the national strategic development plan which allocated more than 90% of the budget to sustainable development and poverty alleviation. Complementarities with the investments of Government (through the State and the Agriculture Revival Program) and other donor funded initiatives can also support the technology implementation and maintenance.

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

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

2.2 Action Plan for Rain Water Harvesting (Haffirs) Technology

2.2.1. About the Technology

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

ern part of the country. Rain water harvesting is one of the priority programs for rural socio-economic development in the country. Compared to other means of development, rain water harvesting, in particular haffirs, is to develop while ensuring high socio-economic returns.

Haffirs are natural depression or man made ground reservoirs in the earth at suitable locations to store water for drinking purposes for human and livestock as well as for agriculture. Haffirs and dams can also be made by machinery to serve drinking water and/or irrigation purposes. The implementation of haffirs technologies is in line with the protection of the ecological and human eco-system. It contributes to well-being and food security of the local communities and their livestock. The concept is that water running in natural stream during the rainy season is diverted at certain suitable locations into these haffirs. Guide bunds are required to divert water into the haffirs. When collected water can be used for human consumption, yet filtration is required to meet drinking water standards. The size of the haffirs ranges from 30,000 m3to 200,000 m3, and cost of an average haffirs with a capacity of 85,000 m3of water amounts to about USD 850,000.

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

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

2.2.2 Target for Haffirs Technology Transfer and Diffusion

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

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

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

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

The ecological barriers are detrimental for the success and adoption and replication of haffirs. The intensity of rainfall varies temporally even in the same location. At the same time it varies spatially even in the same zone. Based on problem tree methodology, lack of financial funds is considered the main problem hindering the successful implementation of haffirs. Nonetheless, haffirs are considered the lowest cost technology for rain water harvesting. Although a few governmental agencies, research institutes and stakeholders are experienced in the design, implementation and

operation of haffirs technologies in Sudan, there continuous to be a lack of equipped institutions to design and implement the technology efficiently. In addition, the amount of trained experts capable of regular maintenances is very limited and may lead to structural collapse and decreased water storages. A technical and ecological problem that could impede the haffirs project's sustainability is attributed to the soil erosion and maintenance of haffirs. Yet, tillage and natural vegetation strips can be used as a possible measure to overcome soil erosion around haffirs boundaries. Another adaptation barrier to the implementation of haffirs is the unpredictable rainfall characteristics in terms of intensity, duration and distribution. Additional barriers include lack of technical know-how, land tenure, soil siltation and infiltration. To overcome some of these drawbacks, measures to raise knowledge and awareness are essential as well as applying additional filtration and disinfection.

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

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

Financial barriers:

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

Non-financial barriers:

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

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

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

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

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

2.2.4 Proposed action plan for rainwater harvesting (Haffirs) technology

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

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

Currently , all over Sudan, water from haffirs and dams is free of charge, except in some states like Blue Nile State. This approach of free water from dams and haffirs is common among water users in Sudan. Going forward, State Water Corporation applied water tariff for all water facilities, especially for water yards and hand pumps, would support sutainability of services from these facilities. This is not fully applied in the case of surface water harvesting, where the water provided naturally and should be free of charges. The prevailing free water supply approach needs to be changed and a water tariff system applied instead. This can be implemented by developing regulations ratified by state councils and accomplished by responsible partners. Water tariff system provides additional resources for operation and maitenance and will reduce overall cost. In addition it

insures community contribution and promotes ownership along with sustainability of services and long term development. Usually the role of the government and development partners is to support construction and to handover facilities to communities and local authorities for operation and maintenance. WFP, CARE International and other food granting agencies have introduced a food for work approach, whereby these agencies provide food instead of cash for the community taking responsibility for digging. Food will be provided for each community member against the number of cubic meters excavated. This approach is cheap but time consuming.

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

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

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

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

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

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

2.3.1 About the Technology

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