation, pest and diseases lead to low productivity. The technology of breeding new improved crop varieties depends on genetic crop diversity and crop gene resources adapted to the targeted areas. The process is composed of the following:

- Selection of the areas and local varieties adapted to the area

- Breeding process for tolerance to adverse environmental conditions such as drought, flooding and heat

- Resistance to diseases and pests

- Agronomic traits affecting yield quality, competences against weed

- Meet the need of farmers and end users

- Evaluation started during the breeding process and continues through variety release

- Testing process for environmental adaptation and farmer acceptance

- Breeding seeds production for released improved variety

- To apply the technology of improved crop varieties in the rain-fed area of the country, the following requirements are needed:

- Technical skills and institutional organization

- Consultancy in designing the breeding programs of improved varieties with national and international organizations

- Technical training for researchers, states and federal staff who are working with the agriculture extension

- Establishment and rehabilitation of research units

The potential covers the main rain-fed areas in south Gadarif, Kassala, south White Nile and Blue Nile, North Kordofan and North Darfur states, and can be extended from east to central and west of Sudan.

1.2.2 Identification of Barriers for Improved Crop Varieties

Improved crop varieties are consumer goods which are specifically intended for the mass market, households, businesses and institutions. The market characteristics of improved crop varieties include a high number of potential consumers, interaction with existing markets and requiring distribution, maintenances and installer networks in the supply chain, large and complicated supply chains with many actors, including producers, assemblers, importers, wholesalers, retailers and end consumers (Shaxson *et. al*., 2008).

Farmer experimentation using only native varieties can limit the range of benefits and responses that may be found amongst the materials being tested, although local adaptation and acceptance are ensured. One of the major problems that can arise with the introduction of exotic species is the outbreak of pests. There are several examples of introduced species that have escaped control becoming pests or agricultural weeds (Ojasti, 2001). A limitation of crop diversification is that it may be difficult for farmers to achieve high yields in terms of tons per hectare given that they have a greater range of crops to manage (Hall, 2003). Farmers also face risks from poor economic returns if crops are not selected based on a market assessment. Furthermore, lack of financial funds for agricultural research leads to limited budgetary allocations for research and development. Thus, it is essential to develop more sustainable research with appropriate integration of technology adaptation and to strengthen farmer seed research companies, extension agents and policy makers (Ojasti, 2001).

After the stakeholder consultations and based on the national team's knowledge the main barriers confronting the development and adoption of improved crop varieties through breeding were identified and categorized. Appendix I shows the problem tree for improved crop varieties. The main barriers are:

- Information and awareness: There is a low level of awareness and perception of improved crop varieties among farmers. Agricultural extension in Sudan is not efficient as there are no systematic programs and services for awareness development. In addition, all the programs are sporadic which is reflected in the low level of adoption of new crop varieties. The barrier of farmer's perception is also associated with extension services. Farmers are reluctant to make changes in their habits and traditions and habitually follow practices carried out by their ancestors. This is a cornerstone barrier against adoption of improved crop varieties, a barrier that has substantial social and cultural dimensions.

- Human skills: This barrier is also associated with efficiency of extension services and lack of technical know-how. Training, particularly through demonstration, is a vital means for the transfer of technical know-how from the research stations to the farmers. Failure of transferring knowledge reduces the number of skilled farmers who are capable of producing the improved crop varieties, consequently there is a limited number of improved crop variety providers.

- **Infrastructure:** In Sudan research stations are often characterized by limited infrastructure and shortage of technological information. Most researches in the field of improved crop varieties are confining to researches leading to academic degrees, including Master and Doctor of philosophy. Necessary equipment, particularly pertaining to crop physiology, is very expensive and unavailable which also contributes to the explanation of why only a limited number of crops have been improved. The developing countries typically lack access to information; they are not aware of what technologies fit their conditions and where they can find suitable ones. Thus, international technology exchanges are helpful for overcoming this obstacle.

- **Cultural and social difficulties:** Changing food habits is one of the barriers, even to testability; and palatability of certain types of food may make rural people reluctant to divert to improved crop varieties.

By exploring the barriers for improved crop variety technology transfer and diffusion, the barriers can be classified into two broad categories, namely: economic and financial barriers, and non-financial barriers. The former deals with costs and tangible benefits; the latter includes cultural and social factors such as state of knowledge and skills, as well as awareness and perception. Table 1 shows the economic and financial and non-financial barriers.

The effects of these barriers is reflected in the limited use of improved crop varieties, in particular seeds or seedlings, simply because the improved varieties are out of reach of the small-scale farmers due to their high costs of application and the consequences of adoption. This limited availability of improved crop varieties in turn leads to low yields. This phenomenon is now very common in the low rain savannah and semi-arid zone of Sudan. The productivity of the agricultural land declined sharply and the only available strategy to cope with this situation is to expand the cultivable area in order to harvest the same amount the farmer used to harvest from smaller lands. The negative consequence of this strategy is represented in the huge efforts exerted by the farmers and their families (labor force) and the time spent to cover the different agricultural activities in small fragmented agricultural parcels or devastated areas. The lack of financial resources, limited availability of improved seeds and low yield automatically translates into food insecurity which may lead to instability of rural communities as they resort to transitional or permanent migration, or suffer worsening poverty. It is worth noting that this situation may lead to children malnutrition and high mortality rates of children below the age of five.

Table 1: Barriers to improved crop varieties in the Sudan

Economic and financial	Non-financial
High cost of local production	Limited availability of improved seeds varieties
High price of seeds/seedlings	Farmers awareness about existing technologies
Absence of financial facilities	Limited producers
Difficulty making profit	Farmer’s perception of technology
Absence of related infrastructure	Lack of technical know-how
Limited availability of financial resources	Cultural/social difficulties
	Limited use of seeds

1.2.2.1 Economic and Financial Barriers for Improved Crop Varieties

The biggest barrier for technology transfer among developing countries may be the shortage of financial support, as appeared in the case of the Sudan. Technology recipients need new investments to adopt new technologies. The providers need to ensure human and financial resources to transfer the technology. The extent of technology transfer may be limited by the shortage of financial resources. Additional financial resources may need to be accompanied by the removal of institutional barriers in order to be effective such as cost-sharing which may be an important safeguard. According to the Food and Agriculture Organization of the United Nations (FAO, 1990), technology transfer in developing countries involves some 550,000 staff, most of them in public extension services which costs about US$4.5 billion annually. Under the influence of structural adjustment and declining public funding, extension services have tended to shrink in recent years. One of the serious barriers is the absence or paucity of financial facilities, a situation that contributes dramatically to increment in the cost of production, which in turn leads to price increases for seeds and seedlings. Governments and international organizations have the opportunity to encourage the private sector to promote effective modalities for access and transfer through grants and concessional loans. Moreover, operational budgets per researcher in the country have been declining in recent years.

Cost-benefit analysis for facilitated improved crop varieties technology taking sorghum as an example:

Objective of project is to produce improved varieties of sorghum that cultivate 100,000 feddan and grow by 10 per cent annually.

- Use zero tillage to produce a breed seed
- Seed rate /feddan=20kg. So to produce seeds that cultivate 100,000 feddan in a pilot farm of 1,333 feddan, with average production of 15 sack/feddan
- Operating costs= operating expenses + production cost + unforeseen expenses (750,000 +85,333+ 540,000) = 1,375,333 USD
- Costs of sack of seeds= 69 USD
- Current market price/sack = 24 USD
- Subsidy proposed to sell improved seeds at current market price = 24 USD

- Cost of subsidized seeds/ feddan= 39 USD

The capital costs of adaptation improved crop varieties includes one unit comprising of two offices, meeting room, laboratory and rest house for 6,000,000 USD, laboratory equipment costing 1,500,000 USD, and capacity building and training for about 500,000 USD. The total cost is 8,000, 000 USD, and the operating costs of improved crop variety is about 1,375,333 USD. The breakdown of the operation cost is: operating costs (750,000 USD), unforeseen costs (540,000 USD), and production cost 85,000 USD bearing in mind that production costs per feddan is 64 USD.

According to available data, it is well known that the productivity of the traditional farm seeds is three sacks per feddan, while the productivity of the improved sorghum varieties is eight sacks per feddan. Therefore, using improved crop varieties saves the use of five sacks.

As far as returns from the improved crops are concerned, table 2 shows returns of conventional, improved and effect of adaptation to the technology.

In addition, table 3 illustrates three scenarios of traditional, improved varieties and subsidized crops, thereby reflecting:

- Financial analysis undertaken for three scenarios to clear cut the financial impacts of adaptation technology of improved crop varieties
- Comparison between three scenarios per feddan costs
- Costs extracted from the research station costs by converting all costs per feddan
- For traditional scenario, capital costs are 10 per cent, supposed to derive net present value.
- Initial investment costs for both improved crop varieties without subsidy and subsidized scenario extracted from station capital costs
- Pilot farm to produce improved varieties of 1,333 feddan

Table (2) Returns of conventional, improved and effect of improved crop varieties adaptation technology

item	Price sack $	Area	Conventional productivity	Improved productivity	Effect
Sorghum	24	100,000	3	8	5
Returns of effect			7,200,000	19,200,000	12,068,966

Returns Annual growth 10%
Operating costs growth rate 15%
Production costs 65% of returns.

Table (3) Three scenarios of traditional, improved varieties and subsidized scenario.

Item / year	0	1	2	3	4	5	6	7	8	9	10
Traditional cultivation of dura											
Net cash flows	(8)	50	50	50	50	50	50	50	50	50	50
Present value @15%	(8)	43	38	33	29	25	22	19	16	14	12
(Net present value(NPV	+243										
(Profitability index(PI	31										
Improved crop varieties											
Net cash flows	(80)	114	114	114	114	114	114	114	114	114	114
Present value @15%	-80	99	86	75	65	57	49	43	37	32	28
(Net present value(NPV	+494										
(Profitability index(PI	7.2										
Subsidized improved seeds varieties											
Net cash flows	(80)	153	153	153	153	153	153	153	153	153	153
Present value @15%	(80)	133	116	101	88	76	66	58	50	44	38
(Net present value(NPV	+689										
(Profitability index(PI	9.6										

Table (4) Research station adaptation of improved crop varieties as a unit of production

Item/ year	0	1	2	3	4	5	6	7	8	9	10
Initial cost of adaptation	(8,000,000)										
Returns of effect		12,068,966	13,275,862	14,603,448	16,063,793	17,670,172	19,437,190	21,380,909	23,518,999	25,870,899	28,457,989
costs of effect		3,900,000	5,157,750	5,931,413	6,821,124	7,844,293	9,020,937	10,374,078	11,930,189	13,719,718	15,777,675
cash flow of effect	(8,000,000)	7,575,808	7,531,061	8,074,112	8,633,899	9,206,464	9,786,602	10,367,618	10,941,031	11,496,224	12,020,040
Depreciation		414,286	414,286	414,286	414,286	414,286	414,286	414,286	414,286	414,286	414,286
Net cash flows	(8,000,000)	7,990,093	7,945,347	8,488,397	9,048,185	9,620,749	10,200,887	10,781,904	11,355,317	11,910,509	12,434,326
PV @15%		6,947,907	6,007,824	5,581,259	5,173,329	4,783,213	4,410,125	4,053,317	3,712,073	3,385,710	3,073,575
NPV	+39,128,333										
Profitability index (PI)	4.9										

The financial barriers for improved crop varieties are mainly:

- Lack of or limited availability of financial funds for agricultural research leads to limited allocation of budgets for research and development. Almost all the other barriers have a direct or indirect relation with the availability or lack of financial facilities. This is apparent in Sudan where all the states of the country suffer from marginalization due to remoteness from the seats of government. Another financial barrier is the high levels of poverty. Therefore, absence of financial facilities is considered the main barrier for development and adoption of improved crop varieties. There are limited or no funds available for making research at the agricultural research stations and academic institutions. Even when there are some improved crop varieties, the level of adoption lags far behind expectations due to lack of efficient extension services. This barrier is categorized as market failure, and can be considered as key barrier for the development and adoption of improved crop varieties.

- High cost of local production and prices of improved seeds is another factor that is closely linked with limited financial funds. Costs of farmer experimentations are generally low, but results may only have local applicability. Capital investment will relate to the purchase of new seed varieties and labor time. Another factor is the high price of seeds or seedlings. This barrier associates directly with the prices of the improved seeds and seedlings. Since the cost of development is very high, it is logical to hike prices. Accordingly, the developed improved seeds may not be affordable and accessible to all the farmers.

- Difficulty of profit making: Market failure barrier is represented in the difficulty making profits from the improved crop variety technologies. Thus the adoption of this technology needs additional efforts raising awareness for the new products.

1.2.2.2 Non-financial Barriers for Improved Crop Varieties

National team members and the stakeholders have pinpointed a number of non-financial barriers that confront the adoption of improved crop varieties in Sudan. Some of these problems cannot be expressed quantitatively. They are compelling co-benefits that farmers desire, provided the costs are financially manageable over time. These non-quantifiable benefits are mainly institutional capacities on agricultural research which is limited in developing countries.
The main non-financial barriers for improved crop varieties, as perceived by the stakeholders, include;

- Limited availability of improved seeds varieties: research and development are only confining to academic and research institutions. The results of experimentations are placed on the shelves of the libraries and not disseminated to consumers or retailers or anybody in the production chain.

- Limited farmers' awareness about existing technologies: particularly under the prevalence of ineffective extension services and training sessions in the field of improved crop varieties

- Limited producers: lack of technical know-how and skills and complete absence or limiting enabling factors deter investment in the improved crop varieties.

- Limited farmer's perception of technologies: most of the traditional farmers are conservative. Thus, it is not easy to mobilize and sensitize them to adopt new interventions.

- Lack of technical know-how: or the information gap between the new technology and the consumers which would highly restrict the dissemination of the intervention.

1.2.3 Identified Measures for Improved Crop Varieties

Enhancing the adoption of improved crop varieties across the country needs special measures for involving a coalition comprised of public and private sectors. In order to accelerate and guarantee steady transfer and diffusion of improved crop varieties through breeding, a number of measures and studies that could be taken by the government and private organizations or institutions are recommended. It is hoped that these ideas will stimulate the adoption of measures at a wide scale across the whole country wherever the validity of the technology is applicable. It was stressed by many researchers, particularly the Agriculture Research Corporation and faculties of agriculture in different universities of the country that there are many improved crop varieties from breeding in the country that remain under used or unutilized. The Department of Agronomy, Faculty of Agriculture at University of Khartoum released a considerable number of subsistence and commercial improved crops. The research team leader was awarded by the president of the country for the production of improved crop varieties. Other departments of faculties of agriculture in other universities, particularly Gezira University contributed significantly to improved crop varieties. However, the Agriculture Research Corporation is still the leading institute in the field of improved crop varieties.

To make these technologies easily accessible to clients, a number of measures have to be taken. For example, information on available improved crop varieties can be systematically compiled and made available. This can be done by networking existing databases. Other incentive measures could be to encourage suppliers to make the technologies available to users, to assess user needs and to stimulate the adaptation of improved crop varieties by users. Measures for the transfer and diffusion and adoption of improved crop varieties were identified through stakeholder consultations and the national team's own knowledge and experience. These measures are classified in two main groups, namely economic and financial measures and non-financial measures. Appendix I shows the measures for improved crop varieties.

1.2.3.1 Economic and Financial Measures for Improved Crop Varieties

The economic and financial measures that are necessarily considered to offset the economic and financial barriers to the improved crop varieties include provision of financial assistants to the farmers and producers of the improved crop varieties like subsidies and soft loans to encourage the small-scale farmers to adopt the new interventions. Therefore, provision of incentives, subsidies or soft loans will solve the barriers of limited funds, high costs of inputs and lack of profitable markets. Moreover, it is important to consider measures for the compensation of research and development (R& D) expenditures as an incentive to enhance research for better achievements. As mentioned in the barrier analysis, there is a limited or lack of research and development efforts to improve the livelihood of local communities in rural areas. This is why improvement of research and development will nullify the barrier of limited or lack of researches and development. The incentives that could be considered are those that permit the R& D laboratories to retain their surplus earnings, and formulate incentive measures for their own scientists, thus providing a strong incentive for individual scientists. As far as the customers are concerned, the prices of the improved crop varieties should be within their reach. Since most of the small-scale farmers are poor, soft loans should not be linked with collaterals which are not satisfactory for the provision of soft loans. The head of the tribe or the traditional leader of the group should guarantee the debt repayment to avoid delayed provision of loans. Also, lower cost/removal of royalties should be considered through exempting small farmers from paying royalties. Moreover, provision of related infrastructure would enhance and expand the adoption of improved crop varieties.

1.2.3.2 Non-financial Measures for Improved Crop Varieties

This issue encompasses different items that necessitate the availability of enough information about the technology and considerable skills to guarantee the sustainability of the adoption of the improved crop varieties interventions. Therefore, finding solutions to the barrier of information inadequacy or information gap or even lack of skill and awareness necessitates the following:

- Establish a network of experts, develop policies to encourage and support researchers to invest in improved seeds and seedlings; capacity building of extension agencies to increase the providers of improved crop varieties. In addition, raising awareness of the people is necessary to eradicate cultural and social barriers regarding the adoption of improved crop varieties.

- Resolving all the barriers, including financial and economic, and non-financial, for improved crop varieties will expand use of seeds and seedling by the majority of farmers. As a result, there will be high yields of agricultural products which in turn will be reflected in high incomes from the returns from marketing of the improved seeds and seedlings. The ultimate result of the intended measures is the attainment of food security with better nutrition of local people and low expenditure for health.

1.3 Barrier Analysis and Possible Enabling Measures for Zero Tillage Technology

No tillage and Conservation Agriculture (CA) has initially been developed as farming methods to reduce erosion. It has been proven that with CA the erosion rates can be brought to levels below the soil formation, which makes the system in the long term sustainable. A review of human history and the fate of human civilizations through the millennia of human development on earth have shown that the survival of civilizations has directly been linked to the way they treat their soils. Each decline of a civilization was accompanied by significant soil erosion events, which today can still be geo-morphologically proven (Montgomery, 2007). The advantage of zero tillage over tillage agriculture in terms of the duration of plant-available soil moisture is clearly illustrated in the work of Derpsch *et al*, (1991), which shows that the situation with respect to soil moisture conditions in the rooting zones throughout growing-season are more favorable under zero tillage compared to tillage agriculture (Landers, 2007).

1.3.1 General Description of Zero Tillage

Zero tillage is a method of plowing or tilling a field in which the soil is disturbed as little as possible – the crop is planted directly into seed bed which has not been tilled since the harvest of the previous crop. In Sudan there are three major farming systems: irrigated agric systems, semi-mechanized systems and traditional rain-fed production systems. Subject to intensive and repeated tillage, rain-fed areas undergo organic matter diminishment at high rates, which results in diminishing crop yield (non- sustainable agric production system). The production costs increase due to degradation of soil resulting in low yields attended by lack of technologies. Zero tillage aims at making better use of agricultural resources through the integrated management of soil, water and biological inputs. It contributes to environmental conservation and to sustainable agricultural production by increasing rural farmers, productivity and incomes, thereby attenuating poverty. Zero tillage improves the soil, increases production while decreasing the costs of production. It consists of improved agricultural packages: crop residue from previous crops and crop rotation, application of herbicide for the control of emerging and non-emerging weeds (pre- and post-emergence herbicides), planting in rows and application of fertilizer in one operation by a special planter; and agricultural operation starting after the soil received 110 mm of rainfall.

The application of zero tillage production system requires knowledge and skills, and necessitates that farmers should be organized in groups or societies under the umbrella of agricultural service providers. All these things are available in Sudan and accordingly, the applicability of the technology is beyond doubts. Zero tillage has been introduced in Gadarif State since the year 2000. Training and skills development of state federal staff, stakeholders and farmers in the application of technologies of zero tillage, including plating, spraying and application of fertilizer, has taken place in this area. Moreover, skill- operators in maintenance and calibration are available and the farmers are aware about the zero tillage system.

Figure 3: Contribution of Semi-Mechanized System to Soil Degradation

Figure 4: The Effect of Zero Tillage Technology on Plants Re-productivity

1.3.2 Identification of Barriers for Zero Tillage

Zero tillage is a method of plowing or tilling a field in which the soil is disturbed as little as possible. Rain-fed areas subjected to intensive and repeated tillage undergo high rate diminishment of organic matter, which results in diminishing crop yields (non- sustainable agric production system). Zero tillage on the other hand contributes to environment conservation and sustainable agricultural production by increasing the rural farmers' productivity and incomes, thus contributing to decreasing poverty.

Conservation tillage systems offer numerous benefits that intensive tillage systems cannot match. These advantages are summarized as follows:

- Reduced labor requirements
- Time savings
- Reduced machinery wear
- Fuel savings
- Improved long- term productivity
- Improved surface water quality

- Reduced soil erosion
- Greater soil moisture retention
- Improved water infiltration
- Decreased soil compaction
- Improved soil tilt
- Reduced release of carbon gases
- Reduced air pollution

Despite the positive impacts of zero tillage in improving the physical and chemical properties of agricultural soil, which is directly translated into increased crop productivity of agricultural, the practice is confronted with barriers and measures of risk that may confine its adoption to certain sites.

Table 5: Barriers confronting adoption of Zero Tillage

Economic and Financial Barriers	Non-financial Barriers
Lack of financial support	Unavailability of enough information or knowledge
Impossibility of crop rotation	Lack of know how about zero tillage
Difficulty of buying specialized (machine (Small farm size	Lack of government support
Difficulty of buying adequate herbicides	Farmer perception
Poorly developed infrastructure	Lack of adequate policies to promote adoption of intervention
High costs of inputs	Ecological barriers
Unavailability of Zero Tillage machines at markets	Poor research
	Strong demand for crop residues

1.3.2.1 Economic and Financial Barriers for Zero Tillage Technology

The costs of applying zero tillage are high compared to traditional agriculture. The analysis shows that the costs of establishing one unit with zero tillage equipment, i.e. a tractor 90HP+planter+ sprayer, is approximately 31,600 USD, compared to the costs of cultivation of one hectare by traditional method which is approximately 40 USD.

Analyses of other elements in zero tillage also revealed that lack of local production and availability of equipment and other inputs, such as herbicides, add to the significant increase in costs and may present a barrier to its implementation.
Financial barriers are the cornerstone obstructing adoption, success and sustainability of zero tillage. Therefore, during group consultations measures were proposed to overcome zero tillage barriers in the short and long run by using logical problem analysis. The following frame denotes how sequentially different measures can contribute to alleviating such barriers that lead to the successful adaptation of zero tillage. Such measures predominantly rely on a conceptual framework of cooperative activities, including:

- Clustering small farmers into cooperative societies
- Bank finance
- Specialized pool finance
- Extension efforts
- Pilot farm is very impressive on farmers

Assumptions used for the cost-benefit analysis are:

- Exchange rate of 1 USD=SDG 5.8
- Unit farm of 1933 feddan
- Production costs grow annually by 15 per cent
- Sales grow annually by 10 per cent
- Extension services and pilot farms: 1 USD/ feddan for only two years 1 USD/ feddan
- Maintenance costs: 3 per cent of production costs
- Lubrication: 1 per cent of production costs
- Costs estimated based on feddan for financial analysis calculations

Cost items include 1\ Capital initial costs

- Cooperative formulation: procedures to register societies cost 3,000 USD

- Production unit should be dedicated to one tractor

- Tractor could achieve cultural practices as planting, spraying fertilizers, pesticides and herbicides

- Each unit of 1933 feddan should have one tractor with its accessories., i.e. tractor + its accessories= 31,600_USD

- Pilot farm of one feddan incurs a production cost of 64 USD per unit

- Total initial investment costs=(3, 000+31 600+64)= 34,664 USD

Table (A) in Appendix I denotes capital and operating costs, and the effects of adaptation technology. The benefits of adopting zero tillage technologies include increases of crops yield per unit area, preserving soil and decreasing erosion. The cost assumption for the analysis includes; current traditional cultivation yield per feddan in rain fed =4 sack, adaptation effect a yield of 10 sacks, price per sack= 21 USD, and initial investment share per feddan = 64 USD.

