The Republic of Sudan

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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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Abbreviations

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

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Executive summary

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

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

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

Zero-tillage technology contributes to environmental conservation and to sustainable agricultural production. Results indicate that zero-tillage technology increased sorghum production from about 700 kg/ha to 1650 kg/ha. The second main priority action technology for adaptation to climate change has been the development of improved crop varieties. In Sudan sorghum is the most widely produced and consumed cereal crop. Climatic change seriously affects the traditional rain-fed sorghum growing areas. Therefore, to sustain sorghum production in low rainfall regions, the Agriculture Research Corporation

(ARC) has released short maturing, drought tolerant sorghum varieties with high yield and grain quality. Seed production of the adapted varieties is an essential step towards their spread and adoption. Yet, there are several constraints and limitations to quality seed supply discussed in the report. Moreover, the most important benefits and barriers to the diffusion and adoption of the prioritized technologies are presented in the TAP.

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

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

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

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

An automatic water level recorder is the technology developed to predict the situations in order to avoid and to mitigate impacts of flood on human and properties. This technology uses data logger and submersible pressure transducers. It has been designed for remote monitoring and recording of water

level or pressure data. Early warning systems play an important role in countries like Sudan which is susceptible to floods and characteristically has poor infrastructure. Investigations indicated that barriers of the two technologies are generally similar. Therefore, measures to overcome these barriers tend to be similar too. These include the provision of funds, institutional support and capacity building along with policy and legal frameworks which are considered key tools to overcome the barriers of this technology.

Chapter I

Technology Action Plan for the Agriculture Sector

1. 1 Actions at sectoral level

1.1.1 General Description of the Agriculture Sector

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

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

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

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

Source: NAPA 2007; Zakieldeen, 2007

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

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

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

- Soil and nutrient management: enhancing the availability of soil nutrients can be achieved by increasing soil organic matter (conservation agriculture, reduced tillage, continuous soil cover, composting), improved application of fertilizers (micro-dosing, controlled release or deep placement fertilizer technologies), and improved land preparation practices that minimize soil disturbance.
- Genetic resources: developing improved varieties and preserving genetic resources of crops and their wild relatives is critical at the national level to ensure that appropriate climate resilient varieties are developed and accessible to producers. Table 2 shows the potential hazard avoidance of the prioritized technologies. High or low indicates the potential hazard avoidance based on technology characteristics. As shown in the table the targeted technologies present a high potential to avoid hazards, indicating their economic and environmental benefits as an adaptation option.

Table2: Potential hazard avoidance of the prioritized technologies

Circumstances	**Hazard avoidance**						
	Physical (climatic)		**Biological**	**Economic**		**Institutional**	
Technology	Rainfall	Soil degradation	Pests disease weeds	Income gain	Variation in food prices	Access to market & inputs	Extension services
Zero technology	high	high	low	high	low	high	low
Improved varieties	high	low	high	high	low	high	low

1.1.2 General Barriers and Proposed Measures

One of the main barriers of the agricultural sector is that adoption rates of improved technologies are very low due to low public and private sector investment in agricultural research and technology transfer. Other identified barriers include lack of market linkage and investment in infrastructure; Incentive polices for diffusion of the new technology are not strong enough, poor infrastructure, lack of support for research and development, lack of information and limited local management capacity and expertise.

Measures for overcoming these barriers include: Create a network to promote strategies that include information campaign and raising awareness, policies and measures to promote existing technologies transfer and research, plus market and other financial services support. Other enabling environment measures for the agricultural sectors include land register, consumer trend, tax and tariff, finance policy, business regulation and trade**.** Polices developed to overcome these bariers were formulated according to the Council of Ministers Resolution No. 173, 2007 (Agricultural Revival).

