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BUILDING RESILIENCE IN THE FACE OF CLIMATE CHANGE WITHIN TRADITIONAL RAIN-FED AGRICULTURAL AND PASTORAL SYSTEMS IN SUDAN

TECHNICAL FEASIBILITY REPORT

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List of Acronyms

ARC	Agricultural Research Corporation
ASARECA	Association for Strengthening Agricultural Research in Eastern & Central Africa
bcm	Billion Cubic Meter
°C	degrees Celsius
CAADP	Comprehensive Africa Agriculture Development Programme
CIARC	Consortium of International Agricultural Research Centers
FAOSTAT	Food and Agricultural Organization Statistics
GCF	Global Climate Fund
GEF	Global Environment Facility
HCENR	Higher Council for Environment and Natural Resources
HDI	Human Development Index
HH	household
IWRM	Integrated Water Resource Management
Km	kilometre
km²	square kilometre
M^3	cubic meter
M&E	Monitoring and Evaluation
MDG	Millennium Develop Goals
MEA	Multilateral Environmental Agreement
mm	millimeters
NAP	National Adaptation Plan
NAPA	National Adaptation Plan of Action
NBHS	National Baseline Household Survey
SDG	Sudanese pounds
SSA	Sub-Saharan Africa
tC	tonnes of carbon
TTEA	Technology Transfer and Extension Administration
UNCBD	Convention on Biological Diversity
UNCCD	Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WFP	World Food Programme

Glossary

Hafir	An artificial excavation (dugout enlargements) into which surface-water runoff is converged during the rainy season to be stored and used during the dry season. It is basically excavated in the impervious clay soil. Each installed hafir has an annual water storage capacity of 50,000 cubic meters.
Jubraka	Women household gardens refer to the cultivation of a small portion of land mostly around the household is planted with vegetables and serve as a supplementary and urgent source of food and income. Crops are irrigated from rainwater and supplemented when there is dry spell from residual house water.
Khor	non-Nilotic seasonal stream
Sand water-Storage dam	Rainwater harvesting structure made of earth wall built up to 5 meters high across a seasonal water stream that transports runoff-water from catchment areas to streambeds. Each sand water storage dam has an annual design capacity of 20,000 cubic meters.
Wadi	Seasonal stream. Many wadis are scattered in the project area. These streams deposited silt depressions that constitute an important cultivable flats land (Wadi-beds known as wadies).
Water yard	A water extraction and distribution complex which includes borehole, storage tank, animal watering basins and tap stands. Each water yard provides a daily storage capacity of 50 m3, or 1.46 Mm3 per year.
Women's farms	Typically one piece of land (average garden size is between 1 to 4.2 ha), which is cultivated collectively by a group of women, organized into formal groups and supported.

1. Situation Analysis – Climate risk profile

1.1. Country Background: Development Context in Sudan

1.1.1. General

Sudan lies in northeast Africa between latitudes 10°N and 23°N and longitudes 21°45′E and 38°30′E (see Figure 1-1). It covers an area of approximately 184 million hectares and has a population of about 30.9 million distributed across 5 major regions and 18 states. The country borders include South Sudan, six other African nations, and the Red Sea. Most the land consists of vast arid plains interrupted by a few widely separated ranges of hills and mountains.

Figure 1-1: Map of Sudan

1.1.2. Development status

The Human Development Index (HDI) provides an overall assessment of all income and human development dimensions. With an HDI of 0.479 in 2014, Sudan ranked 167 out of 188 countries; lagging Sub-Saharan Africa (SSA) with an average HDI of 0.518 (UNDP 2015). Life expectancy at birth in Sudan was slightly higher in 2014 than that in SSA. Otherwise, Sudan lags behind SSA countries in all health, education, economic and social integration, reflecting poor access of Sudanese to the basic social services (see Table 1-1).

Table 1-1: Sudan National Human development indicators (UNDP, 2015)

Indicator type	Indicator description	Sudan	SSA Average
General	Public spending on health (% of GDP): 2014	6.5	5.6
	Life Expectancy at birth 2014 (years)	63.5	58.5
	Underweight children (moderate or severe) 2008-2013 (% of children under age 5)	35.0	37.2
	Maternal mortality ratio per 100,000 live births 2013	360	506
Education	Mean years of schooling (2014)	3.1	5.2
	Expected years of schooling (2014)	7.0	9.6
	Population with at least secondary education (% ages 25 and older) 2005-2013	15.2	26.5
Economic	Labour force participation rate (% ages 15 and older) 2014:		
	Female	31.3	65.4
	Male	76.0	76.6
	Gender inequality index 2014	0.591	0.575

The Millennium Develop Goals (MDG) are quantified targets for addressing extreme poverty in its many dimensions. Sudan has made significant progress in recent years. The proportion of the population living below the national poverty line has decreased from about 47% in 2009 to 23% in 2015. Other targets such as infant mortality, access to water, and access to sanitation have also showed substantial improvement (Bashir and Faki, 2014).

1.1.3. Climate and drought

Households throughout the targeted states are highly vulnerable to climate change. They have witnessed increasingly more frequent cycles of drought and floods. Smallholder farmers are among the most vulnerable to even small variations in the climate, with major impacts on their livelihoods and food security (NAPA 2007). Annual average rainfall in Sudan is low, ranging from 300 to 700 mm per year. In the north near the Egyptian border, desert conditions prevail, and rain is rare. Throughout the rest of Sudan, most of the rainfall comes over a four-month period that extends from June through September. Air temperatures have been steadily increasing in Sudan. When averaged across all seasons, temperatures in the 2000-2009 period are roughly between 0.8°C and 1.6°C warmer than they were in the 1960-1969 period.

The frequency of extreme climatic shocks is also increasing, particularly drought. Once a feared event that occurred rarely, drought is now one of the most important and frequently recurring challenges that Sudan faces. Since the end of the last drought in 1984, droughts have recurred in 1987, 1989, 1990, 1991, 1993, and 1996, mainly in western Sudan in Kordofan and Darfur states, as well as in areas in central Sudan. Sub-Saharan Africa country drought reports from 1970 to 2004 reveal that Sudan is among the countries with the highest drought frequency. Future drought threatens about 19 million hectares of rain-fed mechanized and traditional farms, as well as the livelihoods of many pastoral and nomadic groups. Additional information on climate change drivers is provided in Section 1.3.

1.1.4. Agriculture & livelihoods

Agriculture, including both crop and livestock production, remains the key priority sector in the growth and poverty reduction agenda of Sudan. Over 60% of the population derives its livelihood from agriculture and about 75% of the labour force is employed in agriculture and related activities. It currently contributes about 37% to GDP and supplies raw material such as cotton lint, oil seeds and livestock products needed by the agro-based industries and generates demand for industrial consumer goods. Despite this, agriculture has not performed well due mainly to inadequate spending on agriculture-related development, poor rural infrastructure and high dependency on rain-fed agriculture (Elbashir and Hamin, 2014). A summary of key characteristics is provided in Table 1-2.

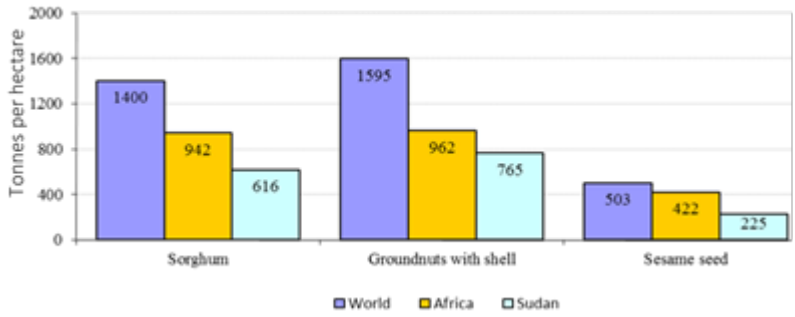
Sudan's agriculture has three distinct crop production systems. These are irrigated farming, mechanized rain-fed farming, and traditional rain-fed farming. Together they account for about 17 million hectares. Livestock total about 105 million head, with camels (4%), goats (33%), sheep (38%), and cattle (29%) managed under three distinct livestock pastoral systems. These are nomadic pastoralism, transhumant pastoralism, and sedentary. More than 75% of the animals are in the nomadic and transhumance management pastoral systems and rely on open access rangelands as the

Table 1-2: Sudan key agricultural characteristics (Department of Statistics, Planning & Agric. Economics, Ministry of Agriculture & Forestry, 2014)

Production system	GDP Share (%)	area (million hectares)	Share of cultivated land (%)	Main food crops (%)		
				Wheat	Sorghum	Millet
Irrigated	10.8	2	12	100	23	1
Mechanized rain-fed	1.0	6	35	0	38	5
Traditional rain-fed	5.5	9	53	0	39	94
Livestock	17.0	NA	NA	NA	NA	NA
Total	36.5	17	100	100	100	100

major feed source. Crop and livestock production systems are inter-related through food, feed, investment, manure, fodder, labour source and transportation linkages.

Figure 1-2: Agricultural productivity comparisons, 2014 (FAOSTAT)



1.1.5. Agricultural productivity

Agricultural productivity in Sudan typically is lower than levels in other locations. In large part, poor agricultural productivity is considered a root cause for the vulnerability of rural livelihoods and economy to future disruptions from climate change. As an example, Figure 1-2 compares average Sudanese productivity of three key crops - sorghum, groundnuts, and sesame seed - to both African and World average productivity levels for the year 2014. Relative to the Africa average, Sudan's yields of these crops are 65%, 80% and 53%, respectively; and only 44%, 48%, and 45% relative to World's average. Average productivity by type of cultivation system is summarized in Table 1-3.

