The Republic of Sudan

Technology Needs Assessment for Climate Change Adaptation

January-2013

Supported by:

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This document is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP Risoe Centre (URC) in collaboration with 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.

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 Sudan 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. Hence, Sudan is considered as one of the many vulnerable developing countries around the world due to its fragile ecosystem and its livelihood which is directly affected by the impact of climate change. 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 different views, background and experiences in climate change. Identified sectors and sub sectors for the TNA would build upon preceding studies conducted earlier such as the National Adaptation Program of Actions and National Communications.

Sudan has set many goals in its Millennium Development Goals (MDGs). Amongst the most important goals identified are eradication of extreme poverty and hunger, combating HIV/AIDS, Malaria and other diseases and ensure environmental sustainability. Conducting TNA will give Sudan a great opportunity in achieving those goals. Technologies identified through the TNA will assist remarkably in overcoming many challenges that face the country in the context of poverty, hunger, human health and environment in general.

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 improvement of the environment and alleviation of poverty. The government exerts great emphasis on the improvement and development of international relations with environmental development partners, and augmenting mechanisms for benefiting from the latest research, expertise and technologies to enable the country for achieving 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 overcome these barriers.

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Acknowledgments

The Higher Council for Environment and Natural Resources **(HCENR)** is deeply indebted to the United Nations Environment Programme **(UNEP)** Risoe Centre **(URC)**, Denmark, for providing support and continuous collaboration in implementing the Technology Needs Assessment (TNA) for Climate Change in Sudan.

Thanks and gratitude are extended to Environmental Development Action in the Third World **(ENDA)** for providing technical assistance through supervision, training and capacity building workshops to make this project a success.

Thanks and appreciations are also extended to the Global Environmental Facility **(GEF)** for financing the TNA project in Sudan.

Valuable efforts have been taken in this project, however it would not be possible without kind support and help of many individuals and institutions, I would like to express my sincere thanks to all of them.

Special thanks and recognition go Mr. Ismail Elgizoli and Mr Namgeldin Goutbi for their valuable help, support and advice throughout the duration of project execution.

Deep sense of gratitude and recognition are extended to the national team, who participated actively in the TNA process, without them we could not have been able to achieve this success.

Deep thanks and gratitude are expressed to all stakeholders for their valuable contribution, provision of constructive suggestions, invaluable support and professional guidance to this project.

I am highly thankful to the consultants of the project and editors who were very dedicated to this work

Particular gratefulness to the Staff of the Higher Council for Environment and Natural Resources specially Ms. Manal Ahmed Abdelgabar, Mr. Algalih Atwa and Mr. Nimairy Wardi, for their assistance, they deserve special recognition in their contribution to this work.

Last but not least, my sincere acknowledgement to those who have not been listed in this humble note of gratitude.

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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 Transfer Initiative
FNC	Forests National Corporation
GDP	Growth Domestic Product
GHG	Green House 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 for Climate Change
MDGs	Millennium Development Goals
MEA	Multi-Environmental Agreements
MEPD	Ministry of Environment and Physical Development
MoST	Ministry of Science & Technology
NAPA	National Adaptation Plan 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 Framework Convention on Biological Diversity
UNCCD	United Nations Framework 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 is 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 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 from the agricultural sector, while seasonal forecasting and early warning system (monitoring system ‒ automatic water level) and rain water harvesting techniques (*haffir*) technologies were selected from 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 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 from 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
	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 FNC 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. 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.

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 core team and 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 the 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, 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.