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

Policy	Lead Agencies	Time Frame	Starting Date
A. Economic and Financial Policies:			
Allocate at least 20% of public expenditure for building and modernization of agricultural and livestock infrastructure and advancement of technological innovation	MFNE	Annually	March 2008
B. Financing Policies:			
Finance research, extension and technology transfer; early warning and pests control, diseases and epidemics at national level	MFNE, private sector	Continuous	Immediately
C. Research Policies			
Permit introduction and adaptation of successful technologies on the basis of scientific criteria agreed upon until the procedures concerning Intellectual Property rights are put in place.	High Council for Agricultural Revival	Continuous	Immediately
D. Technology Transfer and Extension Policies			
Use the village as a centre for providing agricultural services and finance. Earmark 15% of the posts approved annually for employing new agricultural graduates to those coming from the villages chosen as centers.	MFNE, MAF, MAR and other related parties	Complete the study on Dec. implementation in 3 years	Jan. 2008

1.2 Action Plan for Improved Crop Varieties

1.2.1 About the Technology

One of the main focuses of national and international research for adaptation to climate change has been the development of crop varieties that can cope with heat, drought, flood and other extremes and thus help farmers adapt to the changes while sustaining and increasing agricultural production and productivity. Historically, crop scientists and farmers have identified and selected several adapted crop varieties with desirable traits that allow them to achieve optimum yields while withstanding stresses, such as drought, heat, and water-logging. Ecological, economic and cultural factors are always considered in variety selection and release. However, the oureach of the improved varieties is still limited.

In Sudan sorghum is the most widely produced and consumed cereal crop. Climatic change has seriously affected the traditional rain-fed sorghum growing areas which constitute more than 50 per cent of the national sorghum production area. Despite the recent climatic changes productivity and sustainability of sorghum production in low rainfall regions can be increased. During the last few decades the Agriculture Research Corporation (ARC) has released short maturing, drought-tolerant, open-pollinated sorghum varieties (table 4) with high yield and grain market preferred qualities that demonstrated adaptable performance under unfavorable environmental conditions (Elzein*et al*, 2009). Generally, the economic benefit of new varieties is well known in India where it increased the production in some states to 4.04 million pounds.

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

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

Source: Elzein*et al*, 2009

1.2.2 Target for technology transfer and diffusion

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

1.2.3 Technology diffusion barriers and measures

Barriers to improved crop varieties in the Sudan

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

Adoption of improved crop varieties is essential in order to maintain a balance between development and environmental objectives. To accelerate and to guarantee steady transfer and diffusion of improved crop varieties, a number of measures and studies are recommended. For improved crop varieties, measures for the transfer, diffusion and adoption were identified through stakeholder consultations and the national team. These measures were classified into two main groups, namely economic and financial measures and non-financial measures. The level of coverage of this technology is low and constrained mainly by high costs and the unavailability of seeds of the sought varieties, particularly to smallholder farmers in the country.

Currently there is no commercial incentive to invest in these technologies. Collaboration between the private and public sectors hold the key to accessing and facilitating the deployment of these technologies.

The economic and financial measures that are necessarily considered to offset the economic and financial barriers for the improved crop varieties include provision of financial assistants to the farmers and producers of the improved crop varieties like subsidies and soft loans. In this variable it is important to consider measures for the compensation of Research & Development expenditures as an incentive for sake of enhancing research for better achievements.

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

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

- Establish a network of experts
- Develop policies to encourage and support researchers to invest in improved seeds and seedling
- Capacity building of extension agencies to increase the providers of improved crop varieties

- Raising awareness of the people for sake of eradicating cultural and social beliefes hindering adoption of improved crop varieties.