Table 1-3: Sudan water supply characteristics (sources as noted in text)

Resource	Supply (bcm) Total	Available	Notes
Nile River	20.5	18.5	• Consists of River Nile, Blue Nile and White Nile • Subject to seasonal patterns and limited storage vessels • Total of 20.5 bcm refers to Sudan's share under the Nile Waters Agreement (about 14.5 bcm currently utilized)
Wadies and Khors	5-7	0.7	• Consists of highly variable, short duration flows, difficult to monitor/harvest • Subject to sharing with neighboring countries • Gash and Baraka account for between 0.2and 0.8 bcm • Wadi Azum and Kaja account for between 0.5 and 0.8 bcm
Renewable groundwater	4.5	0.4	• Consists of water in Nubian sandstones, Um Ruwaba chain, recent sedimentation • Subject to high cost for pumping from deep wells • Prevalent in remote rural areas with poor infrastructure
Total	30-32	19.6	

1.1.6. Water Resources

Rainfall provides water to the rain-fed mechanized and traditional farming production systems which together account for 88% of cultivated area (see previous Table 1-2). Rainfall also provides water to the small-scale water harvesting projects in remote inland areas. Major water resources are the River Nile and its tributaries, seasonal surface runoff from Wadis and Khors (i.e., non-Nilotic seasonal streams), and renewable groundwater (Table 1-4). Salient details are provided in Annex F.

There are three main activities for water demand, agriculture, livestock, and households. In 2012, water demand throughout Sudan totalled about 32.1 bcm, equivalent to a water supply deficit of about 12.5 bcm. Future water demand is expected to grow by about 3.3% per year and reach about 52.6 bcm in 2027 (Abdullah, 2002). Without major new supplies, Sudan's water supply deficit will reach 33 bcm in that year.

1.1.7. Agro-climatic zones

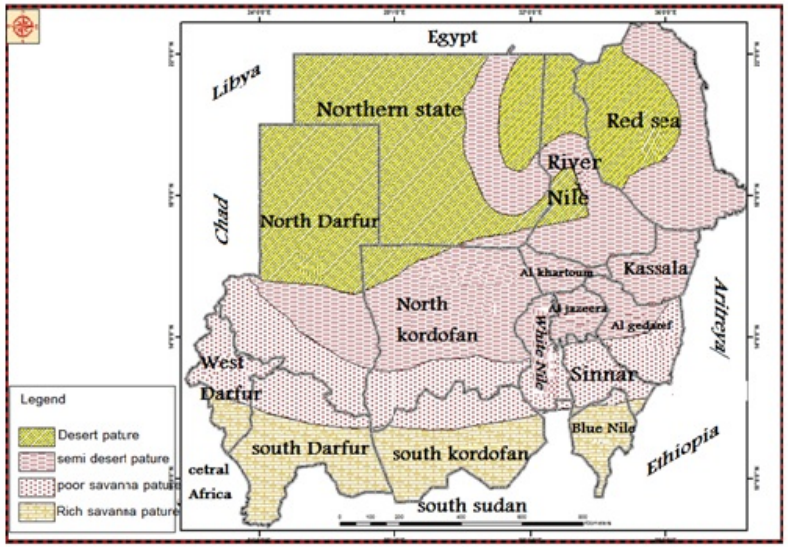
Table 1-4: Average productivity (Kg/ha) by production system (2002/03-2013/2014)

Production System	sorghum	sesame	groundnut
Average irrigated	2,160	NA	2,117
Average Mechanized Rainfed	417	269	NA
Average Traditional Rainfed	505	212	543
Sudan Average	574	236	769
Source: Planning and Agricultural Economic Directorate, Ministry of Agriculture and Irrigation			

Sudan can be classified into five distinct agro-ecological zones, based on climatic factors such as rainfall, the ratio of humid months to arid months, and length of the growing season. The general characteristics of each zone and the area it occupies are outlined in the bullets below and illustrated in Figure 1-3.

- *Desert zone:* This zone is characterized by annual rainfall less than 100 mm per year, less than 1 humid month, and a growing season less than 30 days. This zone is located in the far north of Sudan and accounts for about 34% of the total cultivated land area. All agricultural activities are located along the Nile Bank using irrigation.
- *Semi-desert zone:* This zone is characterized by annual rainfall between 100 and 250 mm per year, 1-2 humid months, and a growing season between 30 and 60 days. This zone is located just south of the Desert zone and accounts for about 21% of the total cultivated land area. Agricultural activities consist of irrigation along the Nile Bank and grazing along seasonal streams.
- *Arid zone:* This zone is characterized by annual rainfall between 250 and 350 mm per year, 2-3 humid months, and a growing season between 60 and 75 days. This zone is located just south of the Semi-desert zone and accounts for about 10% of the total cultivated land area. Agricultural activities consist of irrigation along the Nile Bank, grazing along seasonal streams, and limited rain-fed traditional cultivation.
- *Semi-arid zone:* This zone is characterized by annual rainfall between 350 and 600 mm per year, 3-4 humid months, and a growing season between 75 and 120 days. This zone is located just south of the Arid zone and accounts for about 27% of the total cultivated land area. In the northern part of this zone, agricultural activities consist of irrigation along the Nile Bank, grazing along seasonal streams, and limited rain-fed traditional cultivation in sandy soils. In the southern part of this zone, agricultural activities consist of rain-fed traditional cultivation in clay soils.
- *Sub-humid zone:* This zone is characterized by annual rainfall between 600 and 800 mm per year, 4-5 humid months, and a growing season up to 120 days. This zone is in the far southern most parts of Sudan and accounts for about 8% of the total cultivated land area.

Figure 1-3: Natural pastures in Sudan (Source: Balila, 2012)



Agricultural activities consist of rain-fed traditional cultivation, mechanized farming, and pastoralism.

1.1.8. Microfinance and financial service provision

In 2006-2007 the Government of Sudan endorsed microfinance as a central element of its financial policies to support poverty reduction for farmers and pastoralists to increase adaptive capacity of rural livelihoods. Effectively, in 2007, the Microfinance Unit at the Central Bank of Sudan was established and has issued several directives to banks to deliver microfinance services so as to increase the extension of financial services to the economically active poor. The most influential directive has been to mandate banks to allocate 12% of their annual lending portfolios to microfinance. Of this 12%, 70% should be allocated to rural areas for financing crop production, livestock production, fisheries and non-agricultural activities. The objective of Sudan's microfinancing initiative is to improve livelihood conditions of poor households through better access to credit for making needed agricultural and non-agricultural investments, leading to greater food security and enhanced living standards. Micro-finance Institutions have been established across all 18 states.

One of the biggest challenges is that microfinancing products and services from formal providers are not well customized to suit the needs of local communities, thus giving an advantage to informal providers. From a climate change perspective, another issue is that microfinancing products are not linked with adaptation technologies which have been proven to improve productivity and increase resilience against extreme weather events. Micro-finance and adaptation technologies are strongly linked since a) better access to rural credit enables rain-fed farmers and pastoralists to purchase the equipment which can help build their resilience to climate change (e.g., rainwater harvesting equipment, more drought-tolerant seeds) and b) by using technologies which are more climate-resilient, farmers and pastoralists are more likely to not default on their loan repayments.

1.1.9. Agricultural Research and Climate change

Agricultural research, which is under the responsibility of the central government, has been under-funded for decades. The annual budget allocated to Agricultural Research Corporation (ARC), the Animal Resources Research Corporation (ARRC) and universities is only about 0.3 percent of GDP. About 28% of Sudan's agricultural researchers were involved in crop research, 25% in livestock research, and 8% for forestry and natural resources.

The ARC is the principal research arm of the government on agriculture, in addition to the universities. Despite difficulties, ARC still has a staff of 446 researchers (MSc & PHD) distributed in 10 research centers and 25 research stations. Sudan's research on rain-fed crops is relatively understaffed compared with research on irrigated crops. The country's livestock researchers concentrated primarily on sheep and goats (20%), poultry (10%), and beef (10 %).

Research institutions in Sudan has for several decades been developing and promoting agricultural innovations aimed to deal with the changing environmental conditions. More recently the ARC released sustainable technologies including early maturing-drought tolerant crop varieties and climate-smart husbandry practices for crops and livestock. However, few of these technologies have reached the beneficiaries (limited outreach).

One of the main challenges facing agricultural research in Sudan and Technology Transfer and Extension Administration is to enhance the dissemination of the already research released sustainable technologies. The proposed project represents an opportunity for both Research and extension to disseminate these technologies through the proposed activities. The research stations in target state will participate through the budget allocated to technology and knowledge and capacity building. Table 1-5 provides an overview of research projects addressing climate change adaptation and greenhouse gas mitigation in Sudan during the past ten years.

Table 1-5: Climate change related research projects in Sudan

Project	Overall goal	Funding Agency
CarboAfrica Project: Quantification, understanding, prediction of carbon cycle, and other GHG gasses in Sub-Saharan Africa (2006-2010)	setting up a GHG fluxes monitoring network of Africa	EU-FAO
Eco-Farm Project (2007-2011)	Introduction of crop and livestock climate-smart technologies	DCG
Managing Risk, Reducing Vulnerability and Enhancing Productivity under a Changing Climate (2007-2011)	develop innovative strategies for mitigation of, recovery from, and resilience to climate-induced crises affecting smallholder farmers in the Horn of Africa	CCAA- IDRC-DFID
Climafrica Project: Climate change predictions in Sub-Saharan Africa: impacts and adaptations (2010-2014):	Assess climate impacts in key sectors of SSA livelihood and economy, especially water resources and agriculture	EC-FP7 - FAO
Enhancing climate change adaptation in agriculture and water resources in the greater horn of africa (2011-2014).	strengthening (NAPAs) through economic analysis of adaptation investments that is informed by credible and scientific assessment of climate change impacts.	AARC-IDRC
6. Enhancing the Adaptive Capacity of Smallholders through Response Farming (2013)	Improved response option based on seasonal climate forecasts to cope with impacts of climate variability	ASARECA
Climate Change and Adaptive Production Technology Package for Crop and Livestock Production in Kordofan Region (2012-2014)	Introduction of package of climate change adaptive technologies to overcome the negative impacts of climate change	DCG
8.Improving the livelihoods of rural communities in the nile valley and sub-Saharan africa region: "Sustainable Crop and Livestock Management" (2012-2013)	Enhance food security, livelihoods and adaptive capacity of resource poor farmers to cope with climate variability and change in the dry areas of the world.	IFAD - ICARDA

1.2. Targeted Area background: Specific development context & challenges

1.2.1. Rationale for selection of project intervention sites

Several climate risk assessments were conducted over the period 2003 through 2015 to identify communities and areas in Sudan that are the most vulnerable to climate change and where there is urgent need for adaptive responses to increasing climatic variability (INC, 2003; START, 2005; NAPA, 2007; NAP, 2015; NAPA Follow-up, 2015). Some of these assessments (i.e., NAPA follow-up, 2015) also acquired evidence regarding the specific types of interventions that demonstrated an increase in the resilience of small holder farmers and pastoralists to climate-related impacts (e.g., erratic rainfall patterns). A summary of the core conclusions of these climate risk assessments is provided in the bullets below.