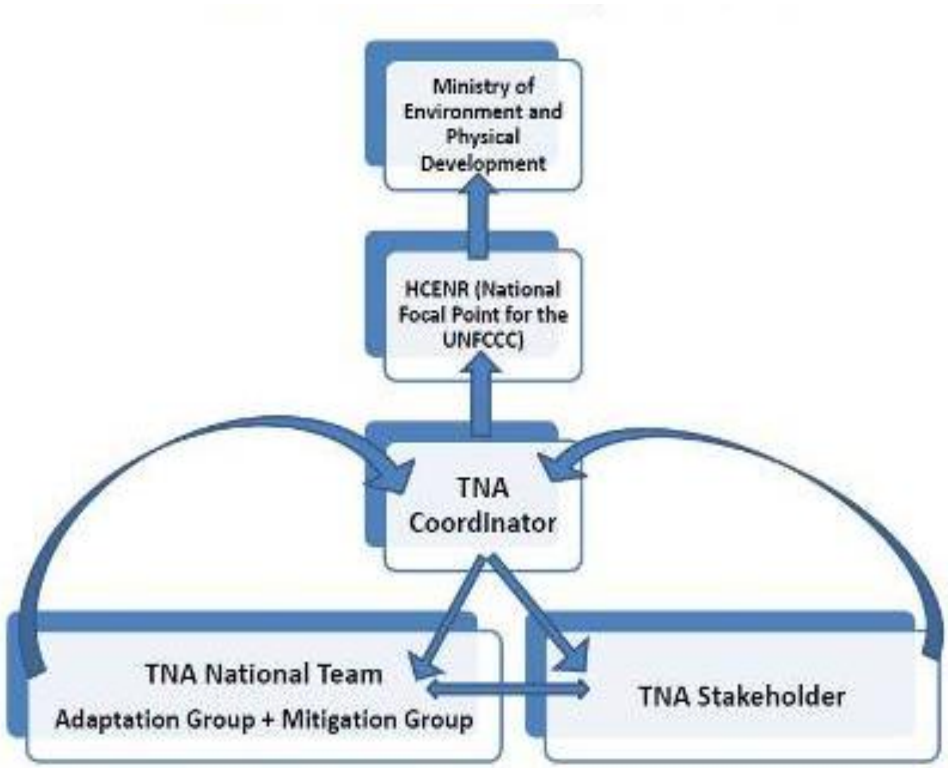

Figure 1. TNA Institutional Organization

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
4- Biodiversity
5- Sustainable Livelihood, and
6- 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, 2001).

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 telephone lines)

Source: NAPA 2007; Zakieldeen, 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 (CO2) that traps heat within the atmosphere. These CO2 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 preventative 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 Plan of Action3 (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 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 systems. 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 (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 breeding	0	0.333	0	1	0.50	0.667	0.396	5th
	0	0.062	0	0.19	0.06	0.08		

Appendix 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 $30 \times 10^9 m^3$/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 about360 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 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. 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 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. 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 floodplain 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	0.0000	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	

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 (Forestation 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

Technology Fact Sheet for Adaptation
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 this 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 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 600mm. 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 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 2-3tones/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 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 750,000USD

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[1]

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

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

(1) Increased crop production
(2) Decreased cost of production
(3) Improved crop quality
(4) Increased farmer's income
(5) New jobs for research workers and seed production technicians, as well as increased number of service providers
(6) 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.

Technology Fact Sheet for Adaptation
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

Haffirs 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 *haffirs*. The size of the *haffir* ranges from 100,000 m3 for large ones to 30,000 m3 for small ones. Guide bunds are required to divert the water into the *haffir*. As water in the haffirs 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 *haffirs* 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

Haffirs 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. *Haffirs*, 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, *haffirs* 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

Haffirs 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.

Technology Fact Sheet for Adaptation
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.

Technology Fact Sheet for Adaptation
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

- A 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 following 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, *haffirs*, 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