Table 6: Net Present Value of Adaptation of Zero Tillage Technology

Year	0	1	2	3	4	5	6	7	8	9	10
Traditional yield (sack/feddan		4	4	4	4	4	4	4	4	4	4
Adaptation Tech yield(sack/fed-(dan		10	10	10	10	10	10	10	10	10	10
Adaptation effect		6	6	6	6	6	6	6	6	6	6
Adaptation benefits $/fed	-64	126	152	168	184	203	223	246	270	297	327
Adaptation Costs		104	120	138	158	182	209	241	277	318	366

Net benefit		22	22	22	22	22	22	22	22	22	22
PV @15%	(64)	110	95	83	72	63	54	47	41	36	31
NPV	+15										
Profitability in-(dex(IP	1.24										

Discount rate adopted 15 per cent, represents capital cost imposed by the Central Bank of Sudan, monetary policy for 2013.

The financial analysis parameters used are profitability index and net present value and calculation of net present value to pinpoint financial feasibility of the adaptation effect created by adoption of zero tillage technology. **Table 6** shows the net present value of adaptation of zero tillage technology.
The main economic and financial barriers confronting transfer and diffusion of zero tillage practices are:

- Soil degradation and weed mismanagement

- Difficulty of buying specialized machine

- Lack of financial support

- High costs of inputs and implementation which makes crop rotation impossible

- Difficulty of buying adequate herbicides

1.3.2.2 Non-financial Barriers for Zero Tillage

The main barriers of adoption of zero tillage are: (1) lack of locally-appropriate knowledge and/or poor research and development for conservation tillage technologies (2) high investment technology in rain-fed areas (3) depending on rainfall which is a most unpredictable variable (4) mindset (tradition, prejudice) (5) lack of adequate policies (6) availability of adequate machines (7) prevalence of small landholdings and (8) unavailability of suitable herbicides to facilitate

weed management. Ecological barriers to zero tillage production systems include low precipitation with low biomass production, short growing seasons and soils at risk of water logging. Socio-economic constraining factors include strong demand for crop residues as forage for livestock, uncertain land use rights and poorly developed infrastructure (market, credit, extension service). It has also been stated that zero tillage poses many new management challenges for the new farmers who are familiar with traditional types of agriculture. If farmers never witnessed the practice of zero tillage through demonstration method or demonstration of results it would be very difficult to adopt the intervention. In Sudan, this is not easy to be achieved due to the lack of efficient extension services. This verifies why lack of know-how represents a corner stone for the adoption of the zero tillage method. The social pressure which is represented in the urgent need of the agricultural residues for different uses (traditional building mulch and a source of fuel) represent a real challenge for the adoption of zero tillage. This pressure is in line with the lack of awareness which needs special consideration.
In Sudan, due to the misconception that the zero tillage soils are degrading at an alarming rate skirmishes between individuals develop into conflicts between tribes and finally escalate into political power disputes as in the case of the Darfur crisis.

1.3.3 Identified Measures for Zero Tillage

Barriers confronting the adoption of zero tillage must be overcome by politicians, public administrators, farmers, researchers, extension agents and university professors. These are very important for Sudan in order to transfer and adopt the technology of zero tillage. With adequate policies to promote zero tillage, it is possible to obtain what is called the triple bottom line of economic, social and environmental sustainability, while at the same time improving soil health and increasing production (Friedrich *et. al*., 2009; Friedrich and Kassam, 2009). Therefore, in order to have a right measure to abolish the barrier of the lack of adequate polices, investment must be made to ensure sufficient and sound research and efficient extension services, all of which requires governmental commitment to adopt the intervention through sound and effective polices. This coincides with what Friedrich *et. al*., (2009b) proposed. Accordingly, researchers and extension personnel need to reflect on the benefits of no-till farming systems. Farming systems should foster research and development efforts in order to overcome the bottlenecks of the system and help extension personnel in diffusing the technology so that farmers can have a sound basis for practical application.

Through various discussions and consultations, the national team and the stakeholders identified measures to overcome the barriers against zero tillage diffusion. These measures are classified as economic and financial measures, as well as non-financial measures. The former are those which take place when any changes in prices and quantities are assumed to be attributable to the imposed changes resulting from technology adoption. They can be translated into measures of economic surplus change, which are allocated to producers and consumers according to the supply and demand elasticity. The latter are usually intangible measures which cannot be classified into quantitative data including policies, legislation, awareness, or knowledge.

1.3.3.1. Economic and Financial Measures for Zero Tillage

The main economic and financial measure for zero tillage technology is availability of finance which can take different forms like subsides, incentives and soft loans. Sudan is one of the least developed countries with high levels of poverty. All the governmental institutions are under staffed and underfunded. Moreover, due to the civil war and the war with South Sudan, agriculture is not a top priority for the government. Therefore, incentive measures could be introduced to encourage suppliers to make the technology available to users through conducting a survey to assess user needs and to stimulate the adoption of zero tillage by users containing specific provisions regarding legislative, administrative or policy measures for access to and transfer of technology. Subsidies are not working in Sudan because the Ministry of Agriculture is always underfunded under the economic embargo imposed on the country for more than two decades. Despite these complications in the country, soft loans are a possible means for solving the constraints and measures of risks confronting the diffusion and transfer of zero tillage technology. The private sector can be mobilized to play the role of the donor to enhance agricultural productivity. Unlocking capital for projects can be achieved through loan guarantees, low interest loans or innovative recoupment structures. Another measure that has a direct relation to the financial measure is the guarantee of inputs and necessary equipment to enhance the adoption of technology.

1.3.3.2 Non-financial Measures

Good program design and delivery are critical to ensure that the complementary measures in the zero tillage packages deliver their full potential for adaptation to climate change and variability. It is essential that lessons are learned from previous efforts to ensure that programs meet their needs in overcoming barriers. Information on available zero tillage could be systematically compiled and made available to farmers through efficient extension services of the Ministry of Agriculture and Animal Resources. In Sudan the level of illiteracy is very high. Therefore, brochures, pamphlet and handouts are of no use and only service a small proportion of the small-scale farmers. The best method for dissemination of information is through individual or group extension methods. The mass media extension method is of limited use due to illiteracy. The importance of this step is to fix any misunderstanding or cultural and social barriers that confront the adoption of the technology. Through awareness raising any misconception will be checked. This will give fruitful results if targeted programs reach the right people to encourage the adoption of zero tillage. On the other hand, improvement of research through support of research and academic institutions would solve many of the barriers to zero tillage adoption. Finally, existence and availability of skilled labor is of paramount importance in creating an enabling environment for solving the barriers and attainment of good results. If all the measures were guaranteed the result will be the improvement of soil structure and the control of weed will be well managed. This will take place if specified budgets are allocated for these measures. The short-term results of the measures for zero tillage are exemplified in high yield per unit area, efficient land use, rehabilitation of natural rangelands, prevalence of peace, reduction of livestock mortality, cheap food prices and decrease of vulnerability to food insecurity will be guaranteed. In the long term the results will be alleviation of poverty.

1.4 Linkages of the Barriers Identified in the Agriculture Sector

For improved crop varieties the barrier of lack or limited availability of financial funding has two dimensions. The effect on the producers of improved seeds and seedlings is exemplified in the high costs of local production of improved crop varieties and for the consumer the high prices of the seeds and seedlings imposed by the producers represent a challenge to adopt the new technology of improved crop varieties. This situation invariably leads to difficulties in making profit. On the other hand, the absence of related infrastructure for improved crop varieties will automatically be translated into shortage of technological information which ultimately will be translated into lack of technical know-how. All these factors give rise to social difficulties that confront changing food habits of the local people.

As far as zero tillage is concerned, there are some barriers out of control like ecological barriers which are represented in the low precipitation, water logging and frequent drought cycles. The lack of financial support represents a corner stone in the failure of dissemination, diffusion and adoption of zero tillage technology. Lack of financial support can lead to difficulties buying specialized machines and adequate herbicides. As a result what is actually used at the field is poorly developed infrastructure. Moreover, unavailability or lack of enough information regarding zero tillage in effect perpetuates reliance on traditional methods of farming that insinuates soil degradation.

Table 7 shows the linkages of the barriers for the two technologies for adaptation of agriculture sector.

Table 7: Linkages of the Barriers for the Agriculture Sector

Market linkage - Currently no market for this technology - Products not outstanding or maintaining long-term stability - Lack of investment on infrastructure, leading to short-term, low efficiency
Enabling factor - Incentive polices for diffusion of the new technology are not strong enough - Procedures for approval or registration are usually complicated, sometimes unsuitable or unavailable to market demand - Poor infrastructure - Sustainable production is not done on voluntary basis
Support actions - Lack of support for research and development - Lack of information - Lack of project management - Limited local management capacity and expertise

1.5 Enabling Framework for Overcoming the Barriers in the Agriculture Sector

This section discusses the vital elements of the enabling framework that should be enhanced to improve the quality and efficacy of the technologies for agricultural sector transfer and diffusion. The enabling frameworks are those resources and conditions that are generated by institutions which are beyond the immediate control of the beneficiaries. In brief, the enabling framework provides the environment conducive for the transfer and diffusion of adaptation technologies for the agricultural sector. Table 8 shows the enabling environment for the agricultural sector. The enabling framework for the agricultural technologies, i.e. improved crop varieties and zero tillage, are explored relying on six general groups, namely:

- Finance policy or market support since the lack of this variable results in or contributes significantly to the creation of the key problem

- Land registrar: In Sudan most of the lands are under customarily land tenure systems in which lands are not registered. Under such conditions the government has a limited control over the resource. Therefore, the government should enhance the registration of the lands in order to guarantee sustainability of the activities.

- Business regulation: the flow of seed crops from the producer to the clients pass through several channels. If the government has not enough control over these channels this may result in corruption or monopoly of the activities. The same can be applied for the zero tillage. The adoption of the intervention necessitates the organization of the farmers beside their sensitization and mobilization. To deliver extension services it is important to regulate the business by knowing the number of farmers and organizing them into working groups.

- Trade standard: the government should issue prescription for the trade standards in the different input whether for the improve crop variety or zero tillage.

- Tax and tariff: the government should encourage farmers to improve their productivity either through improved crop varieties or zero tillage, or both. This can be through exemption of royalties to enhance the import of necessary inputs.

Consumer trend: the government can change the attitude of the farmers through extension to the extent of changing their food habits.

To make the slogan become real, the enabling framework should encompass the following measures:

- **Network of experts:** creating a network of expertise is an important medium that allows exchange of ideas and information to ensure demonstration as well as innovative and successful implementation of measures to promote strategies that include compulsory information campaign messages and raising awareness.

- **Policies and measures**: promote existing technologies transfers in countries such as Sudan that have many obstacles which need resolving by implementation and enforcement measures as well as new, rationalized policies towards new directions.
- **Change organization/behavior** usually occurs outside the market system but it is important in improving market and non-market functions. Those obstacles caused by the actual state of the current operation or organizations may request a change in the management approach.
- **Market support systems and other financial services** to ensure accountability, functionality and providing these services to achieve efficiency; taking into account that there are multiple relevant systems in one place which are supposed to translate into various financial services, quality insurance system, consultancy and information services.
- **Skills, education and training** constitute key foundation to development. Planning and investment in this area is necessary, together with other measures to bring the required skills and ensure appropriate education and training.
- **International Cooperation and IPR issues** may not be sufficient nationwide for promoting technology and required international linkage. Trade and international IPR systems need examining and the tasks under other international agreements also have influence.

The above mentioned table is applicable for the two technologies due to their similarities in terms of geographical area of application, primary stakeholders (small-scale farmers) and secondary stakeholders (Ministry of Agriculture).

Table 8: Enabling environment for agriculture sector

Enabling environment	Market actors	Category	Condition	Support services
Finance policy or market support	Government institutions	Finance	Set up support fund	National banks
Land registrar	Institutions	Policy, legal and regularity	Polices for registration	Legislation
Business regulation	Producers	Financial support	Capacity building	Training and network of expert
Trade standard	Local producers	Human skill	R & D	Finance
Tax and tariff	Institutions	Policy, legal and regularity	Minimum taxes	Policies & measures
Consumer trend	Consumer	Social	Awareness raising	Extension services

Chapter 2

Water Resource Sector

In Part I of the TNA adaptation report, two groups of adaptation technologies have been selected by the stakeholders as high prioritized and suitable adaptation technologies for Sudan's specific needs. These are Rain Water Harvesting (Haffir) and Seasonal Forecasting in tandem with and Early Warning System – Automatic Water Level. The first technology (Haffir) would improve the livelihood of many villages by providing clean potable water as well as water for irrigation and animals. Automatic Water Level is crucial to predict the expected situations of storms and floods in order to minimize climate change risks and enhance adaptation plans before the disaster might take place. For all water source technologies the main objectives are as follows: to increase water supply security, to build flexibility for managing all types of water supply and demand scenarios, to minimize damage from disasters, to maximize the efficiency of water usage, to include all stakeholders in water management, and to build knowledge/know-how and data for water management. Water scarcity is the single most annoying impediment for development and stability. Competition for shared natural resources, in particular water and land, is a root cause of conflict and instability. Since water is the essence of life without which life cannot be sustained, its availability is vital for any socio-economic development. Therefore, rainwater harvesting will be the entry point for socio-economic development in rural Sudan. The livelihood of the country's rural population, who live away from the Nile, depends entirely on rains. Because of its many advantages, rainwater harvesting development programs rank among the highest government strategies for rural socio-economic development. The high risk of rain-fed farming coupled with poor-resource farmers suppresses rural development, while inputs that increase crop productivity such as proper land preparation, improved seeds, fertilizers and pesticides are not used. The natural characteristics of the Sudan make rainwater harvesting an important tool to sustain life, peace and livelihood for rural communities. The main aim of rainwater harvesting is to manage the rain water from the moment it falls and ensure that it is used productively before it returns to the atmosphere by evaporation. Water harvesting may occur naturally or through intervention. The main influencing factors in water harvesting potentials are rainfall intensity, duration and distribution. Rainfall is a most unpredictable variable, runoff and catchment characteristics depend upon the area and type of the catchment over which it falls as well as surface features.

2.1 Preliminary Targets for Haffirs Technology

The targeted area for development relying on selected technologies for the water resource sector is geographically very large. It is the belt bounded roughly by 300 and 700 mm isohyets. It extends from central Sudan to the border with South Sudan and runs across the country from east to the west. There are no accurate figures of the pastoralists and their herds, nor farmers and their lands that are impacted by water scarcity. However, in the literature it is generally agreed upon that the rural population constitutes about 70 per cent of the total population. Contribution of farming and livestock rearing in the national economy is significant. Rain amounts are fair to quite good for rainwater harvesting development. However the problem lies with temporal and spatial distribution of rain as well as its capture and storage. The Government of Sudan has decided to embark on water harvesting projects to initiate socio-economic development and to meet the increasing demands for water.

The prospects for rain water harvesting development are very good in the concerned regions for both pastoralists and farmers' communities. Traditional rain-fed farming in the region is usually at subsistence level. Its productivity is very poor and barely adequate to secure basic family food requirements let alone generate income. Sorghum and millet are the main staple crops with low nutritional values.

2.2 Barrier Analysis and Possible Enabling Measures for Haffir

Lack of financing funds is one of the most persistent impediments facing socio-economic development in the country. This is particularly so for rainwater harvesting development. Despite the difficulties facing Sudan's economy in the short run there are broad indications that the economy will improve gradually in the long run, such as stringent austerity measures, revival of the agriculture sector, gold mining and significant inflow of direct Arab and foreign investments. Improvement of the economy will lead to better livelihood prospects and services for the people of Sudan and in particular water supply and augmentation. Rainfall characteristics (intensity, duration and distribution) are most unpredictable variables. Regarding the costs, *haffirs* are of lower cost compared to dams. However, while medium and long term prospects for Sudan's economy appear bright there is no immediate prospect for funding water harvesting on the scale required.

2.2.1 General Description of Haffirs

Water harvesting is the capture, diversion, and storage of rain water for different uses mainly for drinking and irrigation where water becomes available to the crop and thereby enabling economic agricultural production. *Haffirs* are manmade ground reservoirs in the earth at suitable locations to store water for drinking purposes for both human and livestock. The concept is that water running in natural streams during the rainy season is diverted at certain suitable locations into these Haffirs. The size of the Haffirs ranges from 100,000 m^3 for large one to 30,000 m^3 for small ones. Guide bunds are required to divert the water into the *haffirs*. If it is used for human drinking filters are required to ensure clean potable water. As far as the applicability of the technology is concerned the construction of *haffir*s and their management requires skills and institutional organization, consultancy in design of the *haffirs* and its implementations and training for skills development of state staff and local communities to operate the *haffirs*. Maintenance of the water harvesting projects is one of the core requisites for sustainability.

Haffirs are widespread in different areas of Sudan. Rain water harvesting is one of the priority programs for rural socio-economic development in the country. Rain water is not only important for drinking, it is also important in agriculture and pasture as most of the livelihood of the rural people depend on farming and animal rearing. Compared to other means of development, rain water harvesting is cheap to develop with high socio-economic returns. After thorough investigations, technical experts in the country have come to the conclusion that many water harvesting techniques can be used to avail water for drinking and farming on small-scale all over the targeted area. *Haffirs*, small dams, reservoirs in natural depressions and contour bunds, inter alia, can be used. The technology is confronted by some barriers like lack of financing funds, which is one of the most persistent impediments facing socio-economic development in the country. This is particularly so for rainwater harvesting development. Despite the difficulties facing Sudan's economy in the short run, broad indications such as stringent austerity measures, revival of the agriculture sector, gold mining and significant inflow of direct Arab and foreign investments suggest that the economy will improve gradually in the long run. Improvement of the economy will lead to better livelihood prospects and services for the people of Sudan and in particular water supply and augmentation. Rainfall characteristics (intensity, duration, distribution) constitute a perennially unpredictable variable. Regarding costs, *haffirs* cost significantly less than dams. *H*affirs are manmade ground reservoirs in earth at suitable locations to store water for drinking purposes for both human and livestock (Fig. 5).

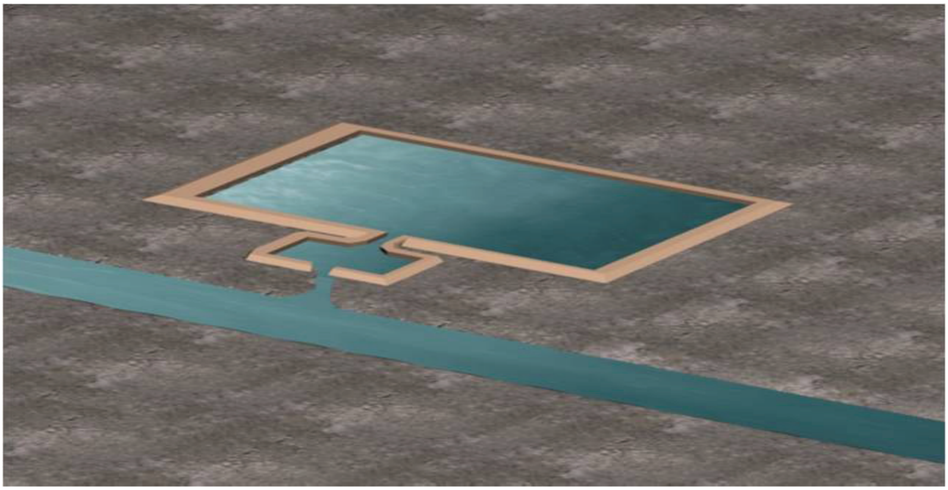

Figure 5. 3D View for Haffirs System.

Source: Elkhidir, 2011

Figure 6: *Haffirs* with a silt trap – Western Sudan

Source: Sanjak, 2004

2.2.2. Identification of Barriers for Haffirs

The ecological barriers are detrimental for the success and adoption of the *haffirs* and their replication. The duration of rainfall has great effect on the amount of rain water. Long duration of rainfall means high floods because of long runoff periods. This has significant effect on water harvesting. If good water harvesting techniques are used, a lot of rainwater can be stored. If rainfall is uniformly distributed within an area the runoff will also be uniformly distributed in that area. Moreover, sustainability is a crucial factor during water harvesting project implementation and after the completion of the project as well. Based on problem tree methodology, lack of financing funds is considered the main problem posing several limitations and barriers to rainwater harvesting (financial barrier). In spite of the financial barrier, *haffirs* are considered the lowest cost technology for rain water harvesting. However, there is a limited number of equipped institutions to design and implement this technology efficiently. In addition, designing and implementing *haffirs* requires regular consultations between project implementers and stakeholders, which is also considered a constraint confronting adoption. In addition, the amount of trained experts capable of regular maintenances is very limited and may lead to structural collapse and decreased water storages.

A technical and ecological problem that impedes the sustainability of *haffirs* projects is soil erosion and *haffirs* maintenance. Tillage and natural vegetation strips can be used as a possible measure to overcome soil erosion around *haffirs* boundaries. Other barriers are lack of technical know-how, land tenure, soil siltation and infiltration. To overcome these drawbacks, enhancement of knowledge and awareness, as well as additional filtration and disinfection are important to be applied. In Sudan, the implementation of *haffirs* is usually done by a national contractor and sub-contractor determined by public tender; therefore the majority of haffirs are government owned, though some are private. *Haffirs* technology produces non-market goods. It is identified as public and the market mapping could not be created due to the lack of clear market chain and dealers.

2.2.2.1 Economic and Financial Barriers to Haffirs

Measures adopted for better adaptation of water harvest technology (*Haffirs*) encompass the following;
- Government intervention and subsidy for development of marginal areas and promoting productive activities
- Non-governmental organizations' contribution in social development
- Private sector involvement as part and parcel of social activities
- *Zakat* in rural areas should be directed to finance society's basic needs
- Experts in soil analysis
- Increase awareness and encourage cooperation between actors in different interfering activities

The cost –benefit analysis for facilitating *Haffirs* adaption is derived from the capital costs of *haffirs* and benefits extracted from the adoption thereof. The capital costs include:
- Excavation costs: one square meter costs 10 USD
- Area of moderate *Haffirs* of 30,000m^2 size = 300,000m^3
- Annual maintenance 1 USD/ m3= 30,000 USD/ year
- Soil survey and analysis cost 3 per cent of *Haffirs* excavation costs =9,000 USD

Benefits extracted from adoption of Haffirs are:

- *Haffirs* are a source of water for human and animal
- *Haffirs* supply extra water for crops in areas of short rainy seasons
- *Haffirs* existence saves life of animals and decreases mortality rate and consequently livestock loss costs by 5 per cent
- Saves life of animals by eliminating thirst, prospers nomads' economy by selling well fattened animals and flourishes process-

ing activities of animal products such as meat, milk and skins

- Numerically, *haffirs* technology adaptation saves 5 per cent of herd loss which is a significant multiplier effect benefit.
In brief, the cost items of Haffirs are: excavation of 30,000m^3 (300,000USD), and soil survey and analysis is 9,000 USD.
Benefits extracted from the adaption of *haffirs* includes: annual loss due to thirst is 5 per cent of a 5,000 head a herd; thus saved lives of 5 per cent represent a return expected from the adoption of Haffirs. So, the loss cost of mortality is about 5 per cent; lost return for mortal of 5 per cent equal price of one head which is equivalent to 155 USD. This makes a total loss saved-return of 38,793 USD. Appendix I, Table B shows returns of *haffirs* technology adoption. Table 9 shows the net present value for adaption of *haffirs* technology.

Table 9: Net present value for adoption of Haffirs technology

Item/year	0	1	2	3	4	5	6	7	8	9	10
Initial costs	-309,000										
Return		38,793	51,304	58,999	67,849	78,027	89,731	103,190	118,669	136,469	156,940
Present value	-309,000	38,793	38,793	38,793	38,793	38,793	38,793	38,793	38,793	38,793	38,793
NPV @15%	+78,913										
Profitability(PI)	1.3										

2.2.2.2 Non-financial Barriers

Beyond the obvious cost limitations, several non-financial barriers and limited access to water and *haffirs* water harvesting technology have been detected after the problem tree and measures. These barriers can inhibit technology adoption, efficiency of *haffirs* and sustainability of water availability from *haffirs*. They include:
- Lack of human technical skills and scarcity of technical know-how obstruct the implementation and the expected maintenance of *haffirs*. Biased decision on *haffir*'s location results in an inadequate distribution. This can affect the community culturally and socially. Also the cultural custom of water collection from *haffirs* by children and girls from far distances would expose girls and children to secu-

rity risks.