- *Most vulnerable people groups.* Small holder farmer and pastoralist households throughout Sudan represent the single most vulnerable communities to climate change
- *Most vulnerable regions.* Of the five major regions of Sudan, the most vulnerable small holder farmer and pastoralist households are found in the Darfur, Kordofan, Eastern and

Nile regions. By comparison, the Central region is more resilient to climate change impacts because of higher levels of infrastructure and development activity.

- *Most vulnerable states.* Within the most vulnerable regions of Sudan, there are specific states where small holder farmer and pastoralist households exhibit particularly high vulnerability to climate change due to a combination of climatic (i.e., recurrent drought, erratic rainfall, extreme temperatures) and development factors (i.e., high levels of poverty, lack of access to markets, poor infrastructure).

  Notably, the drought situation in some of the Darfur states is indeed grave and is accompanied by severe socio-economic consequences. The selection of the most vulnerable Darfur states as well as the distribution of project resources were based on the results of extensive consultations that took place in the early stages of project concept development. During this consultative process, climate related risks/impacts, government extension service availability, community prioritization, ongoing resilience-building initiatives, and other factors were considered and weighed relative to population adaptive capacity in a quasi-multicriteria assessment process. The result of these field activities revealed that communities in the Darfur states should be considered a priority resulting in the Darfur states having a higher direct beneficiary share as a percentage of the total population in the project areas when compared to the overall project average. Annex B provides a summary of stakeholder consultations.

Table 1-6: Targeted regions & states for adaptation activities (source: consultative meetings)

Region	No.	State
Darfur States	1	North Darfur
	2	**West Darfur**
	3	South Darfur
	4	**East Darfur**
	5	**Central**
Kordofan States	6	North
	7	**South**
	8	**West**
Eastern States	**9**	**Kassala**
	10	Al Gedarif
	11	**Red Sea**
Nile States	**12**	**Northern**
	13	River Nile
	14	**Khartoum**
Central States	15	Al Gezira
	16	Blue Nile
	17	White Nile
	18	Sennar

Based on the climate risk assessments, a total of nine (9) specific states were identified as meriting high priority for adaptation interventions to increase the resilience of small holder farmer and pastoralist households to climate change. These specific states to be targeted by the proposed project are identified by red-shaded cells in Table 1-6. The subsections that follow provides details about the demographic, climatic, ecological, and development profiles of these targeted locations for project activities.

1.2.2. Overview of target areas

As indicated above, of Sudan's five major ecological regions, there are four (4) which have been identified through the climate risk screening process as representing suitable target regions. Within these regions, nine (9) of Sudan's 18 states are suitable for establishing the spatial extent of project interventions. Background physical and socioeconomic information for these states is indicated in Table 1-7. Major characteristics regarding livelihoods, production systems, and resource constraints for the states in the four targeted regions are briefly summarized in the bullets below. Additional background details about the states where project activities are proposed is provided in Annex A.

- *Darfur states:* Three states are targeted by the project: West Darfur, East Darfur, and Central Darfur. Traditional agriculture is the most important form of production in these states. It is characterized by various types of small-scale sedentary cultivation and

pastoralism. Integration of animal and crop production is traditionally practiced. Water is the most important resource limiting agricultural productivity and human settling. The southern part of the targeted area is characterized by the availability of several seasonal water courses that are comparatively water-rich, which offer possibilities for irrigated small-scale potential for fruits and vegetable production.

Table 1-7: Targeted regions & states (Elbashir and Hamid, 2014)

Region	Name	Population	Area (ha)	HDI
Darfur States	West Darfur	754,710	2,300,000	0.53-0.54
	East Darfur	1,213,784	5,500,000	N/A
	Central Darfur	553,515	3,400,000	N/A
Kordofan States	South Kordofan	867,918	7,947,000	0.53-0.54
	West Kordofan	1,419,983	11,137,300	N/A
Eastern States	Kassala	1,789,806	3,671,000	0.55 - 0.59
	Red Sea	1,396,110	21,888,700	0.55 - 0.59
Nile States	Northern	699,065	34,876,500	0.60 - 0.71
	Khartoum	5,274,321	2,214,200	
	Targeted area total:	**13,969,212**	**92,934,700**	**0.53-0.71**

- *Kordofan states:* Two states are targeted by the project: South Kordofan and West Kordofan. Livelihoods in these states are based on small scale rain fed traditional production systems of cropping and animal husbandry. Animal husbandry is carried out on natural rangeland and crop residues. Many of sedentary farmers on the sandy soils in the South and western Kordofan incorporate production of gum Arabic (acacia Senegal) into their long-term crop production. Household gardens for vegetable production are widely practiced, especially, in South Kordofan. Sedentary rural population and nomads constitute more than 75% of the population.
- *Eastern states:* Two states are targeted by the project: Kassala and Red Sea. About 50% of the Red Sea State is occupied by volcanic rocks alternating with seasonal water courses. Urban population estimates are 62%. The main livelihood groups in the state are pastoralists found across the state primarily in settlement by streams and seasonal water courses. Other livelihood sources are agriculture and fisheries in coastal areas. Consistently dry conditions have destabilized traditional livelihoods. Small scale irrigated horticulture production is widely practiced depending on pumping of groundwater.
- *Nile states:* Two states are targeted by the project: Northern and Khartoum. Most of the population in these states is engaged in intensive, irrigated agricultural production along both banks of the Nile and its vicinity, areas where the water table is enabling reliance on shallow surface wells. In Khartoum State, horticultural and forage production is dominant. Nomadic tribes herd their animals along the wadis (seasonal streams). With exceptional riverain ecosystem most of the area lies within the desert and semi desert ecological zones.

1.2.3. Feasibility assessment of potential target localities and villages

The feasibility of implementing project interventions in rural areas of Sudan was assessed by undertaking consultative workshops and surveys in potential project locations. Details regarding the assessment, including the rationale for site selection for the consultative meetings, are provided in Annex B. National experts from the HCENR conducted these meetings over the period 10 July to 20 August 2016 in the following four central locations:

- El Fula in West Kordofan;
- Port Sudan in Red Sea State;
- Dongola in the Northern State; and
- Khartoum.

Consultations included representatives from each of the nine states participating. The El Fula workshop involved stakeholder from West and South Kordofan; the Port Sudan workshop included representatives from Kassala and the Red Sea State; the Dongola workshop included representatives from the Dongola, Mawawi and Al Dabaha localities; and the Khartoum workshop included representatives from West, Central, and East Darfur, as well as rural areas around Khartoum. In addition to defining the scope and locations of the adaptation interventions, the workshops helped to define modalities of stakeholder engagement and projected roles/responsibilities during project implementation.

At the institutional level, the stakeholder consultation workshops brought together key local officials from agriculture, livestock and water sectors, farmers associations, agricultural extension workers, forest corporations, range and pasture administration, scientists affiliated with regional research institutions, and state government institutions dealing with climate change adaptation issues. Commitments were secured from these stakeholder entities to participate in project activities through in-kind contributions of their technical expertise and logistical support functions.

At the beneficiary level, the stakeholder consultation workshops brought together village leaders, women, and subsistence farmers/pastoralists. The consultations provided opportunities to share experiences and knowledge related to climate change adaptation and activities, as well as to outline project activities and engagement required as a condition for participation. Commitments were secured from these stakeholders to participate in project activities through a range of in-kind contributions including land set asides for vegetable gardens, shelterbelt construction, and rangeland protected areas, as well as commitments to local training workshops regarding alternative crop rotation schemes, modified cultivation practices associated with drought resistant seeds, pest management plans, and other project interventions.

1.2.4. Overview of targeted localities and villages

Based on the results of the consultation process, the specific localities, villages, and total number of targeted households per state was established. A brief description of the major targeted state characteristics, together with key dimensions of vulnerability to climate change, is provided in the sections and bullets below, together with an overview of the number of targeted households and their current livelihoods.

Darfur states: The three Darfur states occupy the far west of Sudan, extending between latitudes 8°20'N and 20°0'N and between longitudes 21°52'E and 25°45'E, with a total area of 490,000 km², representing 25% of the total area of the country.

- *West Darfur:* West Darfur is characterized by great environmental diversity with seasonal valleys that can sustain forests, rangelands, and agriculture. About 80% of the state's economy is based on cash crops and livestock production. Nevertheless, the state has a history of chronic food insecurity - it is the most food insecure region in Sudan with greater than 40% of the population unable to obtain a health daily diet. Future projections of increasing temperatures, reduced rainfall, and recurrent drought suggest that crops yields will continue to decline and rangelands will continue to degrade, thus deepening food insecurity in the absent of effective adaptation. A total of 2,829 households in 5 villages in the Genana and Krenik localities are included in the project. Traditional agriculture is the most important form of production and characterized by various types of small-scale

sedentary cultivation and pastoralism. Integration of animal and crop production is traditionally practiced as is horticulture along seasonal streams.

- *East Darfur:* East Darfur is largely characterized by nomadic tribes facing acute water scarcity. Increasingly rainfall variability has led to serious rangeland degradation and in some cases, the disappearance of essential grasses and herbs. Nomads who rely on these resources have been forced to cope by resorting to inferior options for feeding their livestock, namely lower quality tree leaves; limited crop residues, or moving across the border to South Sudan. East Darfur has become the home for significant numbers of displaced people from other Darfur states of the region, all suffering from reduced rainfall. This has amplified the consequences of climatic change for the state and further exacerbated environmental degradation and socio-economic disruption. A total of 47,700 households in 10 villages in the El Dain, Firdous and Asalia localities are included in the project. Traditional agriculture is the most important form of production and characterized by various types of small-scale sedentary cultivation and pastoralism, with horticulture practices along seasonal streams.
- *Central Darfur:* Central Darfur is characterized by diverse climate and soils, including volcanic soils in Jebel Marra (a mountainous area) sandy, clay and alluvial soils in the different valleys traverse the state towards the west to Chad and Central African Republic. Most economic activities are focused on agriculture and pastoralism, with 80% of the population comprised of farmers and pastoralists. Communities are suffering from recurrent droughts, increasing temperature and rainfall variability, which together with high poverty rates have led to a growing misuse of resources as evidenced by overgrazing and denuding of forests. A total of 7,727 households in 13 villages in the Zalingi and Azoom localities are included in the project. Traditional agriculture is the most important form of production and characterized by various types of small-scale sedentary cultivation and pastoralism. Integration of animal and crop production is traditionally practiced. Small scale irrigated horticulture production is widely practiced by streams and seasonal water courses.