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

1.2.4 Proposed Action Plan for Improved Crop Varieties

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

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

Table 5.Proposed Action Plan for Improved Crop Varieties

Actions/ activities	Implementing Period (years)	Outputs and Performance Indicators	Responsible/ Implementing Organization	Supporting Organization	Cost[1] $US	Funding Source
Production and distribution of bulletins and brochures on varietal characteristics range of adaptation and limitations, and their suitability to areas	2	Number of bulletins and brochures produced and distributed, and area covered	MOA(State),ARC, Extension Dept., IFAD project	Framers Trade Union., Private sector	20,000	FMoF, MoA
Introduction,promoting and demonstratingcurrently existing crop varieties that overcome climate related stresses	5	Sites and numbers of demonstration plots set and varieties introduced	CBO,MOA(State) Extension Dept., IFAD project	Agric bank, Framers Trade Union, Private sector	200,000	FMoF, MoA
Development of an efficient seed production and supply systems to ensure rapid access to quality seeds from different sources Facilitate seed multiplication by many partnersthrough promoting the role of local farmers and private sector in the provision of seeds of improved' varieties	5	Seed multiplication farm set: location and quantity local farmers and private companies providing seeds ,type of varieties and quantity	CBO,MOA,IFAD Seed Development project, Private sector,NGOs	Agric. bank, Framers Trade Union	30,000	FMoF, MoA
Providing information and training about seed multiplication methods and regulations	2	Number, type of trainings and attendants	CBO,MOA(State),ARC, Extension Dept., IFAD project	Framers Trade Union, Private sector,	20,000	FMoF, MoA

[1] Cost estimates is based on: 1) inputs needed fort he activity, 2) estimates provided in TNA report Part I

Enhance /Orient plant breeding research capabilities to develop improved varieties (endure climatic stress)	5	Breeding program designed and varieties developed	CBO ,ARC, Extension Dept., IFAD project	Agric. bank, Framers Trade Union., Private sector	200,000	FMoF, MoA
In-situ and ex-situ conservation of genetic resources of the local types	3	Number and types of accessions and types of local material collected and conserved	CBO ARC, (genetic resources unit)	MOA, Framers Trade Union, CIGAR(ICRISAT)	50,000	FMoF, MoA
Encourage farmers' participation in plant breeding stages	3	Varieties developed through farmers' participation in breeding program	CBO,MOA(State),ARC, Extension Dept. IFAD project	Framers Trade Union., Private sector	30,000	FMoF, MoA
Training of future plant breeders	5	Plant breeders trained(area and number)	ARC, IFAD Seed Development project	CIGAR (ICRISAT)centers, Universities	500,000	FMoF, MoA

1.3 Zero Tillage Technology

1.3.1 About the Technology

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

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

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

Source:Lotfie*et al.*, 2009

Table7: Comparison of conventional and conservation tillage costs for smallholders

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

Source:Srrensen*et. al*,1999

1.3.2 Target for zero tillage technology transfer and diffusion

Soil deterioration related to soil erosion and the unplanned use of agricultural machineries as well as the continuous cultivation in the same areas of land without sound crop rotations also contributed significantly to problems related to environmental degradation and crop production under mechanized

rain-fed farming. Despite the major role of the mechanized rain-fed farming system in attaining food security as well as a source of sorghum exports, farmers are still using traditional tools and machineries as well as un-recommended cultural practices. In efforts to develop this sector, promotion of zero tillage technology can facilitate better crop production practices and conserve the natural resources; particularly soil and water. The target set by the TAP is to establish zero tillage technology as the dominant farming system in the agricultural sector by the end of 2030 i.e. around 4-5 million hectares in the mechanized rainfed sector. Targets include large scale farmers, private sector and service providers.

1.3.3 Main barriers and measures to the technology's diffusion

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

Barriers confronting adoption of Zero Tillage

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

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

The main economic and financial measure for Zero Tillage technology is availability of finance which can take different forms like subsides, incentives and soft loans. Incentive measures could be introduced

to encourage suppliers to make the technology available to users. In this connection a survey is necessary to assess user needs. To stimulate the adoption of Zero Tillage by users specific provisions regarding legislative, administrative or policy measures for access to and transfer of technology are necessary. Non financial measures: information on available Zero Tillage could be systematically compiled and made available to farmers through efficient extension services. Improvement of research through support of research and academic institutions would attenuate many barriers to Zero Tillage adoption. Finally, existence and availability of skilled labour is of paramount importance in creating the environment for attenuating the barriers and attainment of good results.