- **Policy and regularity barrier:** Land tenure in Sudan cannot be regarded solely as a production variable but as an extremely significant element in the social structure servicing multifunctional aims and objectives. More than a factor of production, it is a tangible dimension of community and has what is called the "territorial character of community". In general, land provides community stability and centricity and it becomes more significant rather than less, in a period of otherwise rapid social and economic change. In Sudan most of the land is considered government property except the free hold land.
- **Awareness barrier**: the local people in rural areas are usually suspicious of outsiders. They always believe that the intervention of the outsiders is just a means of grasping the resources of the area. This situation creates difficulties in mobilizing and sensitizing local communities to participate genuinely in the activities of *haffirs*.
- **Social barrier (Insecurity in some areas)**: the civil war in Sudan almost restricts the implementation of developmental activities which also include the adoption of water harvesting techniques. Moreover, *haffirs* represents a source for natural resource-based conflicts, particularly between nomads and settler farmers.

The effects of the above mentioned barriers (financial and economic, and non-financial and economic barriers) clearly have negative consequences on the sustainable livelihood of local communities, the environment and health of human beings and animals. The impact of these barriers is exemplified in lack or shortage of water which leads to the exploitation of the same source of water by human beings and animals. There are many incidences of diseases outbreak due to this practice. In certain situations, the conflicts over water sources may escalate to intractable disputes. Under the worst situation, many communities migrate temporarily to other sites with abundant water; and in the history of Sudan some villages were displaced permanently because of water shortage.

2.2.3 Identified Measures for Haffirs

Based on the stakeholder consultations, interviews with decision makers, the consultants' own knowledge and international experiences, the measures to overcome financial and non-financial barriers in water harvesting and seasonal forecasting have been outlined. Building capacity, technology, and economic barriers to the technology transfer and diffusion of the technologies have been identified, which is shown in the problem trees and measure in Appendix I.

2.2.3.1 Economic and Financial Measures for Haffirs

Limited use of *haffirs* is associated with lack of financial support. It is well known that all the rural areas in Sudan suffer from marginalization. Many of the opponent movements in the country attribute their opposition to marginalization. Therefore, if there is a chance to allocate some money for *haffir* intervention, many of the natural resource-based conflicts might be solved. It is important to convince the policy makers to allocate funds for undertaking *haffirs* technology. This can be achieved by the national strategic development plan that allocates more than 90 per cent of the budget to sustainable development and poverty alleviation. Complementarities with the investments of Government (through the State and the Agriculture Revival Program) and other donor funded initiatives can also support the technology implementation and maintenance.

The economic and financial measures are represented in provision or allocation of reasonable amounts of money for the maintenance and rehabilitation of old *haffirs* since these *haffirs* are liable to annual siltation to the extent that any number of them could be buried completely. Thus assignment of finance is needed for improving research and development activities in the water sector; and also for provision of technical know how through establishment of experts' networks, as well as provision of inputs and machinery.

2.2.3.2 Non-financial Measures for Haffirs

It is crucial to put in place the necessary measures for effective project management and implementation with incorporated measures to facilitate the replication and wider adoption of Haffir's technology. These measures include training of rural communities so that they can train their peers, develop the capacity to collaborate with common interest groups in technical and managerial skills in *haffirs* design and improve *haffir* construction and management skills; encourage and enable the private sector to provide timely services to *haffirs* in their communities and villages so as to assure sustainability of water availability in existing *haffirs* and enforce laws that sustain societies and community rights for their land tenure.
The non-financial and economic measures for *haffirs* activities are exemplified in training farmers and extension personnel. Enhancing knowledge and raising awareness, providing good or at least reasonable distribution of *haffirs* across the vulnerable sites to curtail or overcome water deficit is of vital importance to *haffirs* technology adaption. The results of the above mentioned measures can be reflected in the availability of water for domestic use and for animals. Peace will prevail at the areas of natural resource-based conflicts, migration will cease and oppositely there will be resettlement and the health conditions of the people and animals will be very good.

2.3 Barrier Analysis and Possible Enabling Measures for Seasonal forecasting and Early Warning Systems.

Automatic Water Level Technology

2.3.1 General Description of Automatic Water Level technology

The Remote Sensing Technology for the receipt and processing of satellite images are used to estimate daily rainfall quantities over the catchments of the Blue Nile and Atbara rivers in Ethiopia and Sudan. A communication system transmits water levels in the Blue Nile, Atbara River and Main Nile in Sudan to the Flood Warning Center in Khartoum. A computerized Flood Forecast System, consisting of a set of mathematical models with an appropriate user interface allows smooth and rapid data processing and forecasting. The Automatic Water Level is a data logger and submersible pressure transducer combination designed for remote monitoring and recording of water level or pressure data. The water level logger can record over 81,000 readings and has four unique recording options, fast (10 samples per second), programmable interval (1 second to multiple years), logarithmic, and exception. Multiple depth ranges are available from 3 to 500 feet of water level change. A 25 ft vented cable is standard on all water level loggers. Timely information during flood season is highly requested and will prevent loss of life and houses. Installation of automatic loggers and management of them require expert and institutional organization. This technology needs to be implemented in 14 key locations in Sudan. Training and skills development of state staff and local communities for the operation and maintenance of the automatic loggers is very important for the technology's sustainability. Automatic water logger was applied in Sudan in the mid-1990s, yet, this technology no longer exists due to technical reasons. Development of flood forecasting systems for Sudan is an important measure that should build upon existing forecasting systems and capacity. Key elements of flood forecasting and warning systems include: (1) data acquisition networks and data transmission (2) data processing and archiving (3) operational forecast modeling systems and (4) flood warning, dissemination and communications. With respect to flood warnings, effective delivery of relevant information in a form readily understandable by and useful to intended users, from government agencies to floodplain dwellers, is essential. One of the main barriers that disfavor the adoption of the technology are its high costs compared with normal gauges and the fact that the technology is sensitive and easy to be broken. Therefore, special care should be taken to its location.

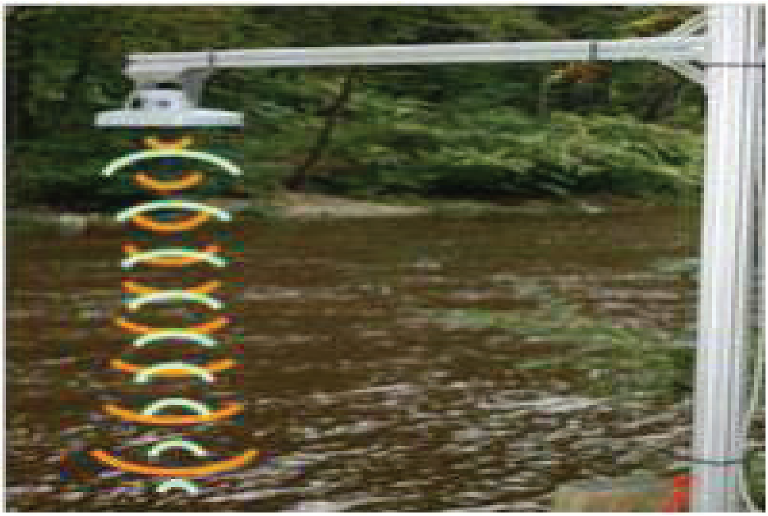

Figure 7: Radar Sensor

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Figure 8: Ceramic pressure cell

2.3.2 Preliminary Targets for Automatic Water Level Technology

The preliminary targets for the Automatic Water Level technology are all the population inhabiting land on the River Nile banks and its tributaries. This mainly covers the White Nile, Blue Nile, Sinnar, Gezira, Khartoum, River Nile and Northern states. These areas represent the bulk of Sudan's population.

2.3.3 Identification of Barriers for Automatic Water Level Technology

The high cost of Automatic Water Level devices, installation cost and required training and sustainable follow up expenses stand as financial and main barrier for the technology application and distribution.

The financial and economic barriers are not the one main obstacles of this technology. There are a number of barriers impeding the implementation of the Automatic Water Level technology and can be summarized as follows:

- Human skill barriers: needs of continuous maintenance, scarcity of technical know-how, cultural and social unsustainable tranquility

- Technical barriers: Ease of logger damage, lack of skilled person to operate and maintain the system

- Infrastructure barriers: like the lack of proper wireless network

- Awareness barrier: Gap of information, research and development

2.3.3.1 Economic and Financial Barriers for Automatic Water Level

Measures that facilitate adaptation of Early Warning System Technology are:

- Government and non-governmental entities intervention and contribution

- Private sector social contribution

- Continuous annual maintenance should be adopted by qualifying technical experts and disperse know-how at all relevant levels

- Supply a unit with skilled persons to handle operating and maintenance of devices

- Improve wireless networks

- Bridge the current information and development gap that contributes to information and awareness barriers

- Adopt capacity building programs

- Install an emergency control unit to facilitate distillation of information on time

The cost – benefit analysis for facilitated Early Warning System Technology adoptions consist of capital cost of early warning system technology which are included in Table 10:

- Devices and its accessories cost = 220,000 USDInstallation costs 10 per cent = 22,000 USD

- Training costs and capacity building programs (10 per cent) = 22,000 USD

Table 10 denotes the capital & operating costs of adaptation technology

Item	$ Cost in
Devices and accessory equipment	220,000
Installation costs 10%	22,000
Training & capacity building	22,000
Operating costs 35% of capital costs	77,241
Maintenance costs 3% of capital costs	6,621
Total adaptation costs	**347,862**

The annual operating costs include:

- Labor and administration = 77,241USD

- Maintenance 3 per cent 6,621USD

Table (C), Appendix I denotes the annual costs saved by adapting the Automatic Water Level technology. The costs offset by this technology are destruction of infrastructures, human properties, animals and crops all of which annually is approximated on average at 1,000,000, USD and the effect of adaptation starts at 50 per cent in the first year of installation and is expected to increase by 25 per cent from the second year forth, until it reaches the maximum costs savings of 90 per cent in the fourth. This is calculated with an error rate of 10per cent due to low levels of awareness in rural areas.

Benefits of adoption of Early Warning System Technology are:

- Such technologies can be used for warning authorities and society about the imminent natural disasters as heavy rains, floods and tornado.
- Evasion of such disasters is economically considered as returns by saving costs of property damage, animal and crops losses.
- Enable the agricultural authorities to determine the crops that fit the rainfall rates and areas, saving money and efforts by facilitating optimum utilization of resources.

The financial analysis is shown in table 11.

Table 11: Net present value of adaptation warning system technology

	0	1	2	3	4	5	6	7	8	9	10
Initial investment	(264,000)										
Annual *returns		500,000	750,000	900,000	900,000	900,000	900,000	900,000	900,000	900,000	900,000
Annual operating costs		83,862	110,907	127,544	146,675	168,676	193,978	223,075	256,536	295,016	339,269
Annual net cash flows		416,138	639,093	772,456	753,325	731,324	706,022	676,925	643,464	604,984	560,731
Present value	-264,000	361,859	483,246	507,903	430,716	363,597	305,233	254,481	210,350	171,974	138,604
NPV @15	3,227,963 +										
Profitability index(-(PI	10.9										

2.3.3.2 Non-financial Barriers for Automatic Water Level

- Institutions and policy:

In Sudan, apart from the contributions of private sector and NGOs, different institutional bodies such as governmental ministries and academic institutions are working with water. Although they deal with these issues in different ways, their mandate and responsibilities are quite similar with certain overlaps and interaction in activities and duties. In spite of all the involvement of different institutions and stakeholders the water resources sector suffers from lack of institutional cooperation and data sharing. One of the reasons is that several legal and administrative regulations prohibit data transfer and data exchange across different governmental agencies. This regulatory barrier leads to institutional barriers for both the rain water harvesting (*Haffirs*) and the seasonal forecasting and early warning (Automatic Water Level) technologies. It also creates a non-collaborative atmosphere among the different institutions. In addition, it destroys communication and data integration across institutions (whether they are governmental agencies, private or academic institutions).

- Capacity building and public awareness:

Sudan has limited technical capacity for managing and maintaining Automatic Water Level. The country also lacks skillful human resources for operation and maintenance. Technological skills, human resource development and capacity building problems and gaps have to be tackled. Technically, most of the governmental agencies and research institutions in Sudan have not enough skills and experience to implement Automatic Water Level technologies confidently and effectively. As a result, this technology requires regular and continuous consultations.

- Technical barriers:

Technical barriers to implement Automatic Water Level include the sensitivity of the technologies. Hence they have to be secured inside a cage or concrete room to avoid exposure to damage. In addition, Installation, operation and maintenance require high technical skilled personnel. Siltation can technically affect the proper work for some logger types. In this case, pressure types have to be used. For real time transfer of data, automatic loggers need high standard wireless network. The main economic barriers have appeared to be lack of funding for the initial project investment, maintenance requirement and program sustainability. Other barriers are the lack of know-how in maintenance and installation of the Automatic Water Level network and the insufficiency of an essential database management. Hence, training and capacity building components are needed.

- Identified Measures for Automatic Water Level

Best water resource management can be achieved by using modern techniques like Automatic Water Level for adequate monitoring and observation of both water quantities and qualities. Adoption of these technologies will assist in reduction or avoidance of the negative impacts of climate change from floods and droughts.

2.3.4.1 Economic and Financial Measures for Automatic Water Level

In order to replace the traditional monitoring system by modern technique, e.g. Automatic Water Level in fourteen river gauge stations in Sudan along the River Nile and its tributaries, the estimated cost has been found to be about 56,000 USD. These costs can be attained by using funds allocated to the pilot station projects. Hence, the benefit revenue from these pilot stations could be allocated to the annual cost of operation and maintenance. Consequently, it would be easy to convince the policy makers to provide more funds from other donors to support the technology implementation and maintenance.

2.3.4.2 Non-financial Measures for Automatic Water Level

In order to overcome the identified institutional barriers and promote sustainable development, it is recommended to adopt integrated water resource management in water resources planning and management across all water departments in Sudan.

However, this requires collaborative cooperation with international experts and professionals in these technologies to assist in identifying the best measures and practices. Eventually, the water resources sector would directly gain valuable experiences in supervision, monitoring, management and operational skills. With this approach the institutional capacity will be increased in the whole country in general, and in the water sector in particular. As mentioned previously, lack of skilled personnel is the major concern in adopting Automatic Water Level Technology in Sudan. To overcome this problem comprehensive training in installation, operation and maintenance and database management is essential. In remote areas much concern should be taken to secure and prevent the expected damage or lost sensor by providing the automatic loggers with steel cage or concrete housing. Furthermore, it is recommended to look for affordable spare parts in the local market which can replace the more expensive ones. This will conserve the collected water resources data and maintain the sustainability of the system. It is will also be beneficial to use the most reliable wireless network for real time data transfer.

Lack of knowledge, experience, and human resources remain major capacity barriers to Sudan's water resources adaptation technologies. Continuous human resources development via series of training courses could work as a suitable measure. Additionally, awareness sessions for the target groups highlighting importance of the technology are much needed. Regarding the two water sector prioritized technologies; the Government should develop an adequate policy to provide the necessary support needed for the establishment and management of an integrated water resource management system in order to monitor patterns of climate change in the country.

2.4 Additional Barriers and Measures in the Water Sector

The seasonal forecasting and early warning system (Automatic Water Level) has a wide international market but it should be ordered and implemented by the government of Sudan, in particular Ministry of Water Resources and Electricity. The Implementation of *haffirs* is usually done by a national contractor and sub-contractor through public tender; the majority of bidding contractors are government owned but some are private.

The interviews with various stakeholders, experts and decision makers, for both water harvesting and seasonal forecasting & early warning system technologies have revealed interesting findings for the two technologies. They have identified relevant capacity, technology and economic barriers that obstruct technology transfer and diffusion of the two technologies. Appendix I shows the problem trees and proposed measures for both technologies. The stakeholder groups have also identified the technologies output services as public and non-market goods which has no market chain and dealers.

2.5 Linkages of the Barriers Identified in the Water Resource Sector

The interviews with various stakeholders and decision makers and experts in water harvesting and seasonal forecasting and early warning system identified capacity, technology, and economic barriers to the technology transfer and diffusion of the two technologies. These are shown in the problem and measure trees in appendix I. The seasonal forecasting and early warning system has a wide international market but it should be ordered and implemented by the government of Sudan (Ministry of Water Resources and Electricity).

Lack of knowledge, experience, and human resources remain major capacity barriers to Sudan's water resource adaptation technologies. Although a few governmental agencies and research institutes in Sudan have experience in design, implementation and operation, of *haffirs* technologies, the majority of institutes lack theses capacities. As a result, most of the sectors may not have enough skills and experience to implement this technology confidently and effectively. Therefore, regular consultation and exchanges of knowledge and experience are required. In addition, the amount of trained experts capable of regular maintenance is very limited and may lead to structural collapse and decreased water storages.

2.6 Enabling Framework for Overcoming the Barriers in Water Resources Sector

In Sudan different institutional bodies including governmental ministries and academic institutes are working with the water sector and are dealing with these issues in different ways, though their mandates and responsibilities are quite similar resulting in certain overlap and interaction in activities and duties; beside the contributions of the private sector and NGO's. In spite of all the different stakeholders and institutes, the Water Resources sector suffers from lack of institutional arrangements and data sharing; hence several legal and administrative conditions and protocols prohibit data transfer and data exchange across different governmental agencies. This regulatory barrier leads to institutional barriers for both the rain water harvesting (*haffirs*) and the seasonal forecasting and early warning (Automatic Water Level) technologies because the regulatory barrier creates a non-collaborative atmosphere among the different institutions. This destroys communication and data integration across different institutions. In order to overcome this barrier it is recommended to adopt integrated water resources management in water resource planning and management across all water departments in Sudan to promote sustainable development. Also, cooperation with international experts and professionals in these technologies to assist identifying the best measure and practices is recommended because the water resources sector can directly gain valuable management and operational experience and supervision, which will increase the institutional capacity of the country. Furthermore, the government should develop a policy providing the adequate support needed for the establishment and the management of an integrated water resources management concerning the two technologies and monitoring the climate change in the country. Technically, Sudan has limited technical capacities for managing and maintaining *haffirs* technology and Automatic Water Level. In addition, the country lacks skillful human resources for operation and maintenance of the technologies. Therefore continuous human resource development, e.g. in the form of a series of training courses and awareness raising programs about the importance of the technology are much needed. Table 12 shows the enabling environment for water sector.

Table 12: Enabling environment for water sector

Market linkage
- No technological transfer network - High technology transfer fees, while old technologies are cheaper and more available - Lack of consideration for externalities such as environment or social factors in calculating technology transfer
Enabling factors
- Week incentive policies for deployment and diffusion of new technology - Lack or rules, standard and implementation - Complicated appraisal and approval procedures - Project location are usually poor urban areas or hard-oil rural areas - Lack of incentives
Support actions
- Lack of support for research and development - Lack of information - Limited project management capacity - Limited local capacity to fill the expert gaps - Required financial mechanism compatible with the new technology

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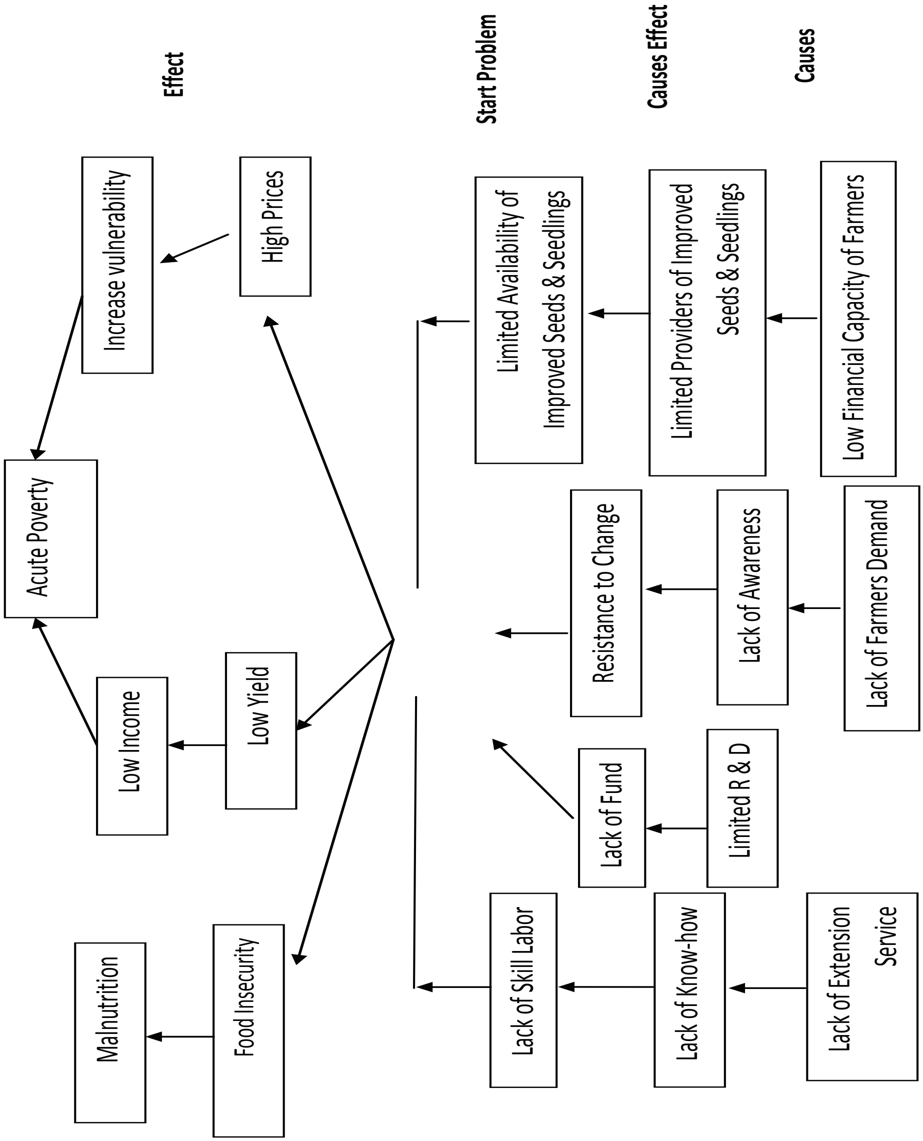
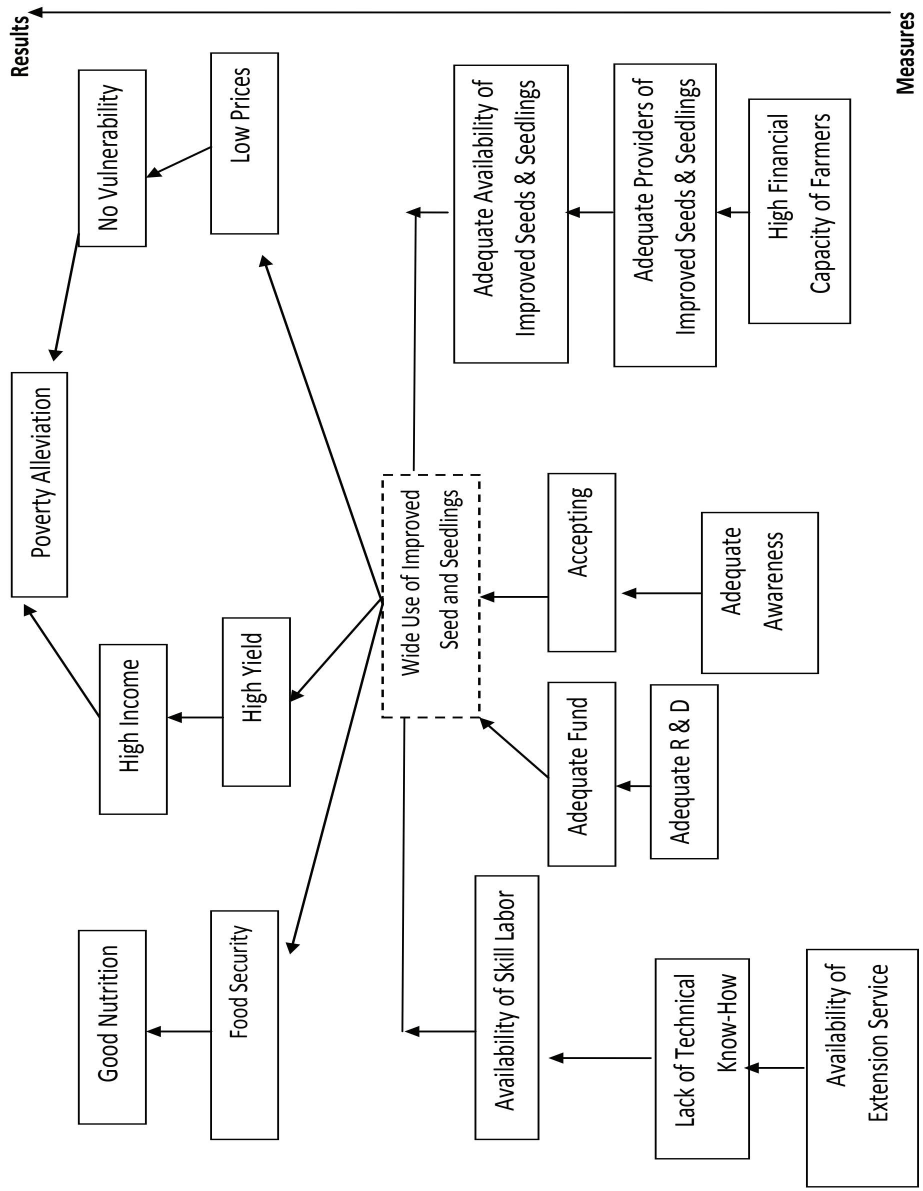
Annex I