- 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.
- 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
- 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 a 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
	SomayaAlsayid	Ahfad University for Women	Lecturer
	NawalHussain	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
	ImanAlrashidDiab	National center for Research	Researcher
	SawsanAbdalla Ali	Forests National corporation	Deputy director
	IssamAldin Ibrahim Abdalla	Ministry of Agriculutre	Staff member
	Haythum Kamal Aldin	Kenana Sugar Company	Employee
	AlmothanaSaad Mohamed	Kenana Sugar Company	Employee
	Igbal Salah Mohamed Ali	Ministry of Water Resurces	Researcher
	WidadMotwakilSaadalla	Ministry of Water Resurces	Researcher
	TarigAlgamri 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
	AbdelrahmanAltahir Ahmed	Kenana Sugar Company	Head Deparment
	Salah Aldin Ali Mohamed	Mininstry of Petrollium	Staff member
	AbdelazimWidaa	Mininstry of Petrollium	Staff member
	Alrabia Mohamed Altahir	Mininstry of Petrollium	Head Deparment
	Mostafa Mohamed Altahir	Ministry of Electricity and Dams	Staff member
	IkhlasAbdelaziz	Industerial Research Center	Researcher
	SayedHajalnour Ahmed	Ministry of Environment , Forestry & Physical Development	Head Deparment
	ThurayaNajib	Practical Acion	Employee
	Ahmed SulaimanAlwakeel	Free Lance	Environemtnal Consultant
	ArigJaafar Mohamed	National Energy Research Center	Researcher
	TaghridAbdelrahim	Ministry of Water Resurces	Staff member
	AlwalidAbas Mohamed	National Energy Research Center	Researcher
	Ali Omer Ahmed	National Energy Research Center	Researcher
	HanadiAttaalfadil Mohamed	Ministry of Industry	Staff member
	AmaniAbdelmahmoud Ali	Ministry of Environment , Forestry & Physical Development	Staff member
	Ismail Fadlalmoula	Sudanese Meteorological Society	Staff member
	QuosayAwad Ahmed	University of Khartoum, Petroleum Department	Lecturer
	Mohamed Saad Ibrahim	Ministry of Animal Wealth	Staff member
	NajlaMahgoubHamadain	Forests National corporation	Staff member
	AwatifAbdalla 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
	D.Suad Ibrahim Jalalaldin	Ministry of Agriculutre	Staff member
	NaimaAbedlgadirHilal	Industrial Research Center	Researcher
	Farough Ismail Abdeljalil	Ministry of Industry	Staff member
	Salah Yousif Mohamed	Forests National corporation	Staff member
	AmiraHasanAlam	Salam Company for Cement Production	Staff member
	Ahmed Amer Mohamed	Shamal Company for Cement Production	Staff member
	AbdelazimYasinAbdelgadir	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
	HayfaHasanFadul	Ministry of Science and Technology	Staff member
	Omayma Mohamed Ahmed	Ministry of Agriculutre	Staff member
	DonyaHasanKhalafala	Ministry of Agriculutre	Staff member
	Somaya Ahmed Alzaki	Institute of Environmental Studies	Lecturer
	AsyaAdlan 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
	SawsanKhairAlsidAbdelrahim	Range and Pasture Administration	Staff member
	AlaminSanjk Mohamed	UofK, Faculty of Forestry	Lecturer
	MirghaniAbnauf	Free Lance	Staff member
	DawoudAbas Osman	Sduanese Industerial Union	Staff member
	Imadaldin Ahmed Ali Babiker	Agriculutral Researh Authority	Staff member
	AbedlrahmanKhidir Osman	Free Lance	Staff member
	MawahibAltayeb Ahmed	National Center for Research	Researcher
	AlfadilBirymaHamed	National Energy Research Center	Research
	SalahaldinHasabAljabir	Ministry of Electricity and Dams	Staff member
	Adam Musa Mohamed	Uinversity of Neelain	Lecturer
	Adel AbdallaRabih	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 Coordinator
	Mutasim Bashir Nimir	HCENR	NAPA Project Coordinator
	AmalAbdelgadirHasan	Ministry of Agriculutre	Staff member
	MahasinBalla Ahmed	Ministry of Agriculutre	Staff member
	AlawiyaYousif 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
	AsmaAbobakr Ismail	HCENR	Staff member
	Adel Mohamed Ali	HCENR	Staff member
	YasirAlzain Ahmed	HCENR	Staff member
	Mohamed Ahmed Yousif	HCENR	Staff member
	Mohamed Yousif Mohamed	Technology Transfer and Agricultural Extension	Staff member
	AmaniAbdelmahmoud 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
	HowidaMirghaniAlmrdi	Ministry of Agriculutre	Staff member
	Wigdan Mohamed Ibrahim	HCENR	Staff member
	KhadijaYounisAbdelmawla	University of Bahri	Lecturer
	Hasan Bashir Nimir	University of Khartoum, Petroleum Department	Lecturer
	NagmaldinGoutbiAlhassan	HCENR	Staff member
	Ahmed Mohamed	Meteorological Authority	Staff member
	HibaMahjoubHasan	HCENR	Staff member

	Mohamed Altahir Mohamed	HCENR	Staff member
	DinanBabikerElkhalil	HCENR	Staff member
	MahjoubHasan	Ministry of Environment , Forestry & Physical Development	Staff member
	Ahmed Ibrahim Ahmed	Ministry of Transportation	Staff member
	AbdelrahmenElamin	EWASCO Company	Staff member
	Hana HamadallaHamad	HCENR	Staff member
	Fathalrahman Ahmed	Ministry of Agriculture	Staff member
	Daoud Abbas	Sudanese Industerial Chamber Association	Staff member
	Mohamed AljakSulaiman	Industrial Research Center	Research
	SeifEldinAbdalmageed	Ministry of Labour	Staff member
	AlamSighayroun Mohamed	Sudanese Industerial Chamber Association	Member
	YasirAbdelkarimAbdelaziz	Sudanese Industerial Chamber Association	Member
	SalwaHamza Ali	Sudani Newspaper	Journalist
	IshragaAlhilo	Sahafa Newspaper	Journalist
	ShzaAlrhma	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	*Sustainability*	*Costs/benefit*	Vulnerability	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 breeding	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 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	0.0000	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	