1.3.4 Proposed action plan for Zero Tillage Technology

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

Table 8: Proposed Action Plan for Zero Tillage Technology[2]

Actions/ Activities	Implementing Period - (year)	Outputs and Performance Indicators	Responsible/ Implementing Organization	Supporting Organization	Cost $US	Funding
Introduce, demonstrate and promote "no tillage" in all agro-climatic zones	5	Location and number of no tillage demonstration plots	CBO ,MOA(State),ARC, Extension Dept. IFAD Projects	Agric. bank, Framers Trade Union, Private sector	400,000	FMoF, MoA
Organize extension campaigns for descriptions of conservation tillage	3	Number and sites of extension campaigns organized	CBO,MOA(State),ARC, Extension Dept., IFAD Projects	Framers Trade Union, Private sector	20,000	FMoF, MoA
Create and implement information and education campaigns to increase awareness	2	Number, typed and sites of information and awareness campaigns organized	CBO ,MOA(State),ARC, Extension Dept., IFAD Project	Framers Trade Union, Private sector	20,000	FMoF, MoA
Facilitate creations of CBOs and enhance their access to financial services markets, inputs and agricultural information	3	CBOs formed (location and number)	CBO,MOA(State),ARC, Extension Dept.,IFAD Project	Agric. bank, Framers Trade Union, Private sector	50,000	FMoF, MoA
Conduct surveys of target areas to determine the obstacles to adoption of conservation tillage	2	Survey results and report	CBOs, MOA (State), ARC, Extension Dept. IFAD Project(South Kordofan)	Agric. bank, Framers Trade Union, Private sector	50,000	Local and external
Conduct research regarding draft animal power (technology in conservation tillage)	4	Research results and report	CBO, ARC, Extension Dept., IFAD Project	Agric. bank, Framers Trade Union, Private sector	80,000	FMoF, MoA nal
Determine and develop appropriate technology transfer capacities to increase	2	Trainings and adoption rate of the technology	CBO, ARC, Extension Department, IFAD Projects	Framers Trade Union, Private sector	30,000	FMoF, MoA

adoption of conservation cropping systems						
Enlist the private sector to help disseminate information on conservation tillage	1	Information received by private companies	CBO, MOA(State), ARC, Extension Dept. IFAD Project	Framers Trade Union, Private sector	15,000	FMoF, MoA
Engage with national and international organizations to serve as information source to promote conservation tillage	2	Connections and network set to communicate with national and international organizations	ARC, Extension Dept., IFAD Project	Framers Trade Union, Private sector (machinery – seed – chemicals)	15,000	FMoF, MoA

[1]Indicators: (1) Risk: climatic conditions, availability of credit and weak extension system/ (2) Success: high yield and return, food security and soil conservation
Cost estimates is based on: 1) inputs needed fort he activity, 2) estimates provided in TNA report part I

Chapter 2

Technology Action Plan for Water Sector

2.1Actions at sectoral level

2.1.1 Water sector description

Adoption and implementation of integrated water resource management will enhance adaptive capacities of human communities and natural ecosystems to climate change, increase living standards and ensure water security and sustainable water resources development. Prioritizing development of climate change adaptation technologies in water resources management will ensure water security, poverty alleviation, social security, public healthcare, enhanced living standards and protect water resources in the context of climate change. Life in Sudan revolves around water. The total amount of fresh water from internal and external sources is around $30\times10^9 m^3$/year, bringing the per capita water availability below the water stress limit of 1,000 m^3. Water resources in Sudan are the River Nile and its tributaries, seasonal streams and groundwater as well as unconventional water. The River Nile basin is shared among ten countries. The seasonal streams and ground water are shared with three countries.

Sudan implemented several activities under multilateral environmental agreements (MEAs) which have direct relations to climate change adaptation and development priorities.

The NAPA process, under the UNFCCC, identifies specific initiatives that are considered urgent and address immediate climate adaptation needs. The major types of initiatives are as follows:

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

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

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

which specifies the role of the government in the protection of the environment and pursuance of sustainable development.