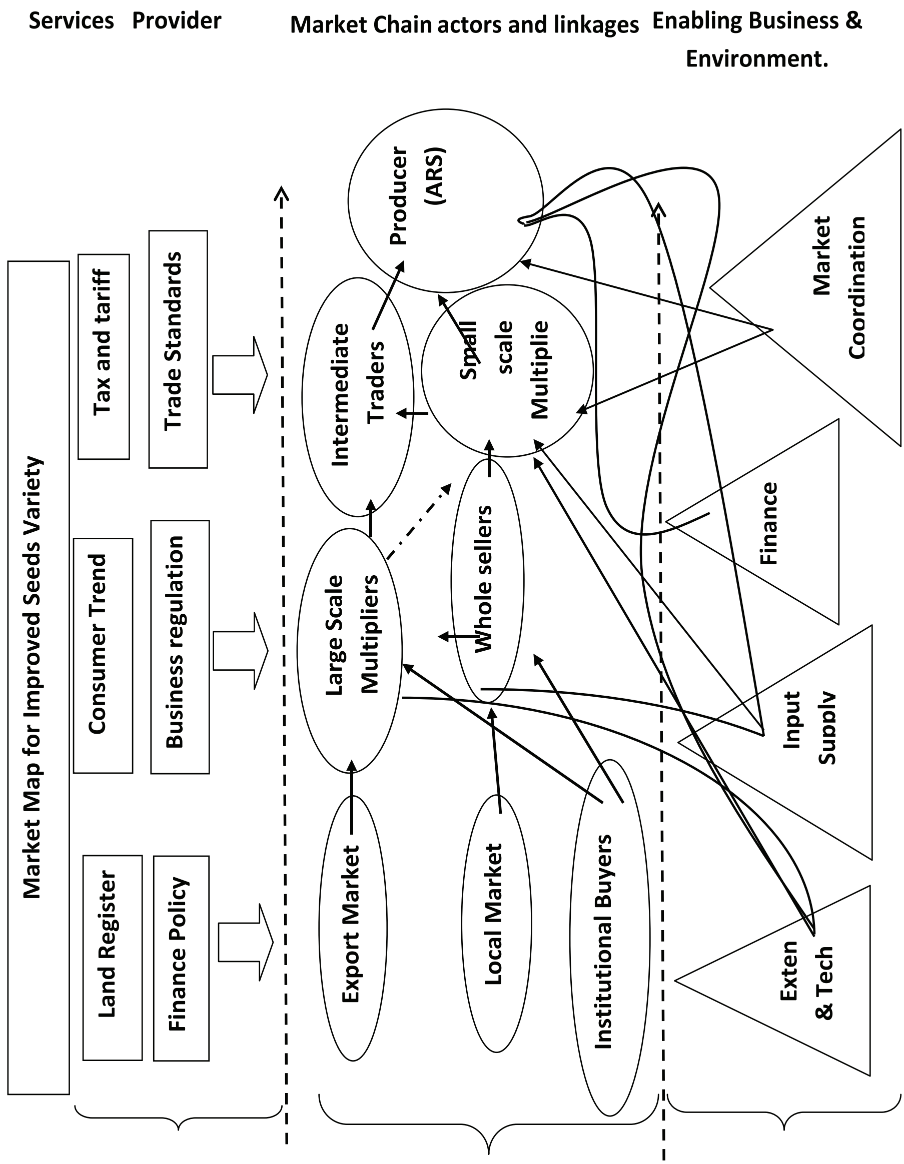
Market Maps and Problem Trees

Problem Tree for Improved Crop Varieties Technology Agriculture Sector

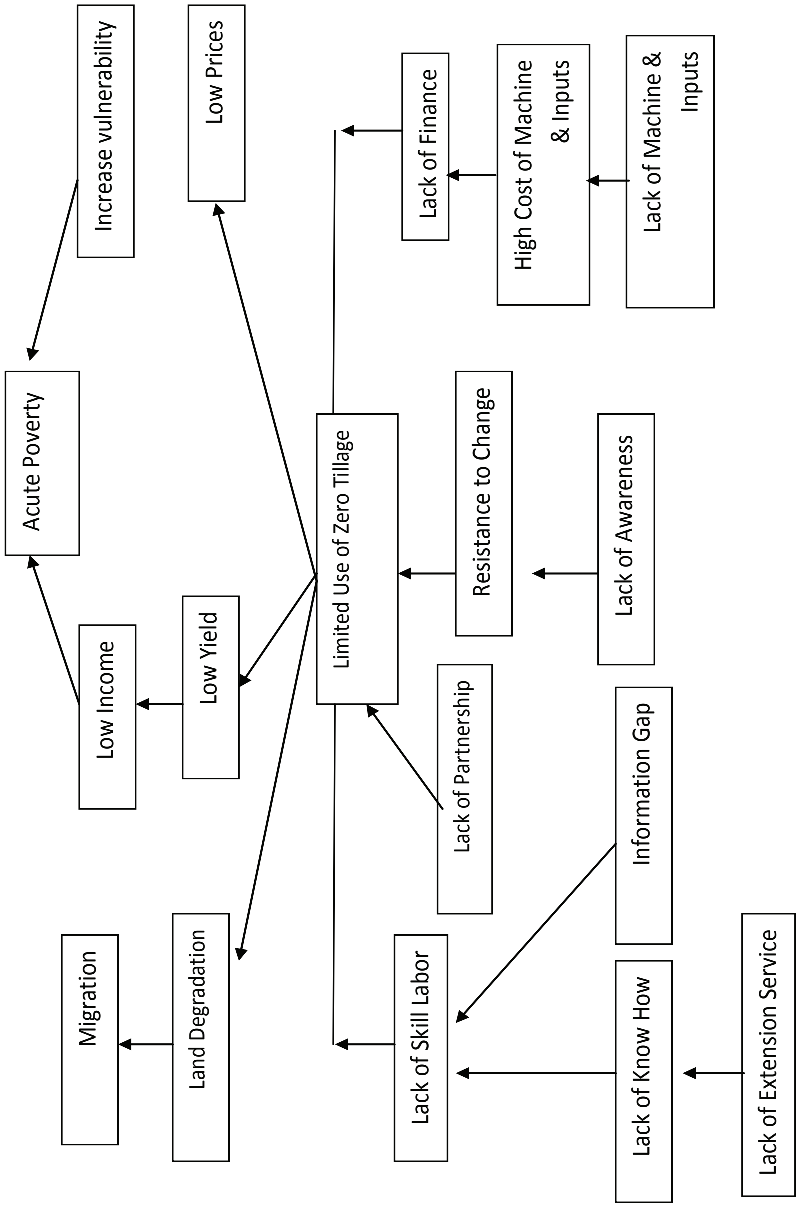


Measures to Overcome Barriers for Improved Crop Varieties Technology
Agriculture Sector




Services Provider
Market Chain actors and linkages
Enabling Business & Environment.
Market Map for Improved Seeds Variety
Tax and tariff
Trade Standards
Consumer Trend
Business regulation
Land Register
Finance Policy
Producer (ARS)
Intermediate Traders
Small scale Multiplie
Large Scale Multipliers
Whole sellers
Export Market
Local Market
Institutional Buyers
Market Coordination
Finance
Input Supply
Exten & Tech

Problem tree for Zero Tillage Technology Agriculture Sector



Measures to Overcome Barriers for Zero Tillage

Agriculture Sector

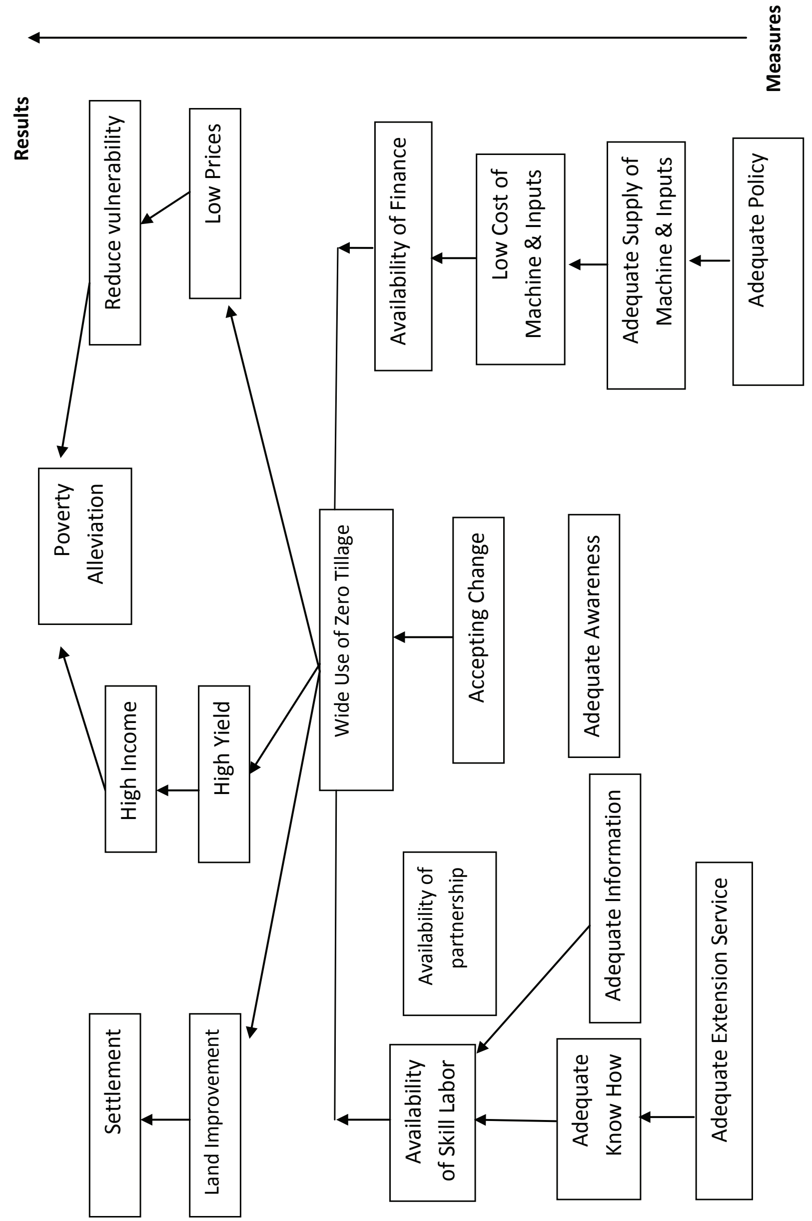


Table (A) Capital and operating costs and effect of Zero Tillage adaptation technology

Capital initial costs of adaptation

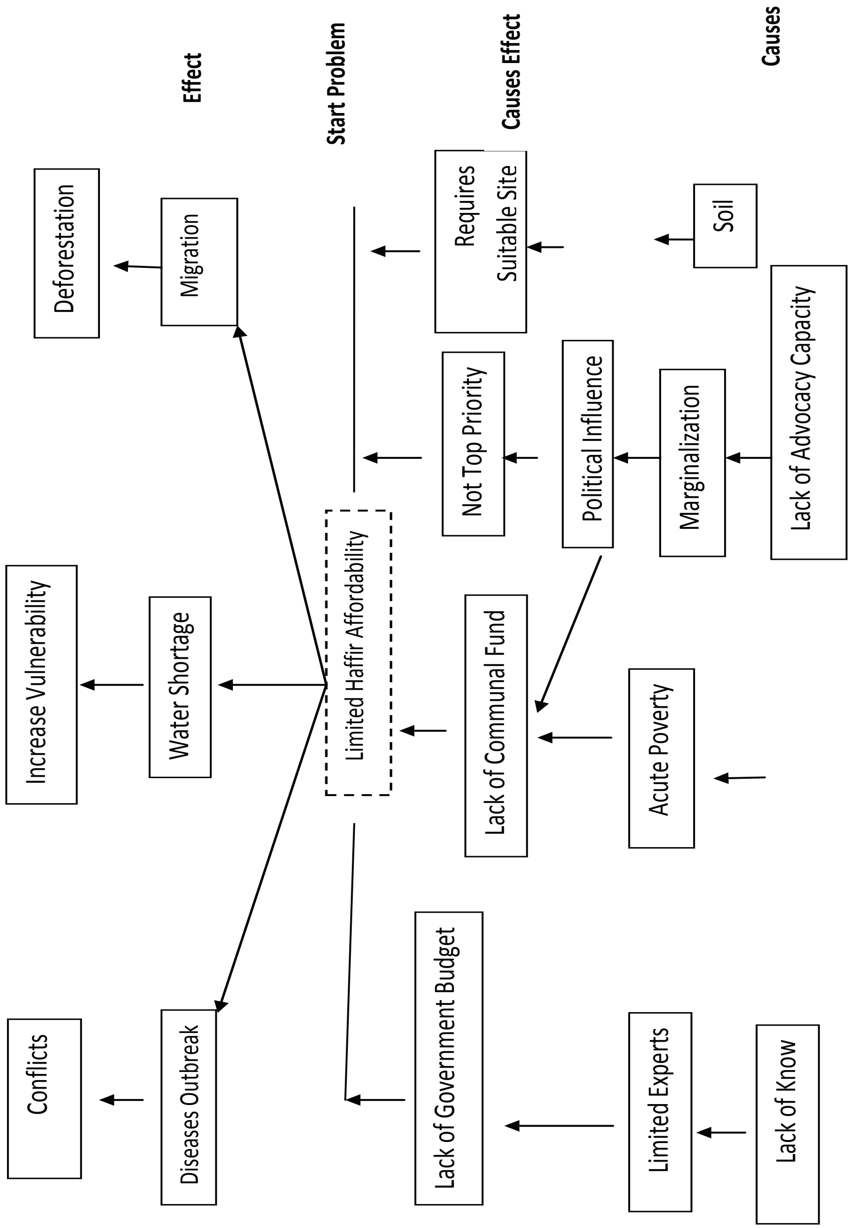
Cost item	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Cooperative society formation & registering fees	**3000**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Tractor & accessory equipment	**31,600**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Pilot farm	**64**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Extension services $1/ fed	**3,866**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Sub- total of capital	**38,520**		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Operating costs											
Production costs	**64**	**64**	**85**	**98**	**112**	**129**	**148**	**171**	**196**	**226**	**260**
Management	**10**	**10**	**11**	**11**	**12**	**12**	**13**	**13**	**14**	**14**	**14**
Maintenance 3%	**2**	**3**	**3**	**3**	**4**	**4**	**5**	**6**	**7**	**8**	**8**
Lubrication 1%	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**3**	**3**
Finance cost-interest	**5**	**5**	**5**	**5**	**5**	**-**	**-**	**-**	**-**	**-**	**-**
Sub- total operating costs	**82**	**104**	**118**	**132**	**151**	**165**	**191**	**217**	**249**	**285**	**285**
Total adaptation costs	38,548	2,101	118	132	151	165	191	217	249	285	285

Table (B): Returns of Haffirs technology adaptation

0	1	2	3	4	5	6	7	8	9	10
Annual returns	38,793	51,304	58,999	67,849	78,027	89,731	103,190	118,669	136,469	156,940

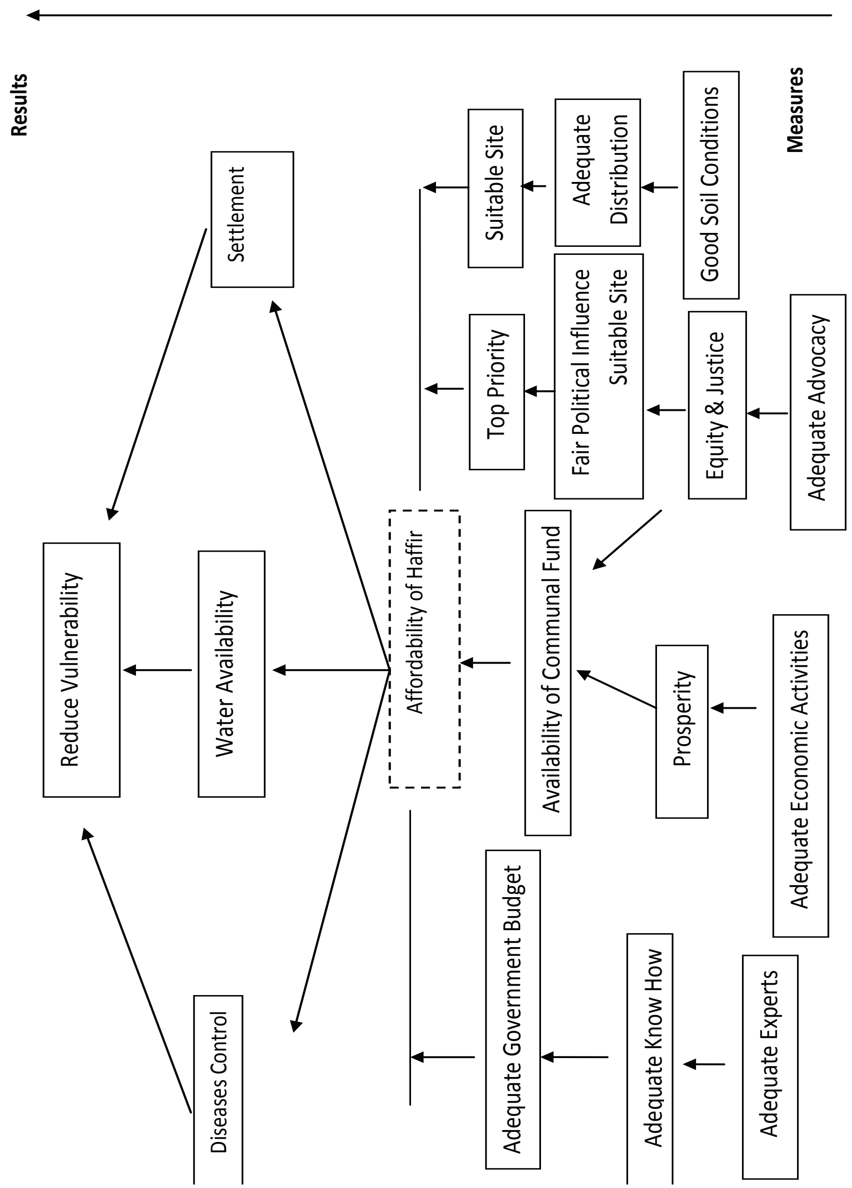
Problem Tree for Water Harvesting (Haffir Technology)

Resources Sector



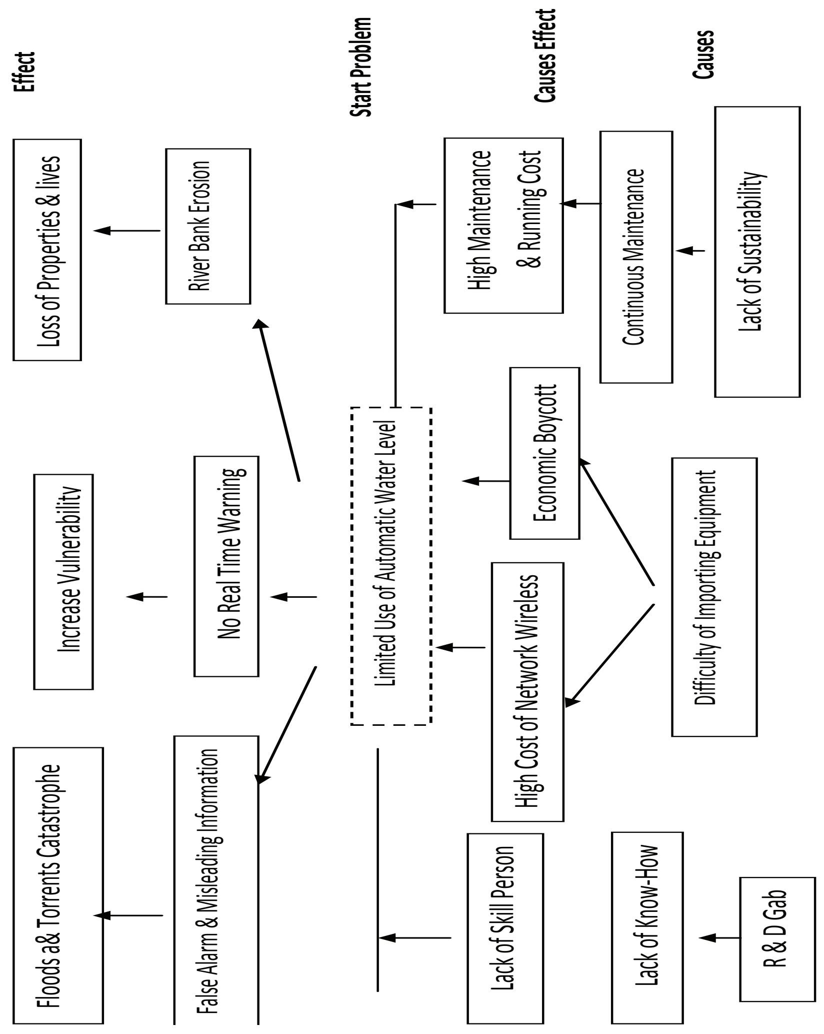
Measures to Overcome Barriers for Haffirs Technology

Water Resources Sector



Problem Tree for Automatic Water Level Technology

Water Resources Sector



Measures to Overcome Barriers for Automatic Water Level Technology

Water Resources Sector

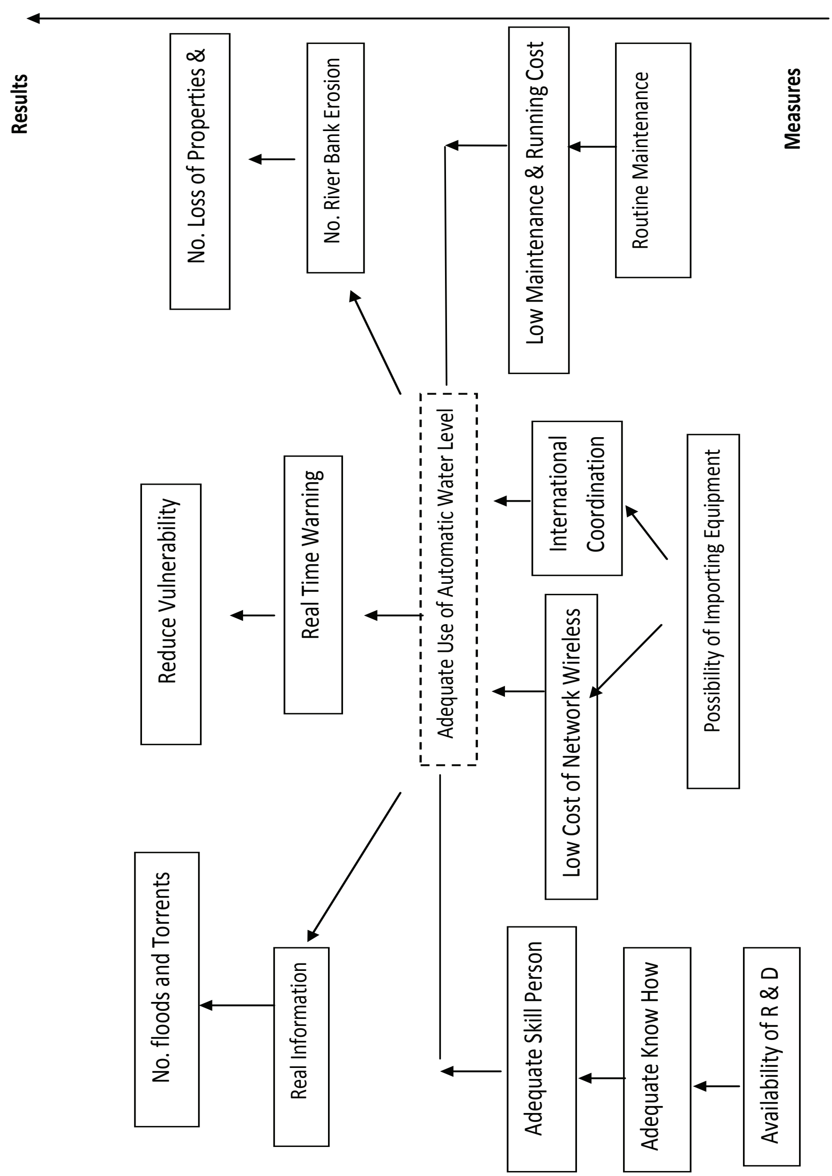


Table (C): The annual costs saved by adaptation the Automatic Water Level Technology

0	1	2	3	4	5	6	7	8	9	10
Annual *returns	500,000	750,000	900,000	900,000	900,000	900,000	900,000	900,000	900,000	900,000
Annual operating costs	83,862	110,907	127,544	146,675	168,676	193,978	223,075	256,536	295,016	339,269
Annual net cash flows	416,138	666,138	816,138	816,138	816,138	816,138	816,138	816,138	816,138	816,138

Annex II.