Kordofan states: The two targeted Kordofan states are situated in the mid-west of Sudan between latitudes 9°30'N and 16°30'N and between longitudes 27°0'E and 32°25'E. It covers an area of about 380,000 km², representing about 24% of the total area of the country.

- *South Kordofan:* The state is characterized by widespread poverty, lack of basic services, poor infrastructure and continued land disputes. Relative to historical patterns, average annual temperatures are expected to increase between 2.5 and 5.0 °C by 2050 while average annual rainfall is projected to decrease between 0 and 26 mm per year by 2050 (UNFCCC, 2003). While South Kordofan is less prone to drought conditions than its northern counterpart, the state is vulnerable to the impact of forced migration. That is, as agricultural regions in other parts of Sudan become less productive, South Kordofan may see an influx of climate refugees while lacking the infrastructure to accommodate rapid population growth. A total of 10,350 households in 24 villages in the El Goz and Dilling localities are included in the project. Traditional agriculture is the most important form of production and characterized by various types of small-scale sedentary cultivation and pastoralism. Small scale irrigated horticulture production is widely practiced. Forestry are important income sources.

- *West Kordofan*: West Kordofan is characterized by nomadic and transhumant tribes that concentrate in areas where water and other services are available. For farmers, higher temperatures and increased rainfall variability has led to crop failure, increased pest incidence, and out-migration by farmers. For pastoralists, lower humidity levels and higher temperatures have led to grassland degradation and animal diseases. The state has experienced diminishing levels of healthy drinking water due to lower rainfall as well as a higher incidence of certain climate-related epidemics. A total of 5,683 households in 28 villages in the Asalam, Al Nohoud, and Alsunut localities are included in the project. The local economy depends upon small scale rain fed traditional production systems of cropping and animal husbandry. There is an exclusive reliance on rainfall for agricultural production.

Eastern states: The two targeted Eastern states lie in the eastern and northern part of Sudan, extending between latitudes 12° 40'N and 22°0'N and between longitudes and 33°55'E and 37°55'E with a total area of 255,597 km², representing about 14% of the total area of the country.

- *Kassala:* Kassala is characterized by widespread poverty and lack of basic services. Roughly 85% of the population live below the poverty line and rely on traditional rain-fed agriculture. Over the past decade annual average rainfall has dropped between 67 and 425 mm per year, while increasing temperature trends mirror those of other regions in Sudan. Nevertheless, flash flooding is growing risk with frequent seasonal flooding from the Gash and Atbara rivers in the western part of the state. While floods have occurred every 6-7 years over 1970-2000. In recent decades, they have been recently occurring every 4-5 years. Drought frequency has also been increasing, with two major droughts occurring in 2008 and 2011. A total of 74,208 households in 16 villages in the Kassala, Telkuk, and Nhar Atbra localities are included in the project. Agriculture and livestock herding are the two major livelihoods Small scale irrigated horticulture production is widely practiced.
- *Red Sea:* The Red Sea state is distinguished from other states in the Eastern region as the only state with a coastline (750 km). The region supports varied and diverse coastal and marine habitats, including coral reefs, mangroves, and seagrass beds. Many species of birds and fish are supported by these ecosystems, many of which are not found anywhere else in the world. These resources also provide food and income for the communities living along the Red Sea coast. The most significant implications of climate change affecting these coastal zones are the increase in sea surface temperature and sea level rise. Rising sea levels threaten to inundate wetlands and other low-lying lands, erode beaches, intensify flooding, and increase the salinity of coastal lagoons and groundwater. In addition, water scarcity is a persistent problem across inland and coastal areas, while overgrazing is rapidly degrading rangelands. A total of 52,000 households in 15 villages in the Agig, Dordaib/Haya, and Guneb Olib localities are included in the project. The main livelihood groups are pastoralists that rely on seasonal water courses. Other livelihood sources are limited traditional cultivation and fisheries in coastal areas. The state has experienced long period of extended drought conditions, with over 90% of cereals consumed coming from other parts of Sudan.

Northern States: The two targeted Northern states extend between latitudes 15°0'N and 22°0'N and between longitudes 25°0'E and 36°0'E with a total area of 493,030 km², representing about 25% of the total area of the country.

- *Northern:* The Northern state is characterized by an economy that depends upon both irrigated and rain-fed agriculture. In this region, rainfall is typically very low, temperatures are high in the extreme, and vegetative cover is sparse outside the immediate vicinity of the Nile. Rising temperatures, decreasing rainfall, fluctuations in River Nile water levels, and increased wind speeds have combined to result in a mix of drought and flooding with adverse effects on crop yields, rangelands, animal production, and river bank erosion. Shifting climates have also hastened the arrival of new plant diseases, such as the date palm disease in the Elgab area, and new skin diseases, such as Jarab, which are not historically common in the state. While irrigated agriculture is vulnerable at all localities, hotpots for rain-fed agriculture include forests and rangelands in Marawi and Adabah localities. A total of 8,929 households in 18 villages in the Dongola, Marawi, and Al Dabaha localities are included in the project. The local economy depends upon both irrigated and rained agriculture. Nile which passes through the region from south to north. Most of the population is engaged in intensive agricultural production along both banks. Horticulture production is widely practiced.
- *Khartoum State:* Khartoum is the capital of Sudan and is in the tropical zone around the River Nile. It is characterized by rapid urban growth and the largest concentration of infrastructure. Dust storms are regular occurrences and river fluctuations threaten riverbank erosion and flooding. Increasing climatic variability have placed serious pressure on Khartoum's crop yields, rangelands, and forests. 2,347 households in 11 villages in rural areas of the Omdurman and Sharg El Nil localities are included in the project. These households are among the 20% of the population that are located in rural areas. Irrigated agricultural production along both banks of the Nile. Horticulture production is widely practiced. Commercial livestock in ranches. Grazing along seasonal streams and limited traditional cultivation and pastoralism in the eastern and northern-eastern part.

1.2.5. Detailed listing and location of target localities and villages

Based on the target location feasibility assessment, a total of twenty-three (23) localities have been selected for project interventions. Within these localities, a total of 138 village communities have been selected for project interventions. The names and coordinates of the targeted villages are indicated in Table 1-8. An indicative map of the targeted localities is presented in Figure 1-4.

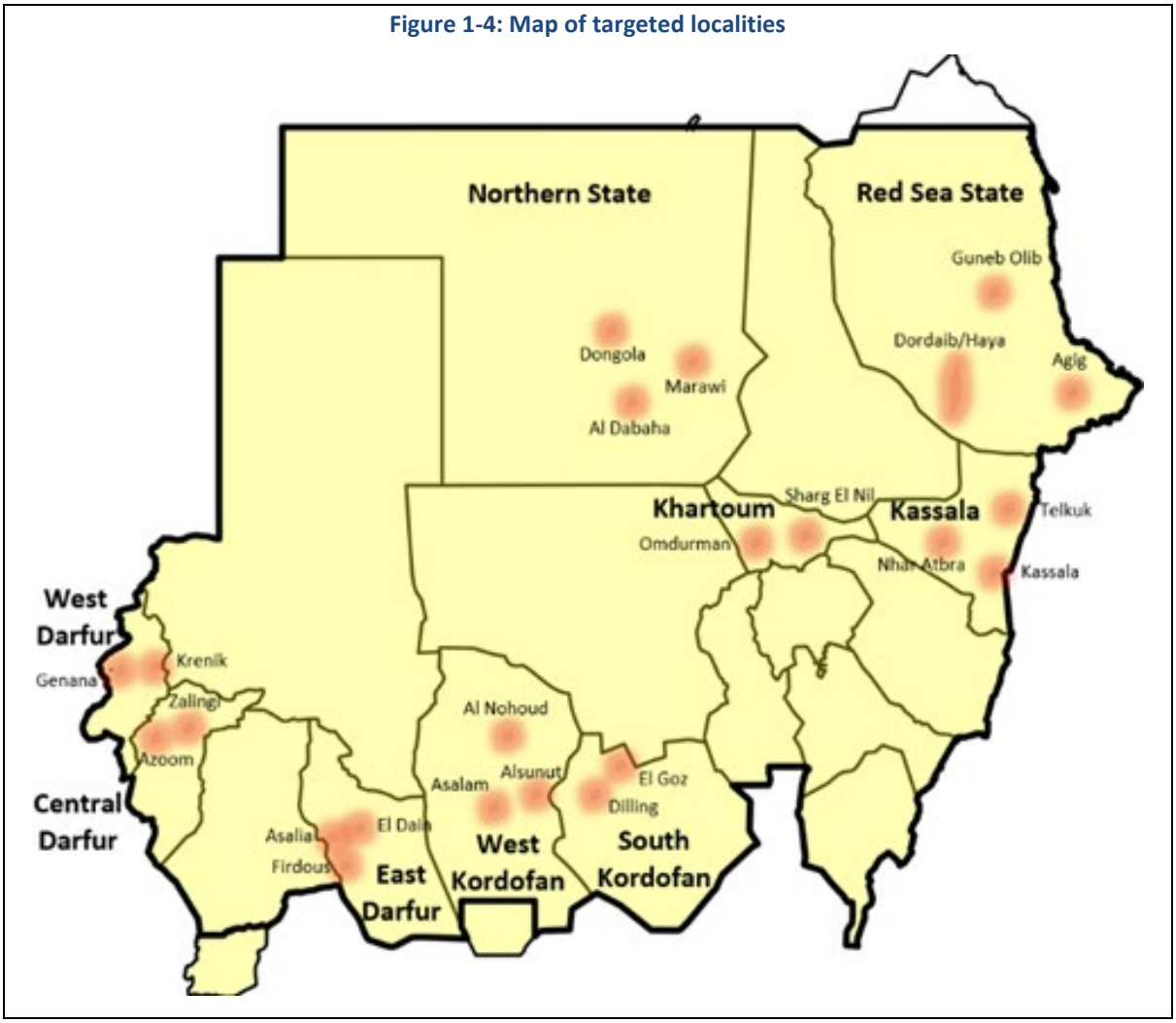
The village communities have been selected on the basis that they share certain common characteristics that render their crop production, water resource management, and pastoral activities highly vulnerable to changes in climatic conditions (see section 1.3 below for information about climate change drivers). These are briefly summarized in the bullets below:

- *Scale:* All project sites are characterized as poor small holder farmer communities that are engaged in subsistence agriculture and pastoral activities.
- *Climate variability:* All project sites are in drought-prone zones which has shown high climatic variability in recent decades.
- *Agricultural systems:* Except for the Northern States, rain fed agriculture (mechanized and traditional) is the predominant production system. In the Northern States, irrigated agriculture dominates.
- *Pastoral systems:* All three pastoral systems are practiced, namely nomadic, transhumant, and sedentary with regional variations throughout the four regions.