In Sudan's TNA process two technologies were selected for water resources sector based on wide stakeholders consultation, namely rain water harvesting (*haffirs*) and seasonal forecasting early warning (automatic surface water level records). The prioritization of the two technologies are based on the following criteria: vulnerability, strategies and targets, sustainability, costs and benefits, utilization scale, and supportive systems. Lack of financing funds is one of the most important impediments facing socio-economic development in the country. This is particularly the case for rainwater harvesting development. Despite the difficulties facing Sudan's economy in the short run, the medium to long term outlook gives optimism that the priorities for the agriclture and water resources sectors can be achieved. However, many non-ginancial barriers may face the implementation of this technology: rainfall is a most unpredictable variable.

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

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

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

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

2.2 Action Plan for Rain Water Harvesting (Haffirs) Technology

2.2.1. About the Technology

The objectives of the rain water harvesting development are to enhance availability and access to water, improving living conditions of both pastoralists and farmers, promoting peace and stability and strengthening resilience of local communities to climate change. Sudan is a country with plenty of rainfall

that increases from north to south in a wide range from very limited rainfall in the north to more than 800 mm a year in the southern part of the country. Rain water harvesting is one of the priority programs for rural socio-economic development in the country. Compared to other means of development, rain water harvesting, in particular *haffirs*, is to develop while ensuring high socio-economic returns.

Haffirs are natural depression or manmade ground reservoirs in the earth at suitable locations to store water for drinking purposes for human and livestock as well as for agriculture. Haffirs and dams can also be made by machinery to serve drinking water and/or irrigation purposes. The implementation of *haffirs* technologies is in line with the protection of the ecological and human eco-system. It contributes to well-being and food security of the local communities and their livestock. The concept is that water running in natural stream during the rainy season is diverted at certain suitable locations into these *haffirs*. Guide bunds are required to divert water into the *haffirs*. When collected water can be used for human consumption, yet filtration is required to meet drinking water standards. The size of the *haffirs* ranges from 30,000 $m^3$to 200,000 m^3, and cost of an average *haffirs* with a capacity of 85,000 $m^3$of water amounts to about USD 850,000.

Although *haffirs* designs differ according to the topography, terrains and purpose, common *haffirs* comprise of a slit trap with an outlet canal attached to shallow wells. The water is usually pumped to the elevated tank and further through gravity channels to the livestock and human collection points. As a system, the *haffirs* should be integrated with environmental rehabilitation whereas ecological and water conservation techniques like micro basins, soil bunds and check dams are applied. Water is diverted towards the *haffirs* by guiding bunds with a feeding canal. The main design criteria for a *haffir*s are suitable intake, protection against high flows using spillways, careful design of inlet and outlet−especially regarding the slopes of connecting pipe, filters to enable cleanwater for human consumption, and fences to protect the *haffirs*.

In addition to benefits addressing climate change adaptation, *haffirs* have several economic and social benefits. Economic benefits include increases in the incomes of farmers and increases of food production and productivity. Social benefits include enhancing the availability and access to water, improving the living conditions of both pastoralists and farmers, promoting peace and stability, enhancing settlement and reducing the competition for water between farmers and pastoralists.

2.2.2 Target for Haffirs Technology Transfer and Diffusion

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

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

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

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

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

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

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

Financial barriers:

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

Non-financial barriers:

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

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

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

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

2.2.5 Proposed action plan for rainwater harvesting (Haffirs) technology

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

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

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

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

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

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

	resources							ns
Support establishment of water resources database and sharing of information	To support proper planning, Effective use of resources	MoWRE, HCENR,	ST	Advocate for water resources data collection and storage, Provide fund	26,000	UNEP, MOWRE, FmoF, HCEWR	Water resource database established, A forum for coordination and information sharing established	Lack of interest in data sharing and competion over resources and power
Building partnership especially with private and non-profitable agencies	To support technology diffusion and coverage	MoWRE, HCENR, PWC, SWCs, FmoF	ST	Establish water resources coordination forum at national level, Involve different stakeholders, Involve research institutions	15,000	FmoF, UNICEF, PWC, MOWRE, SWC, HCENR	A forum for coordination and information sharing established, No. of research institutions involved	Differences in interests and approaches
Build capacity on water harvesting in general on Haffirs construction and rehabilitation specifically	Ensure proper construction of Haffirs, Ensure effective use of resources and to avoid negative environmental impacts	MoWRE, HCENR, PWC, SWCs, FMoF	ST	Advocate and provide funding for researches related to the technology, Provide internal and external trainings, Conduct EIA, Use local capacities like PWC training center	55,000	MOWRE, UNEP, UNOPS, FmoF, SmoF, NGOs, UNICEF	No. of researches related to water harvesting conducted No. of people trained internally and externally No. Of EIA conducted	Limitation in financial resources
	Grand Total 266,500 USD							