List of Stakeholders Participating in the Inception and the Second Workshop

Name	Institute	Position	Approach of consultation
Igbal Salah Mohamed Ali	Ministry of Water Resources	Researcher	meeting discussion
Widad Motwakil Saadalla	Ministry of Water Resources	Researcher	meeting discussion
Taghrid Abdelrahim	Ministry of Water Resources	Staff member	meeting discussion
Mohamed Yousif Mohamed	Institute for Water Harvesting Research	Lecturer	meeting discussion
Abd Elrahman Saghyroon Elzein	Dams Implementation Unit/ Water Harvesting Department	Director	interview
Tagwa Ahmed Elhabo	Ministry of water Resources/ Water Harvesting Unit	Staff member	interview
Ibrahim Salih Adam	Ministry of water Resources	Head of Technical organ of Water Resources	interview
Ahmed Eltayeb Ahmed Adam	Ministry of Water Resources/ Nile Water Directorate	Director	interview
Issam Aldin Ibrahim Abdal	Ministry of Agriculutre	Staff member	

Annex III: Policy Fact Sheets

Agriculture Policy Fact Sheet

Minimum requirements Recommended/ good to have	
Name of Policy	Agricultural Revival "The Green Mobilization": the Council of Ministers Resolution No. 173, 2007 for the formation of the High Committee (The high committee under the chairmanship of the Vice President) for the Study of the Current Situation in the Agricultural Sector and the Proposal of Appropriate Visions for its Future Development.
Name of field:	Agricultural Revival (The Green Mobilization)
Date Effective:	April,2008
Date Announced:	2008
Date Promulgated:	2008-2009
Date Ended:	Continuing
Unit:	Higher Council for Agricultural Revival
Country:	Sudan
Year:	2008
Policy Status:	In force
Agency:	Government and other national institutions including private sectors and farming communities
Funding:	Government- Commercial Banks- Foreign Contribution
Further Information:	25 Year Agricultural Development Strategy (ADS, 2004-2027)
Enforcement:	The programme included a supervision and follow up mechanism chaired by the Vise President, in addition to a High Council for Agricultural Revival, and a General Secretariat responsible for mobilizing and following up revival programmes and projects including the commodity councils.

Penalty:	
Related Policies:	Creating the environment conducive to sustainable development of agricultural productivity and production through the implementation of conductive macro and sectoral policies.
Policy Supersedes:	-
Stated Objective:	The strategic objective is to increase productivity and efficiency at the production and processing stages, Realization of food security, Reducing poverty, Development and protection of natural resources to ensure its renewal and sustainability.
Evaluation:	Follow up mechanism chaired by the Vise President, in addition to a High Council for Agricultural Revival, and a General Secretariat responsible for mobilizing and following up revival programmes and projects
Policy Type:	Economic, financial and finance policies, research policies, technology transfer and extension policies and land use policies (refer to attached tables below).
Policy Target:	Private sector, agricultural support services, farming communities Agricultural production systems(irrigated, mechanized and traditional rain-fed)
URL:	http//www.MoAF.sd
Legal References:	Country 25-Years Agriculture and Articulate a Future Vision and, Action Plan for Agricultural Revival, Republic of Sudan, Council of Ministers, General Secretariat, April 2008.

Description:	Recently, the Sudan has taken a new and strategic direction to support agriculture. This new direction is manifested in the declaration of "The Green Mobilization" and the preparation of the Five-Year Strategic Plan (Agricultural Revival). The executive programme for Agricultural Revival has defined the macro and sectoral policies for creating an appropriate atmosphere for achieving agricultural and agricultural-led industrialization. The programme defined the infrastructure conducive for agricultural development, focused on the development of the supporting services and the protection and development of natural resources .The total cost of this programme is estimated at 10.1 billion SDG (Sudanese Pounds) during 2008 – 2011. This includes governmental contribution, foreign, bank-lending and self-financing in addition to the agricultural season's subsidies. The programme is expected to achieve tangible results, most significant of which is the development of the farming systems and introducing participatory methods of natural resources management, ensuring sustainable use of these resources and reduce conflicts over them.

Policy Fact Sheets for Water Sector:

Policy name	Country Strategy on Integrated Water Resources Management
Date effective	In draft
Date announced	In draft since 2007
Date promulgated	Still in draft
Unit	CC
Country	Sudan
Year	Still draft
Policy status	
Agency	Ministry of Water Resources and electricity
Funding	
Further information	The policy document, in draft since 2007, is mainly related to very limited consultation at all levels along with some conservations on the content of the policy
Enforcement	
Penalties	Policy is giving principle for water resources management; penalties were included in 1995 the Water Resources Act, which is not active
Related policies	Environmental Conservation Act (2001): provides general principles and guidelines to be considered in implementing any development project. Protection of natural resources and endorsement of the principle "of "polluter pays The draft National Water Supply and Sanitation Policy (2009). Recently the Public Water Corporation, supported by UNICEF, has drafted a national Water Supply and Sanitation Policy. The thrust of the policy is to ensure equitable and sustainable utilization and provision of safe water and san-.itation with view of achieving the MDGs

Stated objective	To adapt with climate change and ensure rationale use of water resources
Evaluation	Not yet
Policy type	No list is provided classifying policies
Policy target	No list is provided
URL	
Legal reference	The policy is still in draft
Description	To lay the foundation for a rational and efficient framework to sustain the water needs of national economic development, poverty alleviation, peace, environmental protection and social well-being of the people through sustainable water resources .Management As per information provided limited consultation was one of the key drawbacks of the this policy and consequently limited stakeholders

Policy fact sheets for Water Sector:

Policy name	Water, Sanitation and Hygiene (WASH) Policy
Date effective	In draft since 2009
Date announced	In draft since December 2009
Date promulgated	Still in draft
Unit	CC
Country	
Year	Still in draft
Policy status	Final draft
Agency	Ministry of Water Resources and electricity, (Public Water Corporations (PWC
Funding	
Further informations	The policy document is in draft since 2009, wide consultation conducted at different levels and the policy was highly recommended to be approved
Enforcement	
Penalties	No penalties were included only guidelines .on how to manage water supply
Related policies	
Policy supersedes	
Stated objective	This policy aims to achieve the strategic objectives of quarter of the century 2007-2031, that targeted increasing rates of access to safe water in rural areas by 20 liters per capita per day, and up to 90 liters per capita per day in cities In addition, it aims at increasing rates of sewerage services to 67 per cent of the population of Sudan in rural and urban areas by the end of in 2015 to achieve the objectives of the third Millennium Development Goal. The frequent increase in the levels of services, safe water to 50 liters per capita per day in rural areas and 150 liters per capita per day in urban areas, in addition to coverage of, all schools and public health facilities to achieve the goals by the end of the 2031
Evaluation	Not yet

Policy type	No list is provided classifying policies
Policy target	No list is provided
URL	
Legal reference	The policy is still in draft
Description	The objectives of the policy to improve access of water and adequate sanitation in a sustainable way. This can improve the health and preservation of the environment and the living conditions of the population as well as to contribute to the positive growth of the economy in the country and the best use of .resources The policy widely accepted but it is still in draft due to continuous change in government structures and rapid turnover of key ministers and senior governmental officials. Key stakeholders are SWC, NGOs, private sector, communities and UN agencies

Republic of Sudan

Ministry of Environment, Forestry and Physical Development

Higher Council for Environment and Natural Resources

TECHNOLOGY ACTION PLAN

PART 3

Supported by:

Abbreviations

AIACC	Assessment of Impact and Adaptation to Climate Change
ARC	Agriculture Research Corporation
CBOs	Community Based Organizations
CC	Climate Change
EGTT	Expert Group on Technology Transfer
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
FMoF	Federal Ministry of Finance
GEF	Global Environment Facility
GHG	Greenhouse Gases
GoS	Government of Sudan
GWWD	Groundwater and Wadis Department
HCENR	Higher Council for Environment and Natural Resources
HHV	Household visit
IPCC	Intergovernmental Panel on Climate Change
MEAs	Multilateral-Environmental Agreements
MFNE	Ministry of Finnace and National Economy
MWRE	Ministry of Water Resources and Electricity
NAPA	National Adaptation Programm of Action
NAPs	National Adaptation Plans
NGOs	Non Governmental Organizations
NRWC	National Rural Water Corporation
PWC	Public Water Corporation
SWC	State Water Corporation
TAP	Technology Action Plan
TNA	Technology Need Assessment
UNCBD	United Nation Convention on Biological Diversity
UNCCD	United Nation Convention to Combat Desertification
UNFCCC	United Nation Framework Conventionon on Climate Change
UNEP	United Nations Environment Program
WFP	World Food Programe

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Executive summary

This report represents the Technology Action Plan (TAP) for selected technologies of the two sectors (agriculture and water resources) which were identified as crucial sectors that contribute to the country's food security and socio-economic characteristics. In general, the development process consists of (1) setting up preliminary targets for technology transfer and diffusion for each technology option within each sector (2) identifying barriers confronting diffusion, transfer and adoption of selected technologies (3) investigating possible measures to address the barriers for the transfer and diffusion of technology and (4) eventually developing a technology action plan for each technology option by considering legislations and regulations, financial incentives, institutional arrangements, infrastructure, research and development (R&D) support, and human resources development. The specific development processes and findings of each sector can be summarized as follows:

For the agriculture sector, which is the most important sector of Sudan's economy and crucial for the country's food security, three distinct crop production systems were identified; namely Irrigated, traditional rain-fed and mechanized rain-fed. According to Sudan's National Adaptation Program of Action (NAPA), agriculture has been identified as one of the three highest priority sectors most vulnerable to climate change. Current and potential impacts of climate change in agriculture are changes in agricultural productivity, reduction in duration of crop period, increased crop water requirements and changes in distribution of pests and diseases. There are several farm adaptation technologies that the agricultural sector can undertake to alleviate the effects of present and future climate change scenarios. The aim of the TAP for agriculture is to enhance capability of adaptation to climate change and to minimize its negative consequences on food security. The TAP has been developed on the basis of the TNA prioritization processes that determined improved crop varieties and zero tillage as priority options for the agricultural sector. The main features of the prioritized technologies are meeting the dual challenges of achieving food security and responding to climate variability and change, as well as contributing to environmental conservation and addressing soil degradation.

Improved crop varieties development and varietal dissemination of the TAP include the production and distribution of bulletins and brochures on

various characteristics of adaptation and limitations and their suitability to areas, as well as introducing and demonstrating the currently existing varieties that overcome climate related stresses. Further measures include encouraging and facilitating seed multiplication of many partners, providing information and training about seed multiplication methods and regulations, promoting the role of local farmers and private sector in providing seeds of improved crop varieties, and enhance orient plant breeding research capabilities to develop varieties that endure climatic stress. In-situ and ex-situ conservation of genetic resources of local types, encourage farmers' participation in plant breeding stages and the training of future plant breeders. Expected stakeholders to implement the TAP include agencies, government departments and institutions, academic and research institutions and NGOs.

Zero-tillage technology contributes to environmental conservation and to sustainable agricultural production. Results indicate that zero-tillage technology increased sorghum production from about 700 kg/ha to 1650 kg/ha. The second main priority action technology for adaptation to climate change has been the development of improved crop varieties. In Sudan sorghum is the most widely produced and consumed cereal crop. Climatic change seriously affects the traditional rain-fed sorghum growing areas. Therefore, to sustain sorghum production in low rainfall regions, the Agriculture Research Corporation (ARC) has released short maturing, drought tolerant sorghum varieties with high yield and grain quality. Seed production of the adapted varieties is an essential step towards their spread and adoption. Yet, there are several constraints and limitations to quality seed supply discussed in the report. Moreover, the most important benefits and barriers to the diffusion and adoption of the prioritized technologies are presented in the TAP.

The TAP for zero-tillage technology contains several measures including the introduction, demonstration and promotion of zero-tillage in all agro-climatic zones, the organization of extension campaigns for descriptions of conservation tillage implementation, as well as the creation and implementation of information and education campaigns to increase awareness. In addition, measures need to facilitate the creation of Community Based Organizations (CBOs), conduct surveys to determine the obstacles to adoption of conservation tillage, conduct research regarding draft animal power use in conservation tillage, enlist the private sector to help disseminate information on conservation tillage, and engage with national and international organizations to serve as information source to promote conservation tillage.

As far as the water resources sector is concerned, the sector can be generally characterized by its vulnerability to the impacts of weather and climate-related events. The major problem that faces the rain fed farmers is the availability of drinking water after the rainy season. The majority of the inhabitants and nomadic tribes, who live far from the River Nile and its attributes, depend solely on the erratic rains which represent great risks to their lives and livelihoods. On the other hand, the Nile system frequently represents a high risk for inhabitants residing along the Nile banks and tributaries. Communities settled close to these locations are vulnerable to risks of flooding. Therefore, a reliable warning system is required to reduce the damages from natural disasters (e.g. floods and droughts). For Sudan, Rain Water Harvesting (Haffirs) and Seasonal Forecasting and Early warning system (Automatic Water Level recorders) technologies have been rated as the best adaptation technologies for the water sector.

Haffirs are manmade reservoirs in the earth to store water for drinking and irrigation purposes. In Sudan, the NWC (National Water Corporation) in the past, and currently the PWC (Public Water Corporation) and SWCs (State Water Corporation), have constructed several haffirs in many locations to meet the demand of a growing population. Research has shown that demand is generally far beyond the available capacities.

Shortage of financial resources and locating limited resources for both technologies are considered the main challenges for technology promotion. On the other side, insecurity, lack of enabling frameworks, limited capacity and limited trained staff along with limited awareness, as well as problems hindering the promotion of technologies were identified as the key nonfinancial barriers related to haffirs. The analysis of financial and non-financial measures for the successful application of haffirs technologies has been proposed. The results include funding and awareness raising, institutional and capacity building, as well as strengthening policies and legal frameworks. The provision of funds and fair distribution of haffirs in different regions is essential to provide drinking water for rural communities. At the same capacity building of communities, governmental institutions and other partners is crucial for technology promotion. This is along with the development of policies and dissemination of existing laws to avoid and resolve conflicts emerging from land tenure.

An automatic water level recorder is the technology developed to predict the situations in order to avoid and to mitigate impacts of flood on human and properties. This technology uses data logger and submersible pressure transducers. It has been designed for remote monitoring and recording of water level or pressure data. Early warning systems play an important role in countries like Sudan which is susceptible to floods and characteristically has poor infrastructure. Investigations indicated that barriers of the two technologies are generally similar. Therefore, measures to overcome these barriers tend to be similar too. These include the provision of funds, institutional support and capacity building along with policy and legal frameworks which are considered key tools to overcome the barriers of this technology.

Chapter I
Technology Action Plan for the Agriculture Sector

1. 1 Actions at sectoral level
1.1.1 General Description of the Agriculture Sector

Agriculture is the most important sector of Sudan's economy and it is crucial for meeting the country's food security. It is the main livelihood source for more than 70 per cent of the population and about 80 percent of the labour force is employed in agriculture and its related activities. In addition, agriculture contributes to about 30-35 per cent to Sudan's GDP and generates around 90 per cent of non-oil export earnings. According to Sudan's NAPA (2007) and its First National Communication to the UNFCCC (2003), agriculture has been identified as one of the three highest priority sectors most vulnerable to climate change. For example, crop production is predicted to decline substantially with adverse impacts on both local incomes and food security.

Recent climatic trends in the country have indicated the substantial decline in the precipitation and rising in temperature in several parts of the country, and global warming models predict that this trend will continue. Results showed that there has been a clear decrease in the annual rainfall over the last 30 to 40 years and analysis of temperature indicated that during the last decade temperature has been increasing in several places from decade to decade (Mohamed, 1998). Extreme climate events that affect rural households' food insecurity and enhance vulnerability are presented in table1. The most severe impacts involve changes in agricultural productivity, reduction in duration of crop period and reduced yields, as crop water requirements increased and water availability decreased; this predicament is aggravated by changes in distribution of insect pests, diseases and weeds.

Table1. Extreme climate events in Sudan - sectors affected & impact categories

Event	Sector	Impact
Drought	Agriculture, livestock, water resources and health	Loss of crops and livestock, decline in the hydroelectric power, displacement wildfire
Floods	Agriculture, livestock, water resources and health	Loss of life, crops, livestock; insects and plant diseases, epidemic/vector diseases, decline in hydro power; damage to infrastructure and settlement areas
Heat waves	Health, agriculture and livestock	Loss of live, livestock and crops

Source: NAPA 2007

There are several promising adaptation technologies that the agricultural sector can benefit from adopting to alleviate the effects of present and future climate changes. These technologies should be promoted and disseminated to help poor people live in the fragile rural environment, enhance food security and reduce their vulnerability. These adaptation options include introducing improved crop varieties, zero tillage practices, seed priming and fertilizers micro dosing, water management and soil management practices, as well as crop production practices. The key objective of the TAP adaptation for agriculture is to enhance capabilities of adaptation to climate change to minimize its negative consequences; and to ensure the sustainable development of the agricultural sector in the context of climate change.

The TAP has been developed according to the TNA results on technology prioritization. The results indicated that improved crop varieties and zero tillage were the highest prioritized technology options; subsequently, the TAPs for each of the two technologies were developed.

The main features of the prioritized technologies are meeting the dual challenges of achieving food security and responding to climate variability and change as well as contributing to environmental conservation; also, addressing soil degradation through replenishment of soil nutrients and increasing soil organic matter and water conservation, in tandem with appropriate climate resilient varieties that increase yields and reduce risks, especially in rain-fed agriculture. In agreement with this vision, the Food and Agriculture Organization (FAO, 2010) highlighted key components of climate-smart production systems. These include:

* Soil and nutrient management: enhancing the availability of soil nutrients can be achieved by increasing soil organic matter (conservation agriculture, reduced tillage, continuous soil cover, composting), improved application of fertilizers (micro-dosing, controlled release or deep placement fertilizer technologies), and improved land preparation practices that minimize soil disturbance.

* Genetic resources: developing improved varieties and preserving genetic resources of crops and their wild relatives is critical at the national level to ensure that appropriate climate resilient varieties are developed and accessible to producers. Table 2 shows the potential hazard avoidance of the prioritized technologies. High or low indicates the potential hazard avoidance based on technology characteristics. As shown in the table the targeted technologies present a high potential to avoid hazards, indicating their economic and environmental benefits as an adaptation option.

Table2: Potential hazard avoidance of the prioritized technologies

Circumstances	**Hazard avoidance**						
	Physical (cli-(matic		**Bio-logical**	**Economic**		**Institutional**	
Technology	Rain-fall	Soil degra-dation	Pests disease weeds	Income gain	Varia-tion in food prices	Access to mar-ket & inputs	Ex-ten-sion ser-vices
Zero technology	high	high	low	high	low	high	low
Improved varieties	high	low	high	high	low	high	low

1.1.2 General Barriers and Proposed Measures

One of the main barriers of the agricultural sector is that adoption rates of improved technologies are very low due to low public and private sector investment in agricultural research and technology transfer. Other identified barriers include lack of market linkage and investment in infrastructure; Incentive polices for diffusion of the new technology are not strong enough, poor infrastructure, lack of support for research and development, lack of information and limited local management capacity and expertise. Measures for overcoming these barriers include: Create a network to promote strategies that include information campaign and raising awareness, policies and measures to promote existing technologies transfer and research, plus market and other financial services support. Other enabling environment measures for the agricultural sectors include land register, consumer trend, tax and tariff, finance policy, business regulation and trade. Polices developed to overcome these bariers were formulated according to the Council of Ministers Resolution No. 173, 2007 (Agricultural Revival).

Table 3: Some of the agricultural polices promoted by Agricultural Revival to create a conducive environment for increasing production and productivity

Policy	Lead Agencies	Time Frame	Starting Date
:A. Economic and Financial Policies			
Allocate at least 20% of public expenditure for building and modernization of agricultural and livestock infrastructure and advancement of technological innovation	MFNE	Annually	March 2008
:B. Financing Policies			
Finance research, extension and technology transfer; early warning and pests control, diseases and epidemics at national level	MFNE, private sector	Continuous	Immediately
C. Research Policies			
Permit introduction and adaptation of successful technologies on the basis of scientific criteria agreed upon until the procedures concerning .Intellectual Property Rights are put in place	High Council for Agricultural Revival	Continuous	Immediately

D. Technology Transfer and Extension Policies			
Use the village as a centre for providing agricul- .tural services and finance Earmark 15% of the posts approved annually for employing new agricultural graduates to those .coming from the villages chosen as centers	MFNE, MAF, MAR and other rela-ted parties	Complete the study on Dec. imple-mentation in 3 years	Jan. 2008

1.2 Action Plan for Improved Crop Varieties
1.2.1 About the Technology

One of the main focuses of national and international research for adaptation to climate change has been the development of crop varieties that can cope with heat, drought, flood and other extremes and thus help farmers adapt to the changes while sustaining and increasing agricultural production and productivity. Historically, crop scientists and farmers have identified and selected several adapted crop varieties with desirable traits that allow them to achieve optimum yields while withstanding stresses, such as drought, heat, and water-logging. Ecological, economic and cultural factors are always considered in variety selection and release. However, the oureach of the improved varieties is still limited.
In Sudan sorghum is the most widely produced and consumed cereal crop. Climatic change has seriously affected the traditional rain-fed sorghum growing areas which constitute more than 50 per cent of the national sorghum production area. Despite the recent climatic changes productivity and sustainability of sorghum production in low rainfall regions can be increased. During the last few decades the Agriculture Research Corporation (ARC) has released short maturing, drought-tolerant, open-pollinated sorghum varieties (table 4) with high yield and grain market preferred qualities that demonstrated adaptable performance under unfavorable environmental conditions (Elzein et al, 2009). Generally, the economic benefit of new varieties is well known in India where it increased the production in some states to 4.04 million pounds.