Table 1-8: Locations of targeted localities and village communities

Region	State		Locality		Villages	Location		Aridity classification	Rangeland classification
	#	Name	#	Name		Longitude	Latitude		
Darfur States	1	West Darfur State	1	Genana	4	22° 32′ E to 22° 5′ E	12° 47′ N to 13° 57′ N	Arid	Poor savanna
			2	Krenik	1	22° 32′ E to 23° 16′ E	13° 38′ N to 13° 10′ N	Arid	Poor savanna
			Subtotal		*5*				
	2	Central Darfur State	3	Zalingi	9	23° 30′ E to 23° 45′E	12° 30′ N to 13° 30′N	Arid	Poor savanna
			4	Azoom	4	23° 0′ E to 22°30′ E	12° 30′ N to 14° 30′ N	Arid	Poor savanna
			Subtotal		*13*				
	3	East Darfur State	5	ELdain	3	26° 15′ E to 26° 40′ E	11° 46′ N to 12° 18′ N	Semi-arid	Rich savanna
			6	Firdous	2	25° 46′ E to 26° 8′ E	11° 10′ N to 11° 45′ N	Semi-arid	Rich savanna
			7	Asalia	5	25° 80′ E to 26° 15′E	11° 30′ N to 11° 30′ N	Semi-arid	Rich savanna
			Subtotal		*10*				
Kordofan States	4	West Kordofan State	8	Asalam	9	27° 42′ E to 29° 01′ E	10° 50′ N to 12° 30′ N	Semi-arid	Poor savanna
			9	Al Nohoud	9	27° 56′ E to 28° 52′ E	12° 20′ N to 14° 07′ N	Semi-arid	Poor savanna
			10	Alsunut	10	28° 42′ E to 29° 35′ E	11° 28′ N to 12° 27′ N	Semi-arid	Poor savanna
			Subtotal		*28*				
	5	South Kordofan State	11	El Goz	12	29° 29′ E to 30° 34′ E	12° 06′ N to 12° 45′ N	Semi-arid	Poor savanna
			12	Dilling	12	29° 12′ E to 29° 58′ E	11° 39′ N to 12° 11′ N	Semi-arid	Poor savanna
			Subtotal		*24*				
Eastern States	6	Kassala State	13	Kassala	6	36° 11′ E to 36° 48′ E	15° 20′N to 16° N	Arid	Semi-desert
			14	Telkuk	5	36° 99′ E to 36° 18′ E	15° 37′N to 16° 40′N	Arid	Semi-desert
			15	Rural Nhr	5	34° 36′ E to 35° 35′ E	15° 40′N to 16° 40′N	Arid	Semi-desert
			Subtotal		*16*				
	7	Red Sea State	16	Agig	6	37° 45′ E to 38° 45′ E	17° 22′N to 18° 32′ N	Arid	Semi-desert
			17	Dordaib/Ha	3	35° 0′ E to 36° 45′ E	17° 0′ N to 18° 3′ N	Arid	Semi-desert
			18	Guneb Olib	6	35° 0′ E to 37°15′ E	18° 58′ N to 20° 40′ N	Arid	Semi-desert
			Subtotal		*15*				
Nile States	8	Northern State	19	Dongala	7	27° 36′ E to 31° 15′ E	19° 0′ N to 19° 30′N	Hyper-arid	Desert
			20	Marawi	7	31° 0′ E to 32° 48′ E	16° 35′N to 18° 45′N	Hyper-arid	Desert
			21	AlDabaha	4	27° 36′ E to 31° E	18° 15′N to 18° 40′N	Hyper-arid	Desert
			Subtotal		*18*				
	9	Khartoum State	22	Rural	5	31° 35′ E to 32° 30′ E	15° 45′N to 16° 35′N	Semi-arid	Semi-desert
			23	Rural Sharg	4	32° 30′ E to 34° 30′ E	15° 30′N to 15° 45′N	Semi-arid	Semi-desert
			Subtotal		*9*				
GRAND TOTAL					**138**				

Figure 1-4: Map of targeted localities



1.2.6. Poverty and food insecurity situation in targeted states

Poverty affects many sectors of the population in the targeted villages. A state-level poverty analysis of the 2009 National Baseline Household Survey (NBHS) concluded that poverty in Sudan is predominantly rural (CBS et. al., 2009). The analysis examined consumption trends of five main components, namely food, non-food, durable goods, housing and energy and determined the poverty line at 114 Sudanese pounds (SDG) per month. This is equivalent to about $50 per month using the exchange rate at the time of 2.33 SDG per US$1. The results of the analysis are summarized in Table 1-9.

Poverty mostly affects small-scale farmers and livestock herders in the traditional rain fed sector. In six of targeted states (i.e., West Darfur, South Darfur, East Darfur, South Kordofan, West Kordofan, and Red Sea), poverty encompasses over half of the population, with poverty gaps of around 35% and above (Bashir and Faki, 2014).

Table 1-9:Poverty profile (%) in targeted states, 2009 (CBS, et al, 2009)

Region	Name	Incidence	Gap	Severity	Poverty gap among Poor
Darfur States	West Darfur	55.6	19.8	8.9	35.6
	East Darfur	61.2	24.5	12.7	40.1
	Central Darfur	55.6	19.8	8.9	35.6
Kordofan States	South Kordofan	60.0	20.7	9.4	34.5
	West Kordofan	60.0	20.7	9.4	34.5
Eastern States	Kassala	36.3	14.7	8.0	40.6
	Red Sea	57.7	24.9	13.7	43.1
Nile States	Northern	36.2	10.5	4.2	29.1
	Khartoum	26.0	6.4	2.4	24.7

The impact of poverty is manifested by food insecurity in rural areas of the targeted states. The share of food deprived populations vary from 15% to 44%, compared to the national average of 33% (see Table 1-10). The most food insecure state is Red Sea, having 44% food deprivation incidence. Across all targeted states, the hunger gap varies from 255 to 370 kcal/person/day. The hardest hit states are Khartoum, Kassala and Red Sea states.

Table 1-10: Food security situation in the targeted states (Bashir and Faki, 2014)

Region	Name	Food Deprivation (%)	Minimum dietary energy requirement (kcal/cap/day)	Dietary energy consumption in food deprived population (kcal/cap/day)	Hunger gap (kcal/cap/day)
Darfur States	West Darfur	20	1,717	1,462	255
	East Darfur	32	1,714	1,418	296
	Central Darfur	20	1,717	1,462	255
Kordofan States	South Kordofan	27	1,734	1,478	256
	West Kordofan	27	1,734	1,478	256
Eastern States	Kassala	30	1,786	1,430	356
	Red Sea	44	1,786	1,416	370
Nile States	Northern	16	1,801	1,529	272
	Khartoum	29	1,793	1,450	343

Several malnutrition indicators for children highlight food insecurity issues in the targeted localities. Among the total children population in each state, severe acute malnutrition ranges from 4% to 15%; stunted growth ranges from 22% to 54%, and chronically low weight ranges from 20% to 49% (see Table 1-11). These results are attributed to the interaction of poverty, poor access to water and sanitation, and high disease prevalence (diarrhoea, malaria, fever, cough and others).

Table 1-11: Malnutrition profile (%) in targeted states (Bashir and Faki, 2014)

Region	Name	Severe Acute malnutrition (weight for height)	Global stunting (height for age)	Global underweight (Weight for Age)
Darfur States	West Darfur	6.7	36.6	33.1
	East Darfur	NA	NA	NA
	Central Darfur	NA	NA	NA
Kordofan States	South Kordofan	4.4	36.6	40.3
	West Kordofan	NA	NA	NA
Eastern States	Kassala	5.6	49.1	38.5
	Red Sea	14.7	54.1	49.2
Nile States	Northern	6.4	24.0	22.2
	Khartoum	3.9	21.9	19.9

"NA" indicates that data was not available at the time of the information was developed

1.2.7. Agriculture in targeted states

Across all targeted states, traditional rain fed agricultural practices covers about 9.0 million hectares, representing more than 50% of the total national cultivated land. These areas contribute about 45 % of the national grain production, two-thirds of the livestock population and support about 70 % of the total population. Traditional rain fed sector is entirely dependent on seasonal rainfall, the most critical factor for production. Farming is based on traditional systems of cropping and animal husbandry and is characterized by the following features:

- Sedentary cultivation and integration of crop and livestock production.

- Poor crop and livestock husbandry practices.
- Manual farming operations predominantly carried out by family labor using traditional hand tools.
- Little or no external inputs such as fertilizers, pesticides, herbicides, livestock medicines and improved seeds are used.
- Limited resources and poor access to markets, credit and improved production technologies.
- Fragile natural resource base and farming is carried out under risky environmental conditions.
- Very low crop yields and livestock productivity.

The major crops grown include pearl millet, sorghum, sesame, groundnut, roselle (karkade), field water melon, cowpea and a variety of other minor crops. Local crop varieties are commonly grown. Irrigated agriculture is practiced along the banks of the seasonal wadis used mainly to produce horticultural crops such as tomatoes, chillies, onions, okra, green leafy vegetables and fruits, including mangoes, guava and oranges. Yields are quite low compared to other regions in Africa and elsewhere in the world (see Table 1-12).

1.2.8. Pastoralism in targeted states

There are large livestock concentrations in the targeted states. These herds account for about two-thirds of Sudan's livestock. Overwhelmingly, pastoralism is carried out alongside traditional rain fed agriculture practices. Livestock species are camels, goats, sheep and cattle, raised in three agro-pastoral production systems, based on and the degree of settlement of households and natural and economic conditions:

- *Nomadic system:* camels, desert sheep and some goats are the main livestock species. The nomad's livelihood depends on their livestock and migrates (related to the wet and dry) in search of water and forage (purely pastoral). Seasonal movements range from 250 to 500 km and may reach 800 km in years of exceptional rainfall with browse flushes in the desert.
- *Transhumant system:* Transhumant migrates seasonally during the rainy season following traditional grazing routes to utilize seasonal grazing opportunities in the drier regions to the north and west away from biting fly and heavy mud (wet season). Seasonal movements range from 300 to 600 km. This system is mainly adopted by cattle-owning tribes "Baggara" who in addition to cattle they raise considerable numbers of sheep and goats. This system is interspersed with crop production where millet, sesame and groundnut are cultivated along the route. Cropping activities play a relatively minor role in the system.
- *Sedentary System:* includes both agronomic and livestock components and is dominated by cropping activities based on bush-fallow cultivation system.

Table 1-12: Traditional rain-fed crop yields in targeted states (kg/ha) compared to other regions: (Osman, 2001; Osman and Ali, 2009)

Region	Sorghum	Millet	Sesame	Groundnut
International	1,354	669	405	959
Africa	871	619	362	762
World drylands	800	600	500	1299
Sudan traditional sector	452	336	186	497
Research (North Kordofan)	540	350	546	180
Research (South Kordofan)	952	402	593	173

The major crops are millet, sorghum, sesame and groundnut. Livestock and crops are integrated in different proportions. Sheep and goats and sometimes cattle are used for meat and milk production and as cushion in case of crop failure.

Table 1-13: Traditional livestock productivity (%) in targeted states compared to alternative systems (El-Hag *et al.*, 2007)

Indicator	Traditional technology	Improved technology
Conception rate	60-70	97.1
Lambing rate	55	91.0
Twining rate	5.0	27.3
Ewe mortality rate	12.0	0.0
Mortality rate after birth	24.0	2.0

Livestock productivity is chronically under threat due to several climatic, environmental, and economic factors. Specifically, these factors include recurrent drought, deterioration of rangeland resources, increasing settlement, expansion in farming, limited water resources, overgrazing and blocking of stocking routes. For these reasons, traditional pastoral systems have come under acute pressure and productivity fares poorly compared to alternative, more modern systems (see Table 1-13). Major changes and intermixing have been observed such as migration distances shortened drastically and shifts from transhumance to sedentary systems.

1.2.9. Water harvesting infrastructure in targeted areas

Most of targeted states are in dry lands with rainfall as the principal source of water. Most of the sedentary inhabitants and nomadic tribes are entirely dependent on the fluctuating rains, the source for the local Wadis and Khors, which represent great risk to life and livelihood. Water is always the most prominent limiting factor for agriculture and livestock production in these states. In recent years, competition for water and pasture have become very intense leading in some cases to armed conflict.

Rain water harvesting is the most common technology and practices for provision of drinking water for human beings and animals beside limited irrigation of horticultural crops. Because of its many advantages, rainwater harvesting development programs rank among the highest government strategy for rural socio-economic development and to meet the increasing demands for water. An overview of major water harvesting/storage techniques used in the targeted states is provided in Table 1-14, with estimated capital costs shown in the right column. Experience with each has been very positive during the rainy season relative to improving available water supply. Other specific cost and performance information for these techniques (e.g., O&M costs, efficiency, etc) are provided in Section 2.3.

Lack of financial funds is one of the most important impediments facing rainwater harvesting development because current levels of government funding for rural development are being focused on other priorities (e.g., road infrastructure). Lack of capacity is an aggravating factor because at the local level there is a scarcity of human technical skills technical know-how, and enabling environments for adaptation-related activities. Together, these factors tend to reduce implementation efficiency and maintenance effectiveness, particularly for hafirs. These constraints are further aggravated by lack or few competent consulting and contracting firms experienced in the field of water harvesting. Lack of awareness of unsafe water use directly from harvested water has led to outbreaks of waterborne disease.

In addition to water harvesting storage facilities and supply viewed above the project is supporting intervention in climate change adaptation measures to increase resilience by decreasing land degradation through land reclamation investments relying on on-farm water

management techniques including water harvesting and conservation, water spreading and supplementary irrigation. Table 1-14 is depicting the various types of such techniques and their costs. Research and on-farm demonstration results with each technique have been very successful and most of the rain-fed production systems could benefit from these (ARC annual report, 2011- 2011, Response of Sorghum to Fertilization under The Water Harvesting Techniques).

Table 1-14: Overview of major water harvesting techniques (water supply) used in targeted states (Experts consultation, 2016)

Technique	General features and usage	Estimated cost
Traditional Hafir	• Most common type (manmade earth dugout reservoir) • Constructed at suitable location beside natural streams • Used for drinking purpose and little for supplementary irrigation • Size ranges from 100-150 m^3 • Supports up community of 50 HHs or 4 small adjacent farms • Opening of hafir for drinking and maintenance is decided by community • The quality of water is poor, but fit for human consumption.	• excavation cost per meter $6 on average (limited variation in cost between targeted states)
Traditional open system Hafir	• Well designed and constructed system with inlet and outlet, energy dissipater, connection pipes, slow sand filter, Water Tank and valves, and fence • Size ranges from 30,000 m^3 for small and up to 60,000 m^3 for large ones • Supports 400-500 households and up to 10 animals per household • Provides up to 20 liters/day/person in rural areas, as per WFP standards. • Regular maintenance is required with community participation and support of FFW from WFP or mechanical excavation. • Establishment of water tariff fee with community training on O&M is likely to generate enough resources for support of repair and maintenance. • Depends on the size, it could provide drinking almost throughout the dry season.	• excavation cost per meter on average $6 • for civil work cost around $20,000 per 100 m^3-sized Hafir
Improved Hafir	• Natural depression filled with water during rainy season • Naturally they are vulnerable to sedimentation and hence the project is entitled to enhance its storage capacity by removal of silt and deepening and provide allocation for control silt entry through installation of simple filtering mechanism. • Water for supplementary irrigation in small scale gardens/farms & livestock • Small modernized mobile pumps used to pump water when land is higher and gravity when land is lower than the Pond • Based on location, storage and use of water can extend to next rainy season • The pond provides low quality drinking water for human and animals, but suitable for supporting supplementary irrigation. • Community involvement in O&M is essential for sustainability of services	• Excavation cost of $6/meter • Civil work around $50,000 - $70,000 for larger sizes
Water yards	• Station of water points for human and livestock consumption • Found where underground water is accessible • Supported with pumping system and water cement tank • Constructed mostly along the livestock moving routes • Support large number of livestock population • Income of sale of water is sufficient to meet the O&M requirements	• $5,000 per borehole with accessories • Around $15,000 to $20,000 per water yard station

1.2.10. Conflict potential between agro-pastoralists and nomadic pastoralists

Competition over water resources and rangelands are important causal factors in the initiation and perpetuation of conflict in the drier parts of Sudan. Clashes might take place within or between communities on one hand, and between farmers and pastoralist on the other hand over rangeland and rain-fed agricultural land (and associated water points). UNEP's analysis indicated that there is mounting evidence that the decline in precipitation due to regional climate change has been a significant stress factor on pastoralist societies and has thereby contributed to conflict.

Moreover, available records on conflict in Darfur indicated that out of 49 recorded conflicts took place during the past decades; more than 75% of them were triggered due to high

competition over water and pasture during low rainfall seasons (UNDP, 2007; UNEP, 2009). Climate change adaptation measures are needed to cope with changing environmental conditions and to avoid clashes over declining natural resources. This will require a major investment in improving natural resources management and water availability, as well as the elaboration of new policies for the sustainable use of natural resources.

Across Sudan rural areas there is a traditional mechanism (local governance system or "native" administration) for managing natural resources, including water and grazing land. This administration is the main influential and respected governance system with is a deep rooted practiced mechanism of reconciliation tradition. This institution outstandingly contributed to peaceful coexistence between different groups and established a very long respected norms/rules for land use and tensions reduction among different resource users groups.

1.3. Climate change risks and vulnerabilities in targeted states

Households throughout the targeted states are highly vulnerable to climate change. As noted previously, they have witnessed increasingly more frequent cycles of drought and floods, with smallholder farmers being among the most vulnerable to even small variations in the climate, with major impacts on their livelihoods and food security.

1.3.1. Overview of Sudan's past climatic trends

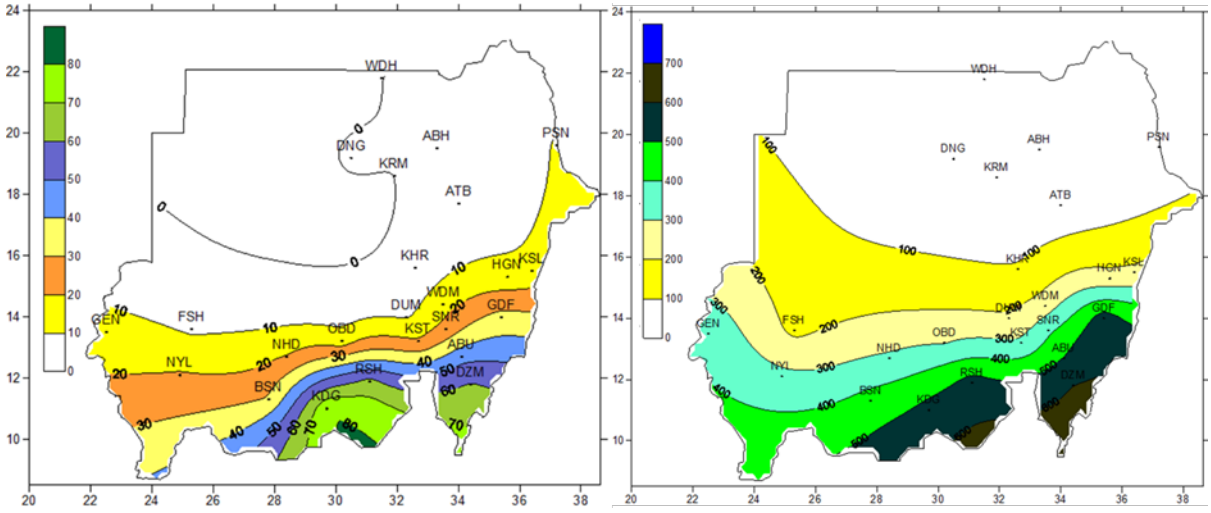
Although Sudan lies within the tropics, the climate ranges from arid in the north to tropical wet-and-dry in the far southwest. Temperatures do not vary greatly with the seasons at any location. Rainfall is the most important variable due to its importance for rained agriculture and water resources, and its high variability both across Sudan and from year-to-year. Variations in the length of the dry season depend on the dominance of two air flows- the dry northeasterly winds, mostly from the Arabian Peninsula or the moist southwesterly winds from the Congo River basin. These two air flows are separated by the ostensible Inter-Tropical Conversion Zone (ITCZ), an area encircling the earth near the equator where the northeast and southeast trade winds come together.

Rainfall trends

From December to February, the country is under the influence of the dry north easterlies. There is practically no rainfall countrywide except for a small area in eastern Sudan. Winds can occasionally bring frontal storms from the Mediterranean and the Red Sea Mountains to the northeast, and with them, occasional light rain. By early May, the moist south westerlies reach the southern parts of Sudan, bringing heavy rains and thunderstorms. By July the moist air has reached Khartoum, and in August it extends to its usual northern limits around Abu Hamad, although in some years the humid air may even reach the Egyptian border. The flow becomes weaker as it spreads north. In September, the dry north easterlies begin to strengthen and push south, and by the end of December they cover the entire country. This can be determined by the retreat of the ITCZ. The most southern parts of Sudan have an annual rainfall of about 700 mm which is spread over the four-month of June, July, August, and September. Khartoum, the capital of Sudan, has a three-month rainy season (July–September) and an annual average rainfall of 161 millimeters (6.3 in); Atbara receives showers in August that produce an annual average of only 74 millimeters (2.9 in). Average seasonal and annual rainfall patterns are illustrated in Figure 1-5 for the period 1970 to 2000.

Figure 1-5: Overall rainfall trends (mm) in Sudan, 1970-2000

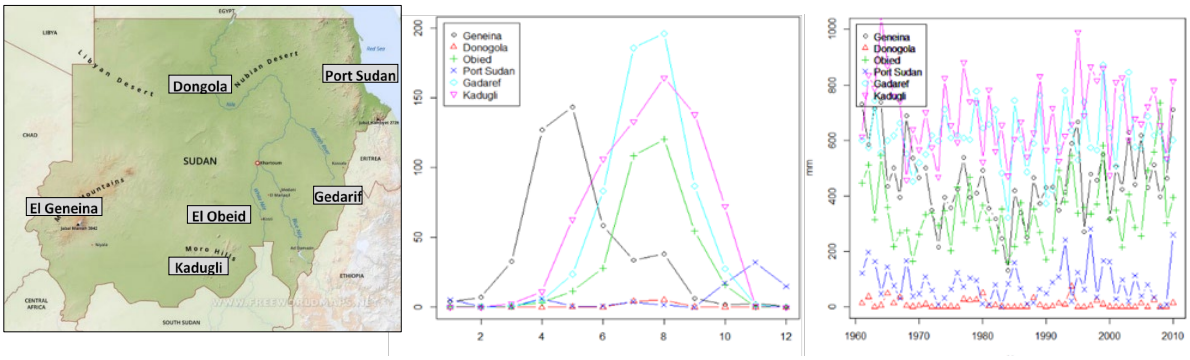
a) Average seasonal rainfall (March, April, May) **b) Average annual rainfall**



To further explore rainfall patterns near the targeted areas, six meteorological stations were selected to examine precipitation trends over Sudan for the period 1961 through 2010. These stations are located on the map in Figure 1-6a highlighted in boxes. These stations reflect the diverse climate of the targeted localities, from the dry desert of the North to the sub-tropical regime of the south. Figures 1-6b and 1-6c show the monthly average precipitation (left) and total annual precipitation (right), respectively, for these same stations for the historic period, showing the strong seasonality, clear north-south gradient, and very high inter-annual variability.

Figure 1-6: Rainfall trends (mm) in Sudan average over specific meteorological stations, 1961-2010

a) Meteorological stations **b) Average monthly rainfall** **c) Average annual rainfall**



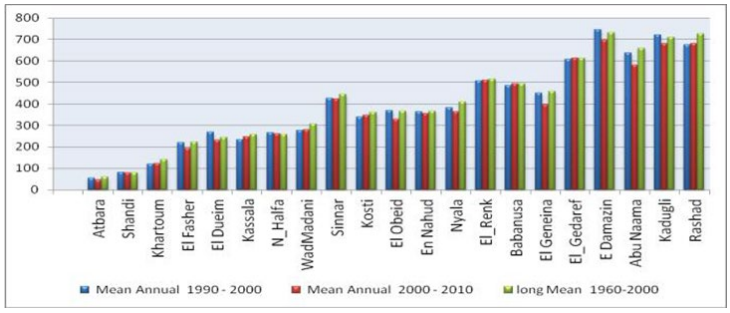
Notably, there has been a steady decline in precipitation in the areas around the Darfur States where the data record from the meteorological station indicates that rainfall has been declining by about 5.12 mm per year on average. Other targeted areas such as Khartoum and South Kordofan show similar rainfall patterns (decline of 4.90 and 3.99 mm per year, respectively) from the beginning of the data record to the last year of the data record. These trends are reflected by mean annual rainfall isohyets. A comparison of the isohyets for the two periods 1941-1970 and 1971-2000 show that they have shifted southward by hundreds of kilometers (Abdalla, 2011). More recently, Mohamed et al (2014) analyzed southward shifts in isohyets using rainfall station data and isohyet maps. Annual rainfall for the periods 1990-2000 and 2000-2010 were compared with long term mean rainfall (1960-2000) in Figure

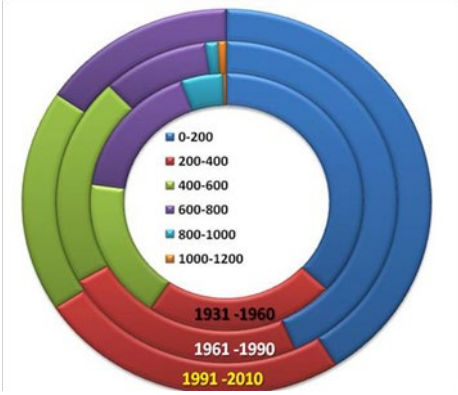
1-7 (top) resulting in calculated changes in areas of different rainfall zones as shown in Figure 1-7 (middle). Finally, these changes in the areas experiencing different rainfall zones (i.e., different intensity ranges) result in a retreat of the desert boundary (i.e., the 200mm isohyet) to the south, primarily in the central regions of Sudan, as shown in Figure 1-7 (bottom). Specifically, the southern limit of Desert and Semi-desert boundary retreated southwards by an average of 186 km between the earlier and later periods.

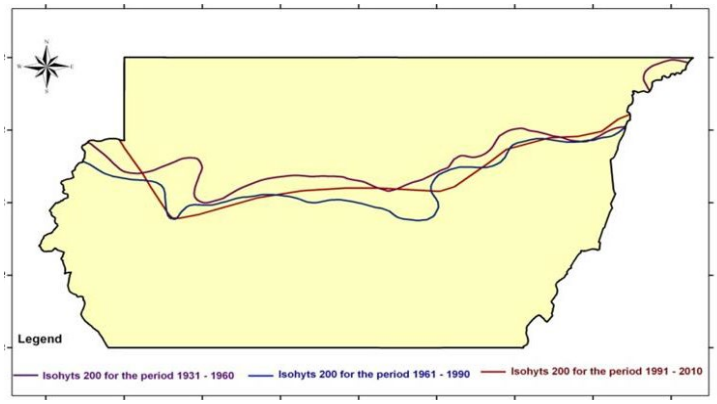
It is important to note that the above results are also confirmed in recent work by FEWS-NET, USGS and University of California Santa Barbara (Funk, et al., 2011). These authors report that summer rains had declined by 10-20% since mid 1970s and an observed 1 degree Celsius warming in Sudan was the equivalent of a further 10-20% reduction in rainfall for crops. They also showed the observed and projected southward movement of the 500mm isohyet (see Figure 1-8).

While the above studies show that movement of the desert boundary impinges on semi-arid zones where livestock grazing and crop production take place, the studies do not attempt to establish a direct link between these rainfall change patterns to changes in grazing patterns at different sites in the region of southward-migrating migrating isohyets.

Figure 1-7: Top: Annual rainfall for the periods 1990-2000 and 2000-2010 compared with long term mean rainfall (1960-2000); Middle: Calculated changes in areas of different rainfall zones; Bottom: Retreat of the desert boundary (200mm isohyet) to the south (source: Mohamed et al, 2014)







Mohamed et al (2016) undertook a rainfall trend analysis for a larger sample size of meteorological stations in Sudan. Digital datasets of rainfall were collected from the Sudan Meteorological Authority for 21 meteorological stations shown in Figure 1-9 for the period 1990 to 2010. These datasets were analyzed to develop mean annual rainfall for each of three study periods, as follows:

- Long-term period: This is a 40-year period from 1960 to 2000 to establish a baseline for average annual rainfall across Sudan;
- Decadal period #1: This is a 10-year period from 1990-2000 to establish average annual rainfall during that decade across Sudan; and

- Decadal period #2: This is a 10-year period from 2000-2010 to establish average annual rainfall during that decade across Sudan.

Figure 1-8: Location of the 500mm isohyet: 1960–1989 (light brown), 1990-2009 (dark brown), and 2010-2039 (predicted, orange) (source: Funk et al, 2011)

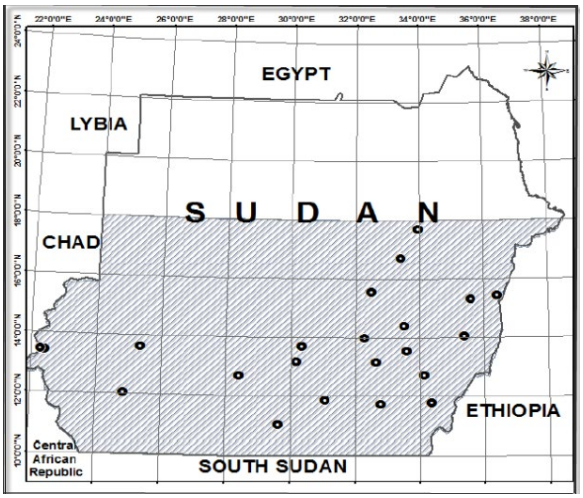
Figure 1-10 provides a graphical summary of the results of the analysis. Compared to the 40-year historical period, average annual rainfall has been declining throughout Sudan as follows:

- During decadal period #1 (1990-2000), 15 out of 21 meteorological stations showed a statistically significant decline in average annual rainfall, with an average drop of 9.3 mm per year (see Figure 1-10a).
- During decadal period #2 (1990-2000), 20 out of 21 meteorological stations showed a statistically significant decline in average annual rainfall, with an average drop of 23.4 mm per year (see Figure 1-10b). This is about 2.5 the decline in rainfall for the previous decade which signals an intensification of lower rainfall trends.

Temperature trends

Temperatures are highest at the end of the dry season when cloudless skies and dry air combine to make them quite high. To the south, with only a short dry season, temperatures are more uniform throughout the year. In Khartoum, the warmest months are May and June, when average highs are near 41 °C, with temperatures reaching 48 °C. In Northern Sudan, with its short rainy season, hot daytime temperatures persist year-round, except for winter months in the northwest where there is precipitation from the Mediterranean in January and February. Conditions in highland areas are generally cooler. Hot, daytime temperatures during the dry season throughout central and northern Sudan fall rapidly after sunset. Lows in Khartoum average 15 °C in January and have dropped as low as 6 °C after the passing of a cool front in the winter. Figure 1-11 summarizes average maximum (top) and minimum (bottom) temperatures for summer and winter during the period 1981 to 2010.

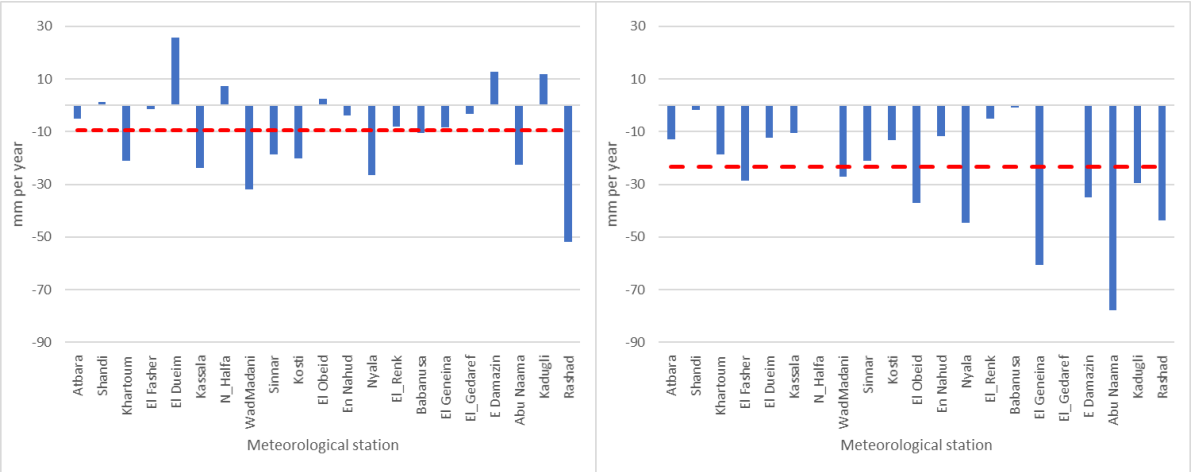
Figure 1-9: Meteorological station locations from which rainfall data was collected (source: Mohamed et al, 2016)



To further explore temperature patterns near the targeted areas, Figure 1-12 show the monthly average temperature (left) and the annual average temperature (right) for the period 1961-2000 for the same meteorological stations depicted in Figure 1-6a. The plots confirm the warm climate that dominates Sudan, with greater seasonal variation

Figure 1-10: Change in average annual rainfall in Sudan

a) 1990-2000 compared to 1960-2000 **b) 2000-2010 compared to 1960-2000**



in the northern stations that include Dongola and Port Sudan. Notably, the observed record suggests fairly strong warming trends, with only Kadugli suggesting a slight negative or cooling trend over this period.

Overall, there has been a steady increase in temperature throughout Sudan, including the targeted regions. During the March to June and June to September periods, temperatures have been increasing between 0.2°C and 0.4°C per decade, on average. The decadal trend of increasing temperature is more intense during the March to June period. When averaged across all seasons, temperatures in the 2000-2009 period are roughly between 0.8°C and 1.6°C warmer than they were in the 1960-1969 period.

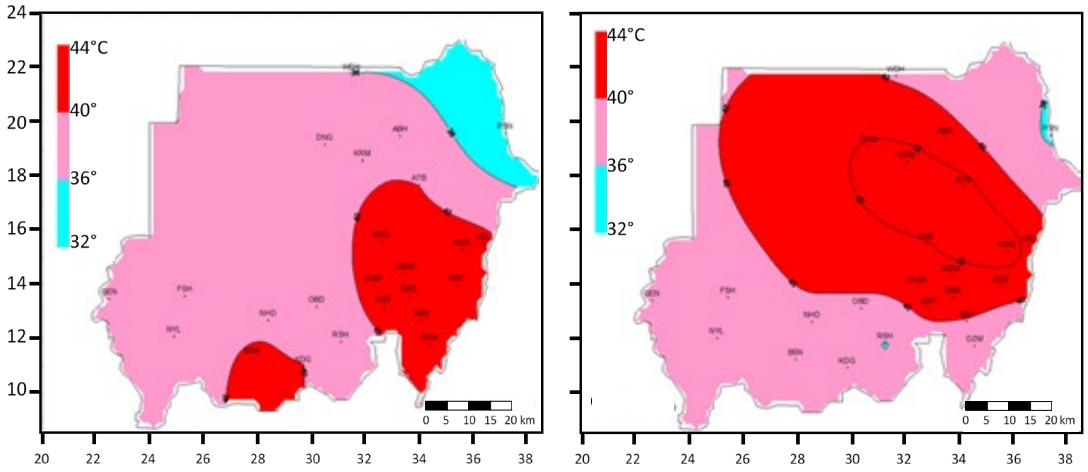
Additional Information on trends in observed climate (from both weather stations and CRU TS 4.03 data), including evidence of its impact on crop yields, is included as Annex 19g. Annex 19g presents additional analysis (to that above), including calculation of extreme indices using Climpact software for 7 stations (the 6 shown in the previous Figure 1-6a with the addition of an extra station: Kassala). However, the timeframe for the analysis is for 30 years (1990-2019), which excludes the 1970s and 1980s when droughts prevailed across the Sahelian zone of North Africa. This is shown to be important for assessing long term changes and trends for the 1950-2018 period, using CRU TS 4.03 data, are shown to provide a clearer indication of longer-term trends which may capture the effect of climate change, including changes in ET_0 and rainfall minus ET_0 as a proxy for water balance with the atmosphere.

Most extreme indicators calculated using Climpact were either not relevant to describe impacts on crops in Sudan or indicated none significant trends. As stated in Annex 19g, the main indices which are directly relevant to crop production in Sudan are:

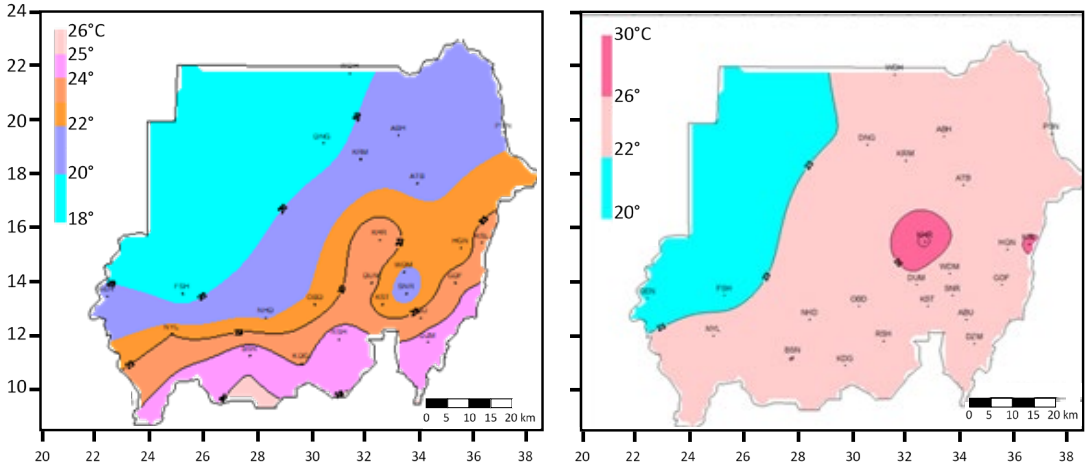
- Maximum temperatures greater than 35°C (which cause damages to sorghum and millet during the growing period);
- Shortened rainfall seasons which do not allow crops to reach maturity and which are inversely proportional to the length of the dry season (CDD); and
- Drought indices which measure rainfall – evapotranspiration for 3-month and longer periods.

Figure 1-11: Average temperature trends (°C) in Sudan for April, May, and June, 1981-2010

a) Average maximum summer temperature **b) Average maximum winter temperature**