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

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

2.3.1 About the Technology

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

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

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

2.3.2 Target for technology transfer and diffusion:

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

Seasonal forecasting and early warning technology (automatic water level recorders) has a wide international market and it should be ordered and implemented by the government of Sudan (Ministry of Water Resources and Electricity). No market mapping has been used in the barrier analysis as it is a public good. Many benefits could be gained from the implementation of the automatic water level measurements. Here are some results from the 14 Key stations:

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

2.3.3. Barriers to the technology's diffusion

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

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

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

Financial barriers:

- High capital costs of the gauge station including the costs of automatic surface water level recorders, installation and maintenance costs, as well as required training of personnel
- Automatic water level recorders have a wide international market; yet they should be ordered and implemented by the government of Sudan, in particular the Ministry of Water Resources and Electricity

Non-financial barriers:

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

- Lack of technical know-how and experience to implement automatic water level technologies confidently and effectively
- Cultural and social unsustainable tranquillity
- Sensitive and easily breakable equipment
- Lack of proper wireless network needed for real time data transfer
- Gaps in information, research and development

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

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

- Funding and awareness raising to finance the pilot station projects comprised of automatic recording systems in 14 river gauge stations along the River Nile. Hence, the benefit revenue from these pilot stations could be allocated to the annual cost of operation and maintenance.
- **A**dvocacy for the program at high level to convince decision makers of the essence and the outcome of the project and thus facilitate funding. Grants and loans also can be advocated to convince decision makers to implement the project, especially those who have an interest in such type of projects.
- Set awareness sessions for target groups at national and state levels to highlight the importance of the project and its impacts along with mobilization of local resources
- Create enabling and conductive policy and legal frameworks in planning and management across all water departments in Sudan
- Institutional strengthening and capacity building to enhance adaptation capacities and human resource development via series of training sessions
- Collaborative cooperation with international agencies of same interest and with international experts and professionals in these technologies to assist in identifying the best measures and practices and strengthen technical know-how
- Securing and preventing expected damage or loss of sensors by providing the automatic loggers with steel cages or protective coverage, especially in report areas.

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

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

- **Funding and awareness raising:** In order to overcome financial barriers related to capital and operational costs of automatic water level recorders in 14 river gauge stations in Sudan, allocated

funds to finance the pilot station projects should be used. Hence, the benefit revenues from these pilot stations could be allocated to the annual costs of operation and maintenance. After providing first successful reports of the technology, policy makers and other donors can be attracted to secure funding to upscale the technology by implementing it in other areas throughout Sudan. This requires determining a long-term budget plan covering implementation and maintenance costs that can be included in the national development programs.

- **Policy and legal framework**: Developing and adopting climate change policies and strategies is essential for the government of Sudan as it will systematically enhance forecasting and early flood warning and help in disaster management and response. As discussed in the previous sections, lack of inadequate policies and legal frameworks constitute a major barrier to the successful implementation of automatic water level recorders. Thus, to overcome this barrier and promote sustainable development, it is recommended to adopt integrated water resources management and catchment management systems across all water departments in Sudan. This can be achieved by developing and finalizing water resource policies. In particular, the TAP proposes establishing collaborative cooperation with international experts and professionals in these technologies to assist in identifying the best measures and practices.
- **Institutional strengthening and capacity building**: Capacity building of the MoWRE should be improved to manage automatic water level recorders and to enhance sustainability. Capacity building for these institutions can be realized in terms of providing training and raising awareness in the installation and operation and management (O & M) of these loggers. Training can be accomplished through the service providers and can include onsite training in installation along with training in O & M. Moreover, training of staff and raising their levels of awareness on possible consequences of climatic changes is essential to keep focusing on managing the impacts of climate changes through available adaptation technologies.

In addition to that, the provision of related equipment and materials like power sources, computers and network inputs will support a smooth and effective implementation of the project. It will also be beneficial to use most reliable wireless network for real time data transfer. Past experience indicated that some of the surface water loggers were vandalized by some local people for unknown reasons. It is worth mentionening that protection of equipment is essential to enhance the effective use of resources which can be achieved by procuring loggers with steel cage or concrete housing. Visit exchanges with countries using the same equipment will be very useful and improve the implementation capacity.

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

No	Action	Why is needed	Who take action	When	How	Cost in USD	Funding source	Indicator	Risk
Funding and Awareness									
1	Integrate the technology into planning and development program at the national level and river basins projects	Providing funds for technology promotion, national projects and NBI has secured funds	MOWRE	ST	Coordinate with national funding agencies and FMoF, Applying for financial support from both domestic and foreign funding agencies, ensure the technology in the national and foreign funded projects	10,000	FFFMoF,		lack of financial resources for funding national project.
2	Build public awareness on the essence of the technology at local, state and national levels	Facilitate understanding and funding, Enhance the role of public communities, Safeguard resources from damage by public	MOWRE	ST	Develop programs and materials for awareness raising using mass media, Organize training courses to raise awareness, Conduct house to house visits at village close to the sites, Conduct focus group discussion to raise awareness, Brainstorming on the requirements, application, and communication of	50,000	FFMoF, MOWRE,	• No. of campaign conducted • No. of training conducted • No. of HHV conducted • No. of FGD conducted	• Limited resources

					prediction and warning data				
3	Determining long-term budget plans to assure that it covers maintenance	Ensure sustainability of service	MOWRE PWC	MT	Develop long term operational plan, Include plans in national development program , Advocate for funding	10,000	FMoF, MOWRE,	Long term budget document provided	Limited funding for devlopment project
Policy and legal framework									
4	Support development of water resources policy	Encourage technology diffusion, Strengthening roles of IWRM focal point	MOWRE GWWD	ST	Review the current draft policy, raise awareness on essence of the policy, advocate for IWRM	70,000	MMOWRE, UNEP, FAO, FmoF, UNDP	water resources policy document provided	Continous chnage in Government structure and senoir officials
5	Develop rules and regulations for coordination between organizations and formulation of water resources forum	Sharing of information, Avoid duplication, Effective use of resources	MOWRE GWWD	ST	Review functions of relevant organizations	7,000	FMoF, MOWRE, , UNEP	Water resources forum formulated	Competion among government institutions on resources and power
6	Develop clear understanding among the relevant agencies in the collection and co-ownership of data and data sharing, and support development of water resources database	Effective planning, Max. use of resources	MOWRE	ST	Raise awareness on data collection and sharing, Share available data with partners	6,000	FMoF, MOWRE,	• Water resource database established • A forum for coordination and information sharing established	• Competion among government institutions on data collection and lack of interest in sharing information

Institutional Strengthening and capacity building									
7	Raise awareness on the application of prediction and warning systems using this technology for different groups of users	Support technology promotion, Improving knowledge on CC, Enhance local capacities in forecasting, Improving knowledge	MOWRE	ST	Arranging local trainings on the prediction climate disaster and warning systems Arrange awareness workshops on the technology importance. Exchanging research scholarships, seminars and trainings on seasonal climate prediction, Collaborating with research institutes from overseas to provide training on forecasting and early warning	60,000	FMoF, MOWRE, ,UNDP, FAO	• No. of trainings conducted • No. of awareness workshops conducted • No. of related research conducted	• Lack of funding from all partners
8	Building a national and international research networks for technology transfer from overseas and to exchange knowledge	Improving knowledge, Updating on new technologies, Provide technical backup for the process	MOWRE ,universities and research institutions	MT	Facilitate networks for local and international experts, Organize training on technology applications			Research networks established	Institutions will not share adequate information
Grant total						**213,000**			

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

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Annex I

List of Stakeholders

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