Table 4.Target area and mean grain yield (kg/ha) of the improved crop varieties

Variety	(Target area(Rainfall mm	(yield (kg/ha
Bashayer	300-450	2436
Butana	300-450	2194
Yarwasha	300-450	1825
W. Ahmed	450-600	3221
AG8	190-800	888

Source: Elzeinet al, 2009

1.2.2 Target for technology transfer and diffusion

From the Part one of the Sudan Technology Needs Assessment it was clearly stated that agriculture is one of the winning sectors for the TNA; and two technologies were selected for this sector, namely: Improved Crop Varieties and Zero Tillage (conservative agriculture). According to the vulnerability Assessment Report (HCENR, 2012), the main food grain production is largely carried out under rain-fed conditions (75 per cent). As the majority of Sudanese farmers rely on rain-fed agriculture, lack of irrigation makes these areas particularly vulnerable to the impact of climate change on their agricultural activities. The average yield of the existing varieties is low due to the depressing consequences of climate change. Lack of adequate, high quality seeds of improved varieties was identified as one of the bottlenecks to improved productivity. Based on this, the rain-fed sector is targeted to improve crop varieties technology transfer and diffusion to improve farmers' access to seeds of researcher-developed varieties. The target set in this report is to cover the sector with improved crop varieties, including high yielding, early maturing, drought-tolerant and heat-resistant crops by the end of 2012. Target groups are farmers, stakeholders, service providers, seed producers, women and farmer groups.

1.2.3 Technology diffusion barriers and measures
Barriers to improved crop varieties in the Sudan

Economic and financial	Non economical and financial
High cost of local production	Limited availability of improved seeds varieties
High price of seeds/seedlings	Farmers awareness about existing technologies
Absence of financial facilities	Limited producers
Difficulty making profit	Farmer's perception of technology
Absence of related infrastructure	Lack of technical know-how
Limited availability of financial resources	Cultural/social difficulties
	Limited use of seeds

Adoption of improved crop varieties is essential in order to maintain a balance between development and environmental objectives. To accelerate and to guarantee steady transfer and diffusion of improved crop varieties, a number of measures and studies are recommended. For improved crop varieties, measures for the transfer, diffusion and adoption were identified through stakeholder consultations and the national team. These measures were classified into two main groups, namely economic and financial measures and non-financial measures. The level of coverage of this technology is low and constrained mainly by high costs and the unavailability of seeds of the sought varieties, particularly to small holder farmers in the country. Currently there is no commercial incentive to invest in these technologies. Collaboration between the private and public sectors hold the key to accessing and facilitating the deployment of these technologies.
The economic and financial measures that are necessarily considered to offset the economic and financial barriers for the improved crop varieties include provision of financial assistants to the farmers and producers of the improved crop varieties like subsidies and soft loans. In this variable it is important to consider measures for the compensation of Research & Development expenditures as an incentive for sake of enhancing research for better achievements.

As far as the customers are concerned, the prices of the improved crop varieties should be within their reach. Since most of the small scale farmers are poor, soft loans should not be linked with collaterals which are not satisfactory for provision of soft loans. Moreover, provision of related infrastructure would enhance and expand the adoption of improved crop varieties.

To overcome the non-financial measures for improved crop varieties it is necessary to:

* Establish a network of experts
* Develop policies to encourage and support researchers to invest in improved seeds and seedling
* Capacity building of extension agencies to increase the providers of improved crop varieties
* Raising awareness of the people for sake of eradicating cultural and social beliefes hindering adoption of improved crop varieties.

Resolving all the barriers (financial and economic; and non-financial and economic) for improved crop varieties will expand the use of seeds by the majority of farmers. This will result in increased agricultural productivity and food security enhancement.

1.2.4 Proposed Action Plan for Improved Crop Varieties

Prospective goals of the action plan for improved crop varieties are:

* Generate awareness and improve farmers' access to seed developed varieties that reduce climatic risks and improve crop productivity
* Scaling up the dissemination of new varieties through facilitation of seed multiplication of the improved varieties
* Involve financial institutions to encourage private sector investments in seed production
* Development of improved crop varieties to with resilience to drought, heat and pests
* Encouraging/promoting adoption of currently existing varieties that overcome climate related stresses

Table 5.Proposed Action Plan for Improved Crop Varieties

Actions/ activities	Implement-ing Period ((years	Outputs and Performance Indicators	Responsi-/ble Imple-menting Organiza-tion	Supporting Organization	Cost[1] US$	Fund-ing Source
Production and distribution of bulletins and brochures on varietal characteristics range of adaptation and limitations, and their suitability to areas	2	Number of bulletins and brochures produced and distributed, and area covered	MOA (State), ARC, Extension Dept., IFAD project	Framers Trade ,Union Private sector	20,000	FMoF, MoA
Introduction,promoting and demonstratingcurrently existing crop varieties that overcome climate related stresses	5	Sites and numbers of demonstration plots set and varieties introduced	CBO, MOA(State) Extension Dept., IFAD project	Agric bank, Framers Trade ,Union Private sector	200,000	FMoF, MoA
Development of an efficient seed production and supply systems to ensure rapid access to quality seeds from different sources Facilitate seed multiplication by many partners through promoting the role of local farmers and private sector in the provision of seeds of improved' varieties	5	Seed multiplication farm set: location and quantity local farmers and private companies providing seeds ,type of varieties and quantity	CBO,-MOA,I-FAD Seed Development project, Private sector,N-GOs	Agric. bank, Framers Trade Union	30,000	FMoF, MoA
Providing information and training about seed multiplication methods and regulations	2	Number, type of trainings and attendants	CBO, MOA (State), ARC, Extension Dept., IFAD project	Framers Trade ,Union ,Private sector	20,000	FMoF, MoA
Enhance /Orient plant breeding research capabilities to develop improved varieties (endure climatic stress	5	Breeding program designed and varieties developed	CBO ,ARC, Extension Dept., IFAD project	Agric. bank, Framers Trade ,.Union Private sector	200,000	FMoF, MoA

In-situ and ex-situ conservation of genetic resources of the local types	3	Number and types of accessions and types of local material collected and conserved	CBO ARC, (genetic resources (unit	MOA, Framers ,Trade Union CIGAR(ICRI-(SAT	50,000	FMoF, MoA
Encourage farmers' participation in plant breeding stages	3	Varieties developed through farmers' participation in breeding program	CBO, MOA (State), ARC, Extension Dept. IFAD project	Framers Trade ,Union Private sector	30,000	FMoF, MoA
Training of future plant breeders	5	Plant breeders trained (area and (number	ARC, IFAD Seed Development project	CIGAR (ICRISAT) centers, Universities	500,000	FMoF, MoA

1.3 Zero Tillage Technology
1.3.1 About the Technology

Zero tillage has received much attention throughout the world in recent years because of its various benefits. It is a crop production system where the soil is not traditionally tilled (disturbed) or cultivated although sticks or other planting equipment are used to make the openings for seeds. It is indicated that zero tillage is a system of farming that uses herbicides or manual methods to control weeds and maintain crop residues on the soil surface. No seedbed is prepared and planting is done with minimum soil disturbance, using coulter (iron blade fixed vertically in front). Zero tillage benefits include economic, agronomic, environmental and social benefits. For example, it improves soil and water conservation and reduces soil compaction and erosion because the topsoil is protected. Furthermore, it improves both soil conditions with the increased organic matter content and nutrient retention; it reduces leaching of nitrogen and other nutrients and provides greater net returns. It also reduces the amount of labour required. In Sudan, the zero-tillage farming system has been introduced as an alternative to the prevailing traditional systems. Current research in Sudan showed that zero-tillage agriculture technology increased sorghum production from about 700 kg/ha to 1650 kg/ha (table 6). However, this technology is not widely known and confied to certain areas. Research evidence also indicate that zero-tillage is promising and recommended (Lotfie et al, 2009), particularly in mechanized rain-fed agriculture, which is sensitive to climate change and constitutes a great portion (35 per cent) of the national cultivated activities. Comparisons of conventional and conservation tillage costs for smallholders indicates that net farm income of conservation tillage is about 60 per cent higher than income from conventional tillage (table 7).

Table 6: Effect of different tillage treatments on sorghum grain yield

Treatment	(Yield (kg/ha	(%) Yield relative to Zero-tillage
Chisel	1346	82
Moldboard	1017	62
Disk harrow	710	43
Wide Level Disk	913	55
Zero-tillage	1649	100
± SE	161.6	-

Source:Lotfieet al., 2009

Table7: Comparison of conventional and conservation tillage costs for smallholders

Crop/cost item(US $)	Conventional tillage(1)	Conservation tillage(2)	Ratio(1/2)
(Farm area(ha	15.6	15.6	-
(Labour (person/day	287	240	1.20
($ Net farm income (US	2570	4272	0.60
(Return to labour (US $ day	8.95	17.80	0.50

Source:Srrensenet. al,1999

1.3.2 Target for zero tillage technology transfer and diffusion

Soil deterioration related to soil erosion and the unplanned use of agricultural machineries as well as the continuous cultivation in the same areas of land without sound crop rotations also contributed significantly to problems related to environmental degradation and crop production under mechanized rain-fed farming. Despite the major role of the mechanized rain-fed farming system in attaining food security as well as a source of sorghum exports, farmers are still using traditional tools and machineries as well as un-recommended cultural practices. In efforts to develop this sector, promotion of zero tillage technology can facilitate better crop production practices and conserve the natural resources; particularly soil and water. The target set by the TAP is to establish zero tillage technology as the dominant farming system in the agricultural sector by the end of 2030 i.e. around 4-5 million hectares in the mechanized rainfed sector. Targets include large scale farmers, private sector and service providers.

1.3.3 Main barriers and measures to the technology's diffusion

Diffusion and adoption of zero tillage is undoubtedly easier in developed countries where suitable equipment and herbicides are readily available. The scale of spreading of this technology is very limited and confined so far to demonstrations by very limited private sector companies. This is mainly due to the high cost involved in the application of the technology and lack of awareness. Nevertheless, the principles of zero tillage are suitable for widespread application in developing countries like Sudan. The most important constraints to adoption of conservation tillage include the mistaken perception that soil cultivation (plowing) is essential for high crop production, the limited availability of affordable and appropriate seeding machinery that is locally produced and maintained, limited or lack of knowledge and experience of how to adopt these practices and the absence of policies and extension role. Barriers to the transfer and diffusion of zero tillage are identified by the TNA Report, Part I:

Barriers confronting adoption of Zero Tillage

Economic and financial barriers	Non-economic and financial barriers
Lack of financial support	Unavailability of enough information or knowledge
Impossibility of crop rotation	Lack of know how about Zero Tillage
Difficulty of buying specialized machine (Small farm size)	Lack of government support
Difficulty of buying adequate herbicides	Farmer perception
Poorly developed infrastructure	Lack of adequate policies to promote adoption of intervention
High costs of inputs	Ecological barriers
Unavailability of Zero Tillage machines at markets	Poor research
	Strong demand for crop residues

Barriers confronting adoption of Zero Tillage must be overcome by politicians, public administrators, farmers, researchers, extension agents and university professors. Measures which are believed to be real solutions to the barriers for zero tillage are classified as economical and financial measures and non financial measures.

The main economic and financial measure for Zero Tillage technology is availability of finance which can take different forms like subsides, incentives and soft loans. Incentive measures could be introduced to encourage suppliers to make the technology available to users. In this connection a survey is necessary to assess user needs. To stimulate the adoption of Zero Tillage by users specific provisions regarding legislative, administrative or policy measures for access to and transfer of technology are necessary.

Non financial measures: information on available Zero Tillage could be systematically compiled and made available to farmers through efficient extension services. Improvement of research through support of research and academic institutions would attenuate many barriers to Zero Tillage adoption. Finally, existence and availability of skilled labour is of paramount importance in creating the environment for attenuating the barriers and attainment of good results.

1.3.4 Proposed Action Plan for Zero Tillage Technology

The main goals of the action plan for zero tillage technology includes: (1) increase the sustained adoption of conservation tillage practices in the mechanized rain-fed agriculture and (2) develop and deliver information on the economic and environmental benefits of conservation tillage to various stakeholders. The necessary action items for the action plan for zero tillage technology are included in (Table 8).

Table 8: Proposed Action Plan for Zero Tillage Technology1

Actions/ Activities	Implementing Period-(year)	Outputs and Performance Indicators	Responsible/ Implementing Organization	Supporting Organization	Cost $US	Funding
Introduce, demonstrate and promote “no tillage” in all agro-climatic zones	5	Location and number of no tillage demonstration plots	CBO , MOA (State), ARC, Extension Dept. IFAD Projects	Agric. bank, Framers Trade Union, Private sector	400,000	FMoF, MoA
Organize extension campaigns for descriptions of conservation tillage	3	Number and sites of extension campaigns organized	CBO, MOA (State), ARC, Extension Dept., IFAD Projects	Framers Trade Union, Private sector	20,000	FMoF, MoA
Create and implement information and education campaigns to increase awareness	2	Number, typed and sites of information and awareness campaigns organized	CBO , MOA (State), ARC, Extension Dept., IFAD Project	Framers Trade Union, Private sector	20,000	FMoF, MoA
Facilitate creations of CBOs and enhance their access to financial services markets, inputs and agricultural information	3	CBOs formed (location and number)	CBO, MOA (State), ARC, Extension Dept., IFAD Project	Agric. bank, Framers Trade Union, Private sector	50,000	FMoF, MoA
Conduct surveys of target areas to determine the obstacles to adoption of conservation tillage	2	Survey results and report	CBOs, MOA (State), ARC, Extension Dept. IFAD Project(-South Kordofan)	Agric. bank, Framers Trade Union, Private sector	50,000	Local and external

Conduct research regarding draft animal power (technology in conservation tillage)	4	Research results and report	CBO, ARC, Extension Dept., IFAD Project	Agric. bank, Framers Trade Union, Private sector	80,000	FMoF, MoA nal
Determine and develop appropriate technology transfer capacities to increase adoption of conservation cropping systems	2	Trainings and adoption rate of the technology	CBO, ARC, Extension Department, IFAD Projects	Framers Trade Union, Private sector	30,000	FMoF, MoA
Enlist the private sector to help disseminate information on conservation tillage	1	Information received by private companies	CBO, MOA (State), ARC, Extension Dept. IFAD Project	Framers Trade Union, Private sector	15,000	FMoF, MoA
Engage with national and international organizations to serve as information source to promote conservation tillage	2	Connections and network set to communicate with national and international organizations	ARC, Extension Dept., IFAD Project	Framers Trade Union, Private sector (machinery –seed –chemicals)	15,000	FMoF, MoA

Indicators: (1) Risk: climatic conditions, availability of credit and weak extension system (2) Success: high yield and return, food security and soil conservation

Cost estimates is based on: 1) inputs needed for the activity, 2) estimates provided in TNA report part I

Chapter 2
Technology Action Plan for Water Sector

2.1Actions at sectoral level
2.1.1 Water sector description

Adoption and implementation of integrated water resource management will enhance adaptive capacities of human communities and natural ecosystems to climate change, increase living standards and ensure water security and sustainable water resources development. Prioritizing development of climate change adaptation technologies in water resources management will ensure water security, poverty alleviation, social security, public healthcare, enhanced living standards and protect water resources in the context of climate change. Life in Sudan revolves around water. The total amount of fresh water from internal and external sources is around 30×109m3/year, bringing the per capita water availability below the water stress limit of 1,000 m3. Water resources in Sudan are the River Nile and its tributaries, seasonal streams and groundwater as well as unconventional water. The River Nile basin is shared among ten countries. The seasonal streams and ground water are shared with three countries.
Sudan implemented several activities under multilateral environmental agreements (MEAs) which have direct relations to climate change adaptation and development priorities.
The NAPA process, under the UNFCCC, identifies specific initiatives that are considered urgent and address immediate climate adaptation needs.

The major types of initiatives are as follows:
* Government Policies and Strategies: these are country-driven policy responses to environmental challenges motivated by either commitments under MEAs or national sustainable development objectives;
* National Programs: these are specific measures designed to meet specific needs and objectives of national policies, to be funded by the national budget and/or bilateral donors;
* Intergovernmental/Multilateral Processes: these are scoping studies that address critical areas affecting or impeding national development; and
* Other Multilateral Activities: these are assorted projects, largely funded through GEF, and focused on capacity building and sectoral development priorities.

In Sudan there are several government policies and strategies that are complementary to climate change adaptation goals. The Environmental Protection Act was enacted in 2001 and provides a framework law to policies, legislations and executive action of federal and states organs (GoS, 2007). Draft Water resources policy also aims at protection and rational use of avialable water resources and adaption to climate change.

One of the most important strategies formulated in the country is the 25-Years Strategy which provides the policy directions to all economic and social sectors and incorporates the country's environmental strategy. Examples of key national programs are: adoption of terrace system for crop production and promotion of water harvesting (hand-dug depressions) for provision of drinking water for human beings and animals. Strategies and policies were reinforced by legislation based on Sudan's 1998 constitution, which specifies the role of the government in the protection of the environment and pursuance of sustainable development.

In Sudan's TNA process two technologies were selected for water resources sector based on wide stakeholders consultation, namely rain water harvesting (haffirs) and seasonal forecasting early warning (automatic surface water level records). The prioritization of the two technologies are based on the following criteria: vulnerability, strategies and targets, sustainability, costs and benefits, utilization scale, and supportive systems.

Lack of financing funds is one of the most important impediments facing socio-economic development in the country. This is particularly the case for rainwater harvesting development. Despite the difficulties facing Sudan's economy in the short run, the medium to long term outlook gives optimism that the priorities for the agriclture and water resources sectors can be achieved. However, many non-ginancial barriers may face the implementation of this technology: rainfall is a most unpredictable variable.

General targets are to strengthen human resilience and natural system adaptive capacity to climate change. This would maintain and enhance people's life quality, ensure water availability and water's essential role in sustainable development. Also, it will protect and stabilize the climate balance on a global scale by accelerating national sustainable development in the light of global climate change, in step with the international community.

To overcome finanacial barriers, it is important to convince the policy makers to allocate funds for technology uptake. This could be achieved by the national strategic development plan which allocated more than 90% of the budget to sustainable development and poverty alleviation. Complementarities with the investments of Government (through the State and the Agriculture Revival Program) and other donor funded initiatives can also support the technology implementation and maintenance.

In order to overcome the institutional barrier and promote sustainable development, it is recommended to adopt integrated water resources management in water resources planning and management. However, collaborative cooperation with international experts and professionals in these technologies is recommended. Lack of skilled personnel is the major concern in adopting these technology in Sudan; to overcome this problem comprehensive training in installation, operation, maintenance and database management is essential. In remote areas much concern should be taken to secure and prevent the expected damage or lost sensor by providing the automatic loggers with steel cages or concrete housing. Furthermore, it is recommended to look for affordable spare parts in the local market which can replace the more expensive ones. This will conserve the collected water resources data and maintain the sustainability of the system. It will also be beneficial to use the most reliable wireless network for real time data transfer.

Lack of knowledge, experience, and human resources remain major capacity barriers; continuous training courses could work as a suitable measure. Additionally, awareness sessions to the target groups are recommended. Concerning the two water sector prioritized technologies, the Government should develop an adequate policy to provide the necessary support needed for the establishment and management of an integrated water resources management system in respect of the imperative to monitor climate change in the country.

2.2 Action Plan for Rain Water Harvesting (Haffirs) Technology

2.2.1. About the Technology

The objectives of the rain water harvesting development are to enhance availability and access to water, improving living conditions of both pastoralists and farmers, promoting peace and stability and strengthening resilience of local communities to climate change. Sudan is a country with plenty of rainfall that increases from north to south in a wide range from very limited rainfall in the north to more than 800 mm a year in the south-

ern part of the country. Rain water harvesting is one of the priority programs for rural socio-economic development in the country. Compared to other means of development, rain water harvesting, in particular haffirs, is to develop while ensuring high socio-economic returns.
Haffirs are natural depression or man made ground reservoirs in the earth at suitable locations to store water for drinking purposes for human and livestock as well as for agriculture. Haffirs and dams can also be made by machinery to serve drinking water and/or irrigation purposes. The implementation of haffirs technologies is in line with the protection of the ecological and human eco-system. It contributes to well-being and food security of the local communities and their livestock. The concept is that water running in natural stream during the rainy season is diverted at certain suitable locations into these haffirs. Guide bunds are required to divert water into the haffirs. When collected water can be used for human consumption, yet filtration is required to meet drinking water standards. The size of the haffirs ranges from 30,000 m3to 200,000 m3, and cost of an average haffirs with a capacity of 85,000 m3of water amounts to about USD 850,000.
Although haffirs designs differ according to the topography, terrains and purpose, common haffirs comprise of a slit trap with an outlet canal attached to shallow wells. The water is usually pumped to the elevated tank and further through gravity channels to the livestock and human collection points. As a system, the haffirs should be integrated with environmental rehabilitation whereas ecological and water conservation techniques like micro basins, soil bunds and check dams are applied. Water is diverted towards the haffirs by guiding bunds with a feeding canal. The main design criteria for a haffirs are suitable intake, protection against high flows using spillways, careful design of inlet and outlet especially regarding the slopes of connecting pipe, filters to enable cleanwater for human consumption, and fences to protect the haffirs.
In addition to benefits addressing climate change adaptation, haffirs have several economic and social benefits. Economic benefits include increases in the incomes of farmers and increases of food production and productivity. Social benefits include enhancing the availability and access to water, improving the living conditions of both pastoralists and farmers, promoting peace and stability, enhancing settlement and reducing the competition for water between farmers and pastoralists.

2.2.2 Target for Haffirs Technology Transfer and Diffusion

General targets are to strengthen human resilience and natural system adaptive capacity to climate change. This would maintain and enhance people's life quality, ensure water availability and water sustainable development. Also, it will protect and stabilize the climate balance on a global scale by accelerating national sustainable development in the light of global climate change; and hence join forces with international community.

Specific targets are to prioritize water resources management adaptation technologies and to ensure water security. Also accruing from attainment of these targets would be improved social security and poverty alleviation. Water resources sustainability would moreover enhances quality of life by protecting public health and ensuring water resources availability in the context of climate change. Water harvest structures like haffirs, small dams, and depression reservoirs are highly needed for drinking water and to some extent for irrigated agriculture. The major problem that faces the rain-fed farmers after the rainy season is drinking water, especially during the harvest time. Perenially demands are far beyond the capacities.

The prospects for rain water harvesting development are very good in the concerned region for both pastoralists and farmer communities. Pastoralists' livelihood is at risk not only because of the erratic rain and degradation of their natural grazing land due to overstocking and overgrazing but also because some of them are no longer able to cross the border to South of Sudan. Traditional rain fed farming in the region is usually at subsistence level. Its productivity is very poor and barely adequate to secure basic family food requirements let alone generate income.

2.2.3 General barriers and proposed measures for technology's diffusion:

The ecological barriers are detrimental for the success and adoption and replication of haffirs. The intensity of rainfall varies temporally even in the same location. At the same time it varies spatially even in the same zone. Based on problem tree methodology, lack of financial funds is considered the main problem hindering the successful implementation of haffirs. Nonetheless, haffirs are considered the lowest cost technology for rain water harvesting. Although a few governmental agencies, research institutes and stakeholders are experienced in the design, implementation and operation of haffirs technologies in Sudan, there continuous to be a lack of equipped institutions to design and implement the technology efficiently. In addition, the amount of trained experts capable of regular maintenances is very limited and may lead to structural collapse and decreased water storages. A technical and ecological problem that could impede the haffirs project's sustainability is attributed to the soil erosion and maintenance of haffirs. Yet, tillage and natural vegetation strips can be used as a possible measure to overcome soil erosion around haffirs boundaries. Another adaptation barrier to the implementation of haffirs is the unpredictable rainfall characteristics in terms of intensity, duration and distribution. Additional barriers include lack of technical know-how, land tenure, soil siltation and infiltration. To overcome some of these drawbacks, measures to raise knowledge and awareness are essential as well as applying additional filtration and disinfection.

In Sudan, the implementation of haffirs is usually undertakenby national contractors and sub-contractors, the majority of which are government owned entities.

Generally, barriers to adapt haffirs technology can be summarized in financial and non-financial barriers as follows:

Financial barriers:

* Inadequate financial funding
* High costs of maintenance
* Economic and financial barriers are represented by inadequate financial funding for the activities of haffirs and water harvesting and in general present the key barrier for the adoption and transfer of the intervention to other sites. However, high cost of maintenance is also composing a large portion of the financial barriers in addition to inadequate funding for construction.

Non-financial barriers:

* Limited human technical skills and know-how
* Lack of policy regulations, in particular regarding land tenure
* Lack of awareness in communities about the activities related to haffirs
* Insecurity related to confilicts and civil war in some parts of Sudan
* Non-financial barriers include limited human technical skills, scarcity of technical know-how, policy and regulations - especially that concerning land tenure in Sudan and in most of the African countries; and awareness of communities about issues and activities related to haffirs. Insecurity

related to civil war in some parts of Sudan poses a general barrier to development.

The effects of the above mentioned barriers (financial and economic, and non-financial barriers) have negative consequences on the sustainable livelihood of local communities, the environment and the health of human beings and animals. The impact of these barriers may result in lack or shortage of water which leads to the exploitation of available water resourses along with outbreaks of disease. In certain situations, conflicts over water may escalate into disputes and, as a consequence, communities migrate temporarily to other sites with abundant water.

Measures to overcome financial and non-financial barriers in water harvesting have been outlined based on the stakeholder consultations, interviews with decision makers and the consultant's knowledge. Financial measures are mainly associated with fund allocations for construction, maintenance and rehabilitation of haffirs; but they may also include efforts to convince policy makers to allocate funds for haffirs technology uptake. This could be achieved through advocacy for sustainable development and poverty alleviation. They also may include assignment of finance for improving research and development activities in the water sector; and provision of technical knowhow through establishment of experts networking and provision of inputs and machinery.

Non-financial measures for Haffirs include: training of rural communities, developing technical and managerial capacities of common interest groups in haffirs design and improving partners implementation capacities; encouraging and faciliating private sector participation,as well as promotion, activation and circulation of enabling laws. These in addition to training, raising awareness and fair distribution of haffirs over vulnerable communities are fundamentals for success in adapting haffirs technology. The results of these measures would be reflected in the availability of water for domestic and for animals use, which will contribute to peace building at the grass root level.

2.2.4 Proposed action plan for rainwater harvesting (Haffirs) technology

Table 8 below shows the proposed action plan for rainwater harvesting. Enabling frameworks and a conductive environment have to be provided to promote haffirs technology. However, this needs to comprise of financing policy and mechanisms, the development/adoption of related policies and regulations as well as institutional strengthening and capacity building.

* Fund raising and awareness raising to allocate funds, loans and grants within the framework of water harvesting projects
* Involve the private sector in the construction and rehabilitation of rainwater harvesting structures (Haffirs)
* Raise awareness at different levels among government officials on the essence of haffirs construction and its impact on the local users
* Political commitment along with involvement of legislative councils at national and state levels, specifically the Service Committee, to enhance the implementation of plans
* Institutional strengthening and capacity building of governments, induviduals and civil society through collective action to maintain resilience in the face of new stresses
* Establish legitimate instituations and facilitate their harmonious working together
* Enhance policy and legal framework to ensure a maximum use of resources by addressing different problems; for example a policy might include a draft policy for water, sanitation and hygiene.

Currently , all over Sudan, water from haffirs and dams is free of charge, except in some states like Blue Nile State. This approach of free water from dams and haffirs is common among water users in Sudan. Going forward, State Water Corporation applied water tariff for all water facilities, especially for water yards and hand pumps, would support sutainability of services from these facilities. This is not fully applied in the case of surface water harvesting, where the water provided naturally and should be free of charges. The prevailing free water supply approach needs to be changed and a water tariff system applied instead. This can be implemented by developing regulations ratified by state councils and accomplished by responsible partners. Water tariff system provides additional resources for operation and maitenance and will reduce overall cost. In addition it insures community contribution and promotes ownership along with sustainability of services and long term development. Usually the role of the government and development partners is to support construction and to handover facilities to communities and local authoraties for operation and maintenance. WFP, CARE International and other food granting agencies have introduced a food for work approach, whereby these agencies provide food instead of cash for the community taking responsibility for digging. Food will be provided for each community member against the number of cubic meters excavated. This approach is cheap but time consuming.

Table 9: Summary of Technology Action Plan for Rainwater Harvesting (Haffirs):

Action	Why is needed	Who take action	year	How	Cost in USD	Proposed unding sources	Indicator	Risk
Integrate the technology into national development projects and-foreign funded programs	Providing-funds for technology promotion		ST	Coordinate with national funding agencies and FMoF, Applying for financial support from both domestic and foreign funding agencies	10,000	FmoF, MOWRE	No. of Haffirs integrated into national and external funded programs.	Lack of funds for development projects
Use community based approach food for work (FFW) in digging of *Haffirs*	Food for work is low cost technology			Coordinate with WFP and relevant NGOs Consult and coordinate with community leaders Provide food for digging	30,000	FmoF, WFP	No. of Haffirs constructed using FFW No. of Haffirs rehabilitated using FFW	The government is not prefering this approach
Advocate and apply Haffirs water tariff	To enhance O & M, Ensure sustainability of services, Promote ownership	MoWRE, HCENR, PWC, SWCs	ST	Conduct awareness meeting and workshop at state, Mahalia and community levels, Involve communities and SWC in the discussion, Conduct awareness workshops for state governments and state legislative councils	45,000	SWC, MOWRE, SMoF	No. of Haffirs with applied water tariff system	Politicain will influence the decision on application of the tariff
Advocate for subsiding taxes related to water inputs in general and specifically for water harvesting projects	To reduce overall cost, To promote *Haffirs* technology	MoWRE, HCENR, PWC, SWCs	ST	Communicate with FMoF and related institutions, Conduct meetings and workshops to highlight the impact of subsidizing cost, Advocate the impact of the technology	10,000	MOWRE, HCENR	No. of financial actions issued related to reduction of taxes of water harvesting techniques inputs	FmoF has limited resources and may not accept the idea

Conduct awareness workshops at national, state and local level to promote Haffirs technology and to ensure commitment	To facilitate funding, Promote ownership	MoWRE, HCENR, PWC, SWCs, Mahalias	ST	Conduct sessions and meeting, Use mass media for message transmission, Coordinate with relevant institutions and partners	15,000	MOWRE, HCEWR, UNICEF, UNEP, UNOPS, PWC, WES	No. of awareness workshops conducted	Lack of funding
Financial accountability	Fair share of resources Proper activities	MoWRE, HCENR,	ST	Follow proper bidding procedure, Transparent bidding analysis	3,000	FmoF, MOWRE	No. of bids called for and managed properly	Politicians may influence the decision on the issue
Finalize water resources policy and streamline water harvesting program and support coordination	To avoid overlap and loss of resources, Strengthening role IWRM agencies, To manage CC impact	MoWRE	MT	Ensure water resource policy is acceptable, Establish water resources coordination system, Adopt IWRM & catchment management system	30,000	FmoF, MOWRE, UNEP, UNDP, FAO, HCENR	Policy developed and adopted, Water resources laws reviewed, Coordination body	-differences in stakeholders interests - continuous changes in government structure and personel
Implement PWC Haffirs technical guidelines and standards	Maximize use of resources, Ensure sustainability	MoWRE, HCENR	ST	Adopt and use the guidelines, Share guidelines with stakeholders, Advocate for them	5,000	MOWRE, FMoF	Technical guidelines adopted and applied	Lack of adequate knlowledge to implement these guideline
Wide consultation with local authorities and communities on Haffirs sites	To avoid conflicts, Promote ownership, Effective use of resources	All stakeholders	ST	Adopt and use the PWC Haffirs guidelines, Conduct awareness workshops and meetings	22,500	FmoF, SWC, PWC, Mahalia	No. of Haffirs constructed/ rehabilitated in consultation with partners	Political interest may affect the proper consultations
Support establishment of water resources database and sharing of information	To support proper planning, Effective use of resources	MoWRE, HCENR,	ST	Advocate for water resources data collection and storage, Provide fund	26,000	UNEP, MOWRE, FmoF, HCEWR	Water resource database established, A forum for coordination and information sharing established	Lack of interest in data sharing and competion over resources and power
Building partnership especially with private and non-profitable agencies	To support technology diffusion and coverage	MoWRE, HCENR, PWC, SWCs, FmoF	ST	Establish water resources coordination forum at national level, Involve different stakeholders, Involve research institutions	15,000	FmoF, UNICEF, PWC, MOWRE, SWC, HCENR	A forum for coordination and information sharing established, No. of research institutions involved	Differences in interests and approaches

Build capacity on water harvesting in general on Haffirs construction and rehabilitation specifically	Ensure proper construction of Haffirs, Ensure effective use of resources and to avoid negative environmental impacts	MoWRE, HCENR, PWC, SWCs, FMoF	ST	Advocate and provide funding for researches related to the technology, Provide internal and external trainings, Conduct EIA, Use local capacities like PWC training center	55,000	MOWRE, UNEP, UNOPS, FmoF, SmoF, NGOs, UNICEF	No. of researches related to water harvesting conducted No. of people trained internally and externally No. Of EIA conducted	Limitation in financial resources
	Grand Total 266,500 USD							

Note: ST: short term 0 -5 years , MT: medium term 5 – 10 years, LT: long term 10 -20 years

2.3 Action Plan for Seasonal Forecasting and Early Warning (Automatic Water Level Recorders)

2.3.1 About the Technology

The development objective of seasonal forecasting and early warning system is to reduce human suffering and damages and capture the benefits of flooding. Monitoring water level fluctuations for early warning system is achieved by one of several technological methods. One is Remote Sensing technology for the receipt and processing of satellite images used to estimate daily rainfall quantities over the catchments of the Blue Nile and Atbara rivers in Ethiopia and Sudan; whereby a communication system transmits water levels in the Blue Nile, Atbara River and main Nile in Sudan to the Flood Warning Centre in Khartoum. A computerized Flood Forecast System, consisting of a set of mathematical models with an appropriate user interface allows smooth and rapid data processing and forecasting. Seasonal forecasting and early warning systems related to Nile floodings and its risk in Sudan are not well developed, mainly because of inefficient and old technologies. Hence, the application of the automatic water level measurement technology is essential to accurately monitor the water levels in the River Nile and its tributaries at the key stations and report early warning information in appropriate time to protect about six millions people residing in the Sudan's flood plain. It is note worthy that this technology fits well for both present and expected climate conditions. To facilitate the success of the technology it is essential for government agencies to provide the floodplain dwellers with flood relevant information (water level fluctuations) in a clear and useful form to be easily understood by the intended users.

The automatic surface water level measurement technology uses a surface water data logger and submersible pressure transducer combination to measure Nile level fluctuations designed for remote monitoring and recording of surface water level or pressure data. A water level logger can record over 81,000 readings. It has four unique recording options and a 25 ft. vented cable on all water level loggers. Installation of the automatic loggers and their management require experienced staff and institutional organizations.

Many economic, social and environmental benefits can be gained from the implementation of the automatic water level such as preventing loss of communities' resources and their lives resulting from floods; and facilitate forecasting of extreme weather events. The climate change mitigation benefits are strengthening local communities' resilience. One of the main drawbacks of the automatic water loggers is their high costs compared with normal gauges. In addition, they are sensitive and thus can break easy. Therefore, special care should be taken to the area of allocating water level measurement technologies.

2.3.2 Target for technology transfer and diffusion:

The Seasonal Forecasting and Early Warning System have been developed to predict storms and floods in order to provide the flood plain dwellers with flood relevant information (water level) and to develop plans in time to minimize negative impacts. This information has to be delivered effectively in a clear and useful form readily understood by the intended users. This technology has an important role in countries like Sudan which are prone to flood while having quite poor infrastructure. Seasonal forecasting and Early warning systems in Sudan are not well developed; this is because the used technologies are old ones and not efficient. Hence, the application of the Automatic water level technology is essential to accurately monitor the water levels in the River Nile and its tributaries because about 6 million people are residing in Sudan's floodplain. It is worth mentioning that this technology fits well for both present and expected climate conditions. Seasonal forecasting and early warning technology (automatic water level recorders) has a wide international market and it should be ordered and implemented by the government of Sudan (Ministry of Water Resources and

Electricity). No market mapping has been used in the barrier analysis as it is a public good. Many benefits could be gained from the implementation of the automatic water level measurements. Here are some results from the 14 Key stations:

* Improvement of the network of hydrological data collection
* Collection of hydrological data on a more regular basis and at a lower cost
* Provision of improved monitoring systems, which is the main input to the existing forecasting models

2.3.3. Barriers to the technology's diffusion

It has been noted that the main economic barriers for the application and distribution of the technology are lack of funding. According to Sagyroon, the costs of the automatic surface water level recorders (Pressure Type - SEBA) are about USD 56,000. The high capital costs of the gauge station including the costs of automatic surface water level recorders, installation and maintenance costs, as well as required training of personals form the main financial barriers. Another important aspect may be that the automatic water level recorders have a wide international market. It is necessary to reiterate that they should be ordered and implemented by the Government of Sudan, in particular the Ministry of Water Resources and Electricity.

The non-financial barriers include overlapping roles and responsibilities of different institutions related to water resources, as well as conflicting policies and regulations. For example, the water resource sector suffers from limited institutional cooperation, coordination and data sharing. Hence several legal and administrative conditions do not facilitate data sharing across different governmental agencies. This creates a non-collaborative atmosphere among the different institutions of the same interest and destroys communication and data integrity across the sector. Further barriers are lack of technical know-how and experience to implement automatic water level technologies confidently and effectively; cultural and social unsustainable tranquillity poses a barrier. Sensitive and easily breakable equipment is an important consideration to bear in mind. Lack of proper wireless network which is needed for real time data transfer and gaps in information, research and development are other barriers to be overcome. Furthermore, siltation can technically affect the proper work for some logger types, therefore pressure types have to be used.

Generally, barriers related to automatic recording systems can be summarized as:

Financial barriers:

* High capital costs of the gauge station including the costs of automatic surface water level recorders, installation and maintenance costs, as well as required training of personnel

* Automatic water level recorders have a wide international market; yet they should be ordered and implemented by the government of Sudan, in particular the Ministry of Water Resources and Electricity

Non-financial barriers:

* Overlapping roles and responsibilities of different institutions related to water resources

* Conflicting policies and regulations related to water management, creating a non-collaborative atmosphere among the different institutions of the same interest and undermining communication and data integrity across the sector

* Lack of technical know-how and experience to implement automatic water level technologies confidently and effectively

* Cultural and social unsustainable tranquillity

* Sensitive and easily breakable equipment

* Lack of proper wireless network needed for real time data transfer

* Gaps in information, research and development

2.3.4 Identified measures for overcoming barriers for the transfer and diffusion of automatic water level measurements

Best water resource management can be achieved by using modern techniques like automatic water level measurements for adequate and effective monitoring and observation of both water quantities and qualities. Adoption of these technologies will assist in reduction or avoidance of the negative impacts of climate change on floods and droughts phenomena. The identified measures to address the aforementioned barriers can be categorized as follows:

* Funding and awareness raising to finance the pilot station projects comprised of automatic recording systems in 14 river gauge stations along the River Nile. Hence, the benefit revenue from these pilot stations could be allocated to the annual cost of operation and maintenance.

* Advocacy for the program at high level to convince decision makers

of the essence and the outcome of the project and thus facilitate funding. Grants and loans also can be advocated to convince decision makers to implement the project, especially those who have an interest in such type of projects.

* Set awareness sessions for target groups at national and state levels to highlight the importance of the project and its impacts along with mobilization of local resources

* Create enabling and conductive policy and legal frameworks in planning and management across all water departments in Sudan

* Institutional strengthening and capacity building to enhance adaptation capacities and human resource development via series of training sessions

* Collaborative cooperation with international agencies of same interest and with international experts and professionals in these technologies to assist in identifying the best measures and practices and strengthen technical know-how

* Securing and preventing expected damage or loss of sensors by providing the automatic loggers with steel cages or protective coverage, especially in report areas.

2.3.5 Proposed action plan for seasonal forecasting and early warning (automatic water level recorders)

The action for diffusion and transfer of automatic water level recorders are threefold: namely (1) funding and awareness raising (2) enforcing policies and legal frameworks and (3) institutional strengthening and capacity building.

* Funding and awareness raising: In order to overcome financial barriers related to capital and operational costs of automatic water level recorders in 14 river gauge stations in Sudan, allocated funds to finance the pilot station projects should be used. Hence, the benefit revenues from these pilot stations could be allocated to the annual costs of operation and maintenance. After providing first successful reports of the technology, policy makers and other donors can be attracted to secure funding to upscale the technology by implementing it in other areas throughout Sudan. This requires determining a long-term budget plan covering implementation and maintenance costs that can be included in the national development programs.

* Policy and legal framework: Developing and adopting climate change

policies and strategies is essential for the government of Sudan as it will systematically enhance forecasting and early flood warning and help in disaster management and response. As discussed in the previous sections, lack of inadequate policies and legal frameworks constitute a major barrier to the successful implementation of automatic water level recorders. Thus, to overcome this barrier and promote sustainable development, it is recommended to adopt integrated water resources management and catchment management systems across all water departments in Sudan. This can be achieved by developing and finalizing water resource policies. In particular, the TAP proposes establishing collaborative cooperation with international experts and professionals in these technologies to assist in identifying the best measures and practices.

* Institutional strengthening and capacity building: Capacity building of the MoWRE should be improved to manage automatic water level recorders and to enhance sustainability. Capacity building for these institutions can be realized in terms of providing training and raising awareness in the installation and operation and management (O & M) of these loggers. Training can be accomplished through the service providers and can include onsite training in installation along with training in O & M. Moreover, training of staff and raising their levels of awareness on possible consequences of climatic changes is essential to keep focusing on managing the impacts of climate changes through available adaptation technologies. In addition to that, the provision of related equipment and materials like power sources, computers and network inputs will support a smooth and effective implementation of the project. It will also be beneficial to use most reliable wireless network for real time data transfer. Past experience indicated that some of the surface water loggers were vandalized by some local people for unknown reasons. It is worth mentionening that protection of equipment is essential to enhance the effective use of resources which can be achieved by procuring loggers with steel cage or concrete housing. Visit exchanges with countries using the same equipment will be very useful and improve the implementation capacity.

Table 10: Summary of Technology Action Pan for seasonal forecasting and early warning (Monitoring System: automatic water level recorders):

No	Action	Why is needed	Who take action	When	How	Cost in USD	Funding source	Indicator	Risk
Funding and Awareness									
1	Integrate the technology into planning and development program at the national level and river basins projects	Providing funds for technology promotion, national projects and NBI has secured funds	MOW-RE	ST	Coordinate with national funding agencies and FMoF, Applying for financial support from both domestic and foreign funding agencies, ensure the technology in the national and foreign funded projects	10,000	FMoF		lack of financial resources for funding national project.
2	Build public awareness on the essence of the technology at local, state and national levels	Facilitate understanding and funding, Enhance the role of public communities, Safeguard resources from damage by public	MOW-RE	ST	Develop programs and materials for awareness raising using mass media, Organize training courses to raise awareness, Conduct house to house visits at village close to the sites, Conduct focus group discussion to raise awareness, Brainstorming on the requirements, application, and communication of prediction and warning data	50,000	FMoF, MOW-RE,	No. of campaign conducted No. of training conducted No. of HHV conducted No. of FGD conducted	Limited resources
3	Determining long-term budget plans to assure that it covers maintenance	Ensure sustainability of service	MOW-RE PWC	MT	Develop long term operational plan, Include plans in national development program , Advocate for funding	10,000	FMoF, MOW-RE,	Long term budget document provided	Limited funding for devlopment project
Policy and legal framework									
4	Support development of water resources policy	Encourage technology diffusion, Strengthening roles of IWRM focal point	MOW-RE GWWD	ST	Review the current draft policy, raise awareness on essence of the policy, advocate for IWRM	70,000	MMOW-RE, UNEP, FAO, FMoF, UNDP	water resources policy document provided	Continous chnage in Government structure and senoir officials
5	Develop rules and regulations for coordination between organizations and formulation of water resources forum	Sharing of information, Avoid duplication, Effective use of resources	MOW-RE GWWD	ST	Review functions of relevant organizations	7,000	FMoF, MOW-RE, , UNEP	Water resources forum formulated	Competion among government institutions on resources and power

6	Develop clear understanding among the relevant agencies in the collection and co-ownership of data and data sharing, and support development of water resources database	Effective planning, Max. use of resources	MOW-RE	ST	Raise awareness on data collection and sharing, Share available data with partners	6,000	FMoF, MOW-RE,	Water resource database established A forum for coordination and information sharing established	Competion among government institutions on data collection and lack of interest in sharing information
Institutional Strengthening and capacity building									
7	Raise awareness on the application of prediction and warning systems using this technology for different groups of users	Support technology promotion, Improving knowledge on CC, Enhance local capacities in forecasting, Improving knowledge	MOW-RE	ST MT	Arranging local trainings on the prediction climate disaster and warning systems Arrange awareness workshops on the technology importance. Exchanging research scholarships, seminars and trainings on seasonal climate prediction, Collaborating with research institutes from overseas to provide training on forecasting and early warning	60,000	FMoF, MOW-RE, ,UNDP, FAO	No. of trainings conducted No. of awareness workshops conducted No. of related research conducted	Lack of funding from all partners
8	Building a national and international research networks for technology transfer from overseas and to exchange knowledge	Improving knowledge, Updating on new technologies, Provide technical backup for the process	MOW-RE ,universities and research institutions	MT	Facilitate networks for local and international experts, Organize training on technology applications			Research networks established	Institutions will not share adequate information
Grant total						**213,000**			

Note: ST: short term 0 – 5 years, MT: medium term 5 – 10 years, LT: long term 10 – 20 years

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Annex I
List of Stakeholders

Name		Institute
1. Igbal Salah Mohamed Ali	Ministry of Water Resources and Electricity	Researcher
2. Widad Motwakil Saadalla	Ministry of Water Resources and Electricity	Researcher
3. Taghrid Abdelrahim	Ministry of Water Resources and Electricity	Staff member
4. Mohamed Yousif Mohamed	Institute for Water Harvesting Research	Lecturer
5. Abd Elrahman Saghyroon Elzein	Dams Implementation Unit/ Water Harvesting Department	Director
6. Tagwa Ahmed Elhabo	Ministry of Water Resources and Electricity / Water Harvesting Unit	Staff member
7. Ibrahim Salih Adam	Ministry of Water Resources and Electricity	Head of Technical organ of Water Resources
8. Ahmed Eltayeb Ahmed Adam	Ministry of Water Resources and Electricity / Nile Water Directorate	Director
9. Issam Aldin Ibrahim Abdal	Ministry of Agriculutre	Staff member
10. Amal Abdelgadir Hasan	Ministry of Agriculutre	Staff member
11. Mahasin Balla Ahmed	Ministry of Agriculutre	Director
12. Alawiya Yousif Mohamed	Ministry of Agriculutre	Staff member
13. Maha Ali Mohamed	Ministry of Agriculutre	Staff member
14. Ayman Mohamed Abdin	Ministry of Agriculutre	Staff member
15. Dirar Ibrahim Dirar Staff member	Ministry of Agriculutre	Staff member
16. Khalid Ahmed Ali	Ministry of Agriculutre	Staff member

Republic of Sudan

Ministry of Environment, Forestry and Physical Development

Higher Council for Environment and Natural Resources

PROJECT IDEAS

PART 4

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List of Abbreviations

CTI	Climate Technology Initiative
IPCC	Intergovernmental Panel on Climate Change
MDGs	Millennium Development Goals
MEA	Multilateral-Environmental Agreements
MOA	Ministry of Agriculture
NAPA	National Adaptation Programm of Action
NGOs	Non-Governmental Organizations
PRSP	Poverty Reduction Strategy Program
RWH	Rain Water Harvesting
TAP	Technology Action Plan
TNA	Technology Needs Assessment
UNCCD	United Nations Convention to Combat Desertification
USD	United States Dollar

Executive Summary

Projects ideas are a short snapshot of the projects proposed to the funding agencies and considered as a first step in the development of a project (a detailed Project Proposal). The project idea aims to support the realization of some of the targets formulated in the Technology Action Plans (TAPs). The TAP focused on two sectors, namely agriculture and water resources, and for each sector two technologies have been selected for adaption. The selected project ideas for the agriculture sector are 'Production of improved crop seeds and seedlings in six states and Zero Tillage' in one state. For the water sector, Haffirs are to be established in 15 states and Automatic Water Level along the River Nile and its tributaries in six states.

The project ideas for the agriculture sector aim at increasing crop productivity and increasing people's income with a view to poverty alleviation and food security strengthening. It is expected that the Ministry of Agriculture and Animal Resources in close coordination with the Sudanese Farmers General Union will leading roles in the prioritized pursuits. Additionally, the Federal and State governments are expected to enhance the adoption of the technology interventions because the projects relate to the country's sustainable development priorities. The expected costs for the project for production of improved seeds and seedlings amount to an estimated 18,290,000 USD in addition to 388,000 USD for the Zero Tillage. It is expected that rain-fed small scale farmers will benefit from these projects which will start as pioneer models to be replicated in the other selected states. The time framework for the production of improved seeds and seedlings is three years; and five years for Zero Tillage. The main non-financial and economic challenges confronting adoption of improved seeds and seedlings production are social reluctance, problems of coordination between actors, ecological barriers, pests and outbreak of diseases. Zero Tillage faces similar problems while the two proposed projects constitute a tremendous financial challenge for Sudan.

As water is crucial for life inevitably the proposed projects aim towards provision of drinking water security for both humans and animals. The selection criteria for areas where Haffirs are to be constructed are (1) sufficient potential water surface run-off (2) suitability of the physical condition of the soil to avoid high infiltration rates (3) areas distant from natural resource-based conflicts and (4) sites remote from River Nile and its tributaries, as well as seasonal water courses. The expected unit costs for the Haffirs is around 105,000 USD (15 Haffirs in all 15 states of Sudan), while for the Automatic Water Level unit costs are about 186,000 USD (14 Stations). The time framework for launching both the Haffirs project and the automatic water level is expected to be one year. The two proposed projects for the water sector will be under the responsibility of the Nile Water Directorate in coordination with national and international experts for training in the different activities of the proposed projects.

Chapter 1
Project Ideas for the Agriculture Sector

1.1 Brief Summary of the Project Ideas for the Agriculture Sector

This report contains project ideas aimed at supporting the realization of some of the targets discussed in the TAP. After reviewing Sudan's development priorities, identified in the Comprehensive National Plan, and the national strategies of the country which aim towards poverty alleviation and guaranteeing sustainable livelihood, these project ideas have been elaborated. The selection of these projects reflects the degree of their relevance and acceptability by the government and local communities. The selected project ideas for the agricultural sector are production of improved seeds and seedlings and Zero Tillage technology for reduction of vulnerability of food security and enhancement of farmers' resilience. Target groups are mainly the Ministry of Agriculture and Animal Wealth and farmers in six states cultivating crops vulnerable to climate change. As for Zero Tillage, the target groups are similar to that of improved crop varieties but focusing on one state instead of six states. The stakeholders, mainly from the Ministry of Agriculture, contributed significantly to the formulation of the project idea. Group discussion has been deployed to arrive at a general consensus for the selection of the projects. Some individual meetings have also been used for consensus on projects ideas. The stakeholders who have engaged in the different processes of Sudan – TNA includes Ministry of Agriculture, Ministry of Water Resources and Electricity, Forests National Corporation, Forests Research Centre and Agriculture Research Centre, besides some academics from different universities.

1.2 Specific Project Ideas

1.2.1 Project Idea for Improved Crop Varieties Technology

This project predominantly aims at improving seeds and increasing seedlings varieties. Under-nutrition, that is an inadequate calorie and protein intake, has been a major concern of medical specialists, nutritionists, agriculturists, and demographers, both at local and international levels in the Sudan. One way of attenuating the problem of under-nutrition is the development and distribution of high yielding and well adapted seeds to farmers. The identification of project ideas is based on the priority needs, developed by the national stakeholders and the national team of TNA, as explained in the previous reports.

Enhancing breeding of improved crop varieties (seeds and seedlings) is expected to take place in six states of the country; particularly in rain-fed areas targeting small scale farmers. Selection of the target groups and areas relied more on individual meetings with concerned parties, namely the Ministry of Agriculture and Farmers Unions in the different states.

Production of improved seeds and seedlings will increase the productivity of major crops, thus contributing to the increase of farmers' incomes. The general result of this project will guarantee food security and diversification of nutrition through producing different crop types which leads to sustainable livelihood in the project areas.

The number of beneficiary states will be six: (1) Gadarif (2) Sennar (3) North Kordofan (4) North Darfur (5) White Nile and (6) Blue Nile. The selection criteria for the project included low level of development interventions (marginalized areas) by the national government and other donors; suitability to traditional rain fed farming; vulnerability to climate change and variability (acute poverty and lack of food security) of farmers in these areas. Similarly, six localities (one from each state) will be targeted for project implementation. The project will focus on organized farmers groups at village level and a total of at least 50 farmers will benefit in each locality.

The selection of the localities will be based on the following criteria:

- Relative size of rural households involved in traditional rain-fed agriculture.
- Locality free of natural resource-based conflict and with conducive work environment.
- Willingness of the community to accept development interventions of the project.
- Willingness and readiness of the community to form farmer groups and mobilize women.
- Potential for productivity increase; and availability of Ministry of Agriculture and Farmers Union staff to facilitate project interventions.

The strategy of the project will base on the establishment of a demonstration farm at each locality for sake of dissemination of information in the six states. This method is selected because it offers the chance for demonstration of methods of raising seedlings using nursery techniques. Sixteen nurseries are proposed to be established at the different localities relying on simple materials in order to guarantee the sustainability of the activity.

1.2.2 Project Idea for Zero Tillage Technology

Research results in the country showed that zero-tillage technology resulted in significant increase in sorghum production (from about 700 kg/ha to 1,650 kg/ha). Research findings also indicate that zero tillage is promising and recommended particularly in mechanized rain-fed agriculture, which is sensitive to climate change and constitutes 35% of the national cultivated land. With the current and future climate change vulnerabilities, the adoption of the technology is expected to increase resilience of vulnerable communities and consequently enhance their adaptation.

The Introduction of zero tillage technology in different parts of the country and its testing with different crop species remain one of the challenges that require careful consideration. However, the findings of the research showed that in spite of the challenges facing the technology, there are numerous opportunities that could be created by the adoption of zero tillage such as:

- Reducing the number of labourers, considering that since farmers are poor and reluctant to hire labour
- Stable yields and improved soil fertility
- Profitable crop production under zero tillage over time relative to conventional agriculture
- Conservation of soil and biodiversity
- Potential economic benefits
- Poverty reduction

At the global level, zero tillage sequesters carbon and consequently decreases CO_2 in the atmosphere. Gedarif State has been selected for this project due to the fact that this state encompasses the main rain fed mechanized agriculture schemes in the country, and the state is responsible for guaranteeing satisfactory crop production for the whole country and export of the surplus. Few years ago fluctuation of rainfall in terms of intensity and distribution led to sharp decline of productivity besides the changes in the physical and chemical properties of the soil. As a remedy for these problems zero tillage has been suggested given its restoration of soil fertility and relatively high productivity. The entire stakeholders involved in Sudan – TNA, through general consensus, agreed on the project and the selection of the project site. It is worth mentioning that the majority of the stakeholders are from the Ministry of Agriculture. Moreover, one of the national team is from the Ministry of Agriculture.

1.3 Project overview

1.3.1 Production of Improved Seeds and Seedlings

Name of the Project	Production of improved seeds and seedlings
Introduction	The farmers in Sudan rely heavily on farm saved seeds and have little access to commercial improved seed. Improved crop varieties seed reach only 10 per cent of farmer producers in Sudan. The rain fed-sector is characterized by low productivity and horizontal expansion of the area in rain fed farming. This has negative consequences for forests and pasture as it creates an agro-ecological imbalance with severe environmental consequences. In addition, the production of improved seed variety on large-scale will strengthen the capacity of research, extension and the private sector in the development, dissemination and adoption of improved seed varieties. This can lead to improved food security and sustainable crop production intensity and livelihoods.
Objectives	This project aims to guarantee satisfactory crop production that leads to food security, improved and diversified nutritional status, and poverty reduction among marginal and small-scale farmers by .upgrading agricultural production and improving income
Outcome	- Establish the necessary infrastructure for plant multiplication, inspection, sanitation and certification - Increase the production of improved seeds and seedlings in six states
Relationship to the country's sustainable development priorities	The project is in line with the Country Agricultural Strategy and its commitment to the UNFCCC which focuses on the organization of seed and seedlings production as well as on the production of certified plant material for high yielding varieties. Moreover, it aims to increase the productivity vertically and induce reduction in cost of production. In addition, the project intends to reduce the need for more new land, a prospect that bodes well for the country's green covering of trees while decreasing GHG emissions.
Project Deliverables	Provision of improved seeds and seedlings of the different crops to all small farmers in the rain-fed areas, which will improve food security and diversify crops. The project will benefit from 16 local nurseries that will have a positive impact on yield of all crops (15 to 50 per cent increase, depending on crop and climatic conditions).

Project Scope	The project is designed for small-scale farmers in six states (South Gadarif, Sennar White Nile, North Kordofan, North Darfur and Blue Nile states) under rain-fed agriculture. The project will focus on farmers presently relying on saved local varieties with low yield, farmers with lack of know-how and skills in producing improved seeds and seedlings. The main crops to be covered are cereals and fruit trees.
Project activities	1. Identification of needs and gaps in the necessary infrastructure for improved seeds and seedlings propagation 2. Elaboration of coordination mechanism between the Ministries of Agriculture and Animal Resources in the states, federal seed administration, seed companies, Farmers Union and local actors 3. Elaboration of communication tools for extension purpose 4. Acquire the necessary inputs related to propagation and production 5. Capacity building of government institutions that provide technical services 6. Community organizations and farm families, using participatory approaches 7. Introduction of related improved technologies such as water harvesting, small-scale irrigation and general improvement in farm management 8. Enhancing the capacities of farmers through Farmer Training Schools and other group initiatives 9. Facilitation of farmers' associations formation and support to them 10. Provision of credit facilities using existing traditional and financial mechanisms 11. Establishment of healthy plant mother plots within the nurseries of local varieties and rootstocks; and upgrading existing tissue-culture laboratories 12. Training of all stakeholders at different levels 13. Training the staff of the MoA in inspection and certification.
Timeline	3 years and a half in operation, the lifetime is in excess of 30 years.

Budget	Budget for project management team (staff) =1.5 million USD i.e 200,000 USD for each state for the 3 years (66,667 USD) as salaries and consultancies One unit (nursery) = 4.5 million USD (the unit composed of 2 offices, meeting room, laboratory, rest house and toilets, vehicles, motor cycles, offices supply and equipment) Laboratory equipment cost= 1.5 million USD (200000 USD for each state) Three units are needed in the targeted areas (13.5 million USD). Cost of capacity building and training for the six states = 500,000 USD Running cost for the six states = 750,000 USD Unforeseen cost for the six states= 540,000 Total cost=18,290,000 USD
Potential source of finance	• Farmers Union • State Government • Federal Government
Measurement/ evaluation	Increase the production of improved seeds and seedlings through the establishment of 16 nurseries which in turn will be reflected in increasing the subsistence and cash crops besides vegetables and fruits. Moreover, the farmers (50 per locality or 300 in the six states) can be used as a measure for the success of the project)
Possible complication/challenge	• Social reluctance from producing improved seeds and seedlings • Financial constraints • Problem of coordination between actors • Ecological barriers • Pest and diseases outbreak
Assumption	• Farmers are willing to produce improved seeds and seedlings • Good coordination between actors.
Responsibilities	Ministry of Agriculture, Department of Technology Transfer and Agriculture Extension.

1.3.2 Zero Tillage Technology

Zero tillage technology for reduction of Vulnerability of food security and enhancement of farmers' resilience in Gadarif State

Name of Project	**Zero tillage technology for reduction of vulnerability to food insecurity and enhancement of farmers resilience in Gadarif State**
Introduction	Under the vulnerability of rain-fed mechanized agriculture in Sudan in general and in Gedarif State in particular, attempts have been made to reduce this vulnerability through adoption of Zero Tillage technology. The project is targeting farmers in the state for sake of increasing crop yield and sustainability of agricultural production
Objectives	• To select cover crops based on goals, • To select proper cropping rotation • To increase crop yields while decreasing input costs.
Outcome	• Increase crop production • Organize farmers into working groups • Increase income generation • Enhance farmers' awareness • Reduce farmers' expenditures
Relationship to the country's sustainable development priorities	The project is well linked to government policies and plans, being in line with the 25-year National Strategy and the Poverty Reduction Strategy Program (PRSP). It has also strong links with the Millennium Development Goals (MDGs).
Project Deliverables	The project will provide the rain-fed farmers in Gadarif State with the technical know-how by demonstration plots and mobilization and sensitization of farmers to adopt the intervention. The project will benefit from the active extension unit of the Ministry of Agriculture and Animal Resources at the state level besides the Higher Council for Environment and Natural Resources at Gadarif State.
Project Scope	In Gadarif State vast rain-fed areas exist that are suitable for the application of zero tillage. The total area under mechanized farming reached 71 400 km2. Most of these areas became degraded owing to various climatic and non-climatic factors. Land degradation has been found to cause decrease of agricultural production. Accordingly, many communities are extremely vulnerable as they do not guarantee food security.

Name of Project	Zero tillage technology for reduction of vulnerability to food insecurity and enhancement of farmers resilience in Gadarif State
Project activities	Awareness raising Organizing local people and establishing leadership committees/ cooperatives to facilitate group work and overcome financial and non-financial barriers Training and capacity building of zero-tillage farming and its management Establishing physical infrastructures necessary for facilitating zero tillage farming Purchasing agricultural machinery and equipment Providing production inputs Introduce pilot farms for research Involvement of private sector and decision makers
Timeline	The estimated timeline for the project is 5 years
Budget	Budget for project management team: 330,000 USD (48,000 USD project manager/year + 18,000 USD assistant/year x 5 years of project) Budget for technical/extension consultants: 35,000 USD (350 USD/man-day x 100 days) Budget for elaborating a financial mechanism for subsidies and for sustaining extension activities: 4,000 USD Budget for communication tools development, including demonstration plots: 12,000 USD Budget for training of trainers: 2,000 USD (100 USD for 6 trainings/person x 20 persons) Budget for field visits and training: 5,000 USD Total budget: 388, 000 USD
Potential source of finance	Federal Government Farmers Union
Measurement/ Evaluation	Increase in production per unit area Increase in income Status of poverty of the farmers Increase in resilience of farmers Change in perception of farmers towards land management and utilization of zero tillage

Name of Project	Zero tillage technology for reduction of vulnerability to food insecurity and enhancement of farmers resilience in Gadarif State
Possible complications/ challenges	Social and cultural barriers (e.g. mistaken perception that soil plowing is essential for high crop production) Insufficient extension services Insufficient policies others
Assumptions	The project will contribute to achieving food security, responding to climate variability and change as well as contributing to environmental conservation.
Responsibilities	Main stakeholders: Ministry of Agriculture at federal and state level, Farmers' Union, NGOs, relevant private sectors, etc. Financing to be provided by both national and international donors

Chapter 2
Project Ideas for Water Sector

2.1 Brief summary of the Project Ideas for the Water Sector

This report presents two project ideas that will contribute to the implementation of two Technology Action Plans (TAPs) in the water sector: Rainwater Harvesting (Haffir) and seasonal forecasting and early warning (automatic water level). The identification of project ideas is based on the priority needs of the national stakeholders, as explained within the previous reports. In parallel, the investigation of on-going projects and current enabling environment lead to the identification of two ideas: the construction of 15 rainwater harvesting (haffir) in 15 states, and the use of 14 automatic water level monitoring stations. The selection of the target groups and areas relied more on individual meetings with concerned parties.

2.2 Specific Project Ideas

2.2.1 Project idea for Technology of Haffir

Water harvesting techniques have been implemented in several states in Sudan and in different forms like earth embankment, dams and haffirs. Haffirs are manmade ground reservoirs to store water for drinking purposes/ or irrigation for both human and livestock. The concept is that during the rainy season water running in natural stream is diverted to these haffirs and stored. The size of the haffir ranges from 100,000 m3 for large one to 30,000 m3 for small ones. Guide bunds are required to divert the water into the haffir. If it is used for human drinking filters are needed for clean potable water. Haffirs can only be established in suitable locations with a reasonable amount of rainfall. This project aims to assist the most vulnerable areas that are prone to climate change and that are characteristic of reasonable amount of rainfall. The selection of the states depends on the following criteria;

- Areas of potential water surface run-off
- Suitability of the physical condition of the soil to avoid high infil-

tration rates
- Areas prone to natural resource-based conflicts
- Sites remote from River Nile and its tributaries and seasonal water courses

2.2.2 Project idea for Technology of Automatic Water Level

Seasonal forecasting and early warning systems related to the Nile flooding and its risks are not well developed in Sudan, mainly because of inefficient old technologies. Hence, the application of the automatic water level measurement technology is essential to accurately monitor the water levels in the River Nile and its tributaries at the key stations. This technology enables early warning report information in an appropriate time to protect about six millions people residing in the Sudan's floodplain. The installation of automatic loggers and management thereof require experts and institutional organization. This technology needs to be implemented in 14 key locations in Sudan along the River Nile and its tributaries.
Training and skills development of state staff and local communities for the operation and maintenance of the automatic loggers is very important for its success and sustainability.

2.3 Project Overview

2.3.1 Construction of 15 rain water harvesting (haffir) in 15 states

Name of the Project	**Construction of 15 Rain water harvesting (haffir) in 15 state**
Introduction	The project aims at assisting the community in water stress areas by implementing one haffir in each state. It focuses on the most vulnerable areas that are prone to climate change and receive a reasonable amount of rainfall.
Objectives	Construction of the *haffirs* can help a number of villages to supply hygienic potable water for humans and livestock. The objectives of the rain-water harvesting development are to enhance availability and access to water, improve living conditions of both pastoralists and farmers, promote peace and stability and strengthen the resilience of the local communities to climate change.
Outcome	Providing easy access to water for people and livestock during dry seasons and increased water availability per capita at a reasonable price.
Relationship to the country's sustainable development priorities	The main adaptation benefits of *haffirs* can be summarized as: projects of water harvesting in some parts of the country have increased community access to reliable water, increasing their capacity to cope with the impacts of reduced precipitation, all of which has been integrated into the NAPA consultation process. Accordingly, these benefits can be attained in new locations where the intervention has not been introduced.
Project Deliverables	15 Rain water harvesting (*haffirs*), one in each state, which has varying capacities of storing water (depending on the rainfall intensity) ranging from 30,000 m^3 to 100,000 m^3. For human water consumption, the water stored in *haffirs* needs to be treated with filtrations to remove all possible contamination. For this purpose, slow sand filtration techniques are usually adopted. However, filter costs (slow sand filter/rapid sand filter/ pressure sand filter) are not included in the costs estimations. Two separate outtakes should be constructed for people and animals. An elevated tank with a reasonable capacity is usually provided to withdraw clean water.
Project Scope	The project is applicable for all areas between latitude 10 – 14 North a distant a part from the River Nile and its tributaries.

Name of the Project	Construction of 15 Rain water harvesting (haffir) in 15 state
Project activities	1. Identification of project target group beneficiaries in each state 2. Review of existing practices in water supply in the selected areas 3. Conducting environmental impact assessment studies 4. Selection of the best locations for the *haffirs* 5. Conducting soil analysis, infiltration rates, site specific requirements by field visits and design *haffirs*. 6. Awareness campaigns at stakeholder level and field visits to the existing RWH *haffir*. 7. Incorporation of water quality test and treatment for the rainwater before discharge for human consumption. 8. Construction of one *Haffir* in each state (total of 15 *Haffirs*). 9. Setup the scheduled maintenance and operation of the *Haffir* by the respective local government body 10. Training of the local staff/communities for regular cleaning of the intake channel
Timeline	1 year
Budget	Budget for construction of 15 haffir is 105,000 USD for two bulldozers (60,000 USD) and Caterpillar (45,000 USD)
Potential source of finance	Federal Government (Ministry of Water Resources and Electricity) State Government NGOs (IFAD, SOS, UNCEIF etc... Local components in kind (voluntary labour)
Measurement/evaluation	Quantity of water stored in *haffir* Period of water availability Prevalence of peace
Possible complications/challenges	Empty *haffir* before the dry season Clogging of the intake channel (*haffir* not filled by water) Water infiltrate to the groundwater storage
Assumptions	Stakeholders are willing to adopt the technology to reduce the cost of water supply from far places.

Name of the Project	Construction of 15 Rain water harvesting (haffir) in 15 state
Responsibilities	Ministry of Water Resource and Electricity should be responsible for scientific studies regarding the selection of suitable sites for the construction of *haffir*, beside the provision of experts. Ministry of Water Resources and Electricity should train the local people about the different activities of maintenance of *haffir* and rational use of the stored water. The traditional leader should allow the pastoralist to benefit from the stored water

2.3.2 Using automatic water level in monitoring station

Name of the project	**Using Automatic Water Level in monitoring station**
Introduction	Sudan has numbers of established stations for water level staff gauges across the river Nile and its tributaries, which have long time series records. This project is concerned about modernising these systems by adopting automatic water level technologies.
Objectives	Installing automatic water level in 14 key stations
Outputs	Improve monitoring system that will enhance the flood forecasting and early warning systems
Relationship to the country's sustainable development priorities	The development objective of seasonal forecasting and early warning is to reduce human suffering and damages, and capture the benefits of flooding. Through this technology it is possible to manage flood risks, including floodplain management and flood mitigation planning, flood forecasting and warning, and emergency response and preparedness at regional, national, local and community levels. This will contribute to the longer term goal of establishing a comprehensive approach to flood management that integrates watershed, river and floodplain management, and incorporates a suite of structural and non-structural flood mitigation measures within a broad multi-purpose framework.
Project Deliverables	Using automatic water level is a priority technology enabling adaptation to climate change through better dissemination of early warning messages to communities. This helps saving lives and capture flood benefits.
Project Scope	The project will cover all automatic water levels in 14 stations along the River Nile and its tributaries (White Nile, Blue Nile and Atbara River).

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Natural Resources

Name of the project	Using Automatic Water Level in monitoring station
Project activities	Visiting the 14 stations and examine their different location needs Selecting the best type of automatic water level Use of compatible wireless system to send information to the headquarters Programming the logger for the reading interval Training the technician in the whole process (installation, operation, validation, and periodical maintenances) Awareness of the local community about its benefits Purchase the automatic water level, installing and testing by experts Purchase of solar batteries/generator as alternative for electricity shortage Training of Nile Water Directorate staff members on database management, monitoring, retrieving, archiving and maintenance with the assistance of experts
Timeline	1 year
Budget	Budget for purchase of 14 automatic water levels: 56,000 USD (4,000 USD *14 = 56,000 USD) Budget for training of technicians: 10,000 USD Budget for technical/ consultants and staff training: 60,000 USD Budget for awareness campaign: 50,000 USD Budget for maintenance: 10,000 USD Total budget: 186,000 USD
Potential source of income	Federal Government (Ministry of Water Resources and Electricity) NGOs (UNEP, GEF etc..........).
Measurement/evaluation	Operating the new system during the flood seasons and validation of the data transfer and its accuracy compared to old procedures.
Possible complications/challenges	Disturbance of the new system due to fault in wireless system/ electricity shortage/sedimentation or stolen of the automatic water level or one of its components.
Assumptions	Decision makers are willing to adopt automatic water level.
Responsibilities	Nile Water Directorate can require the assistance of national experts in training and international experts in installation and operation of the new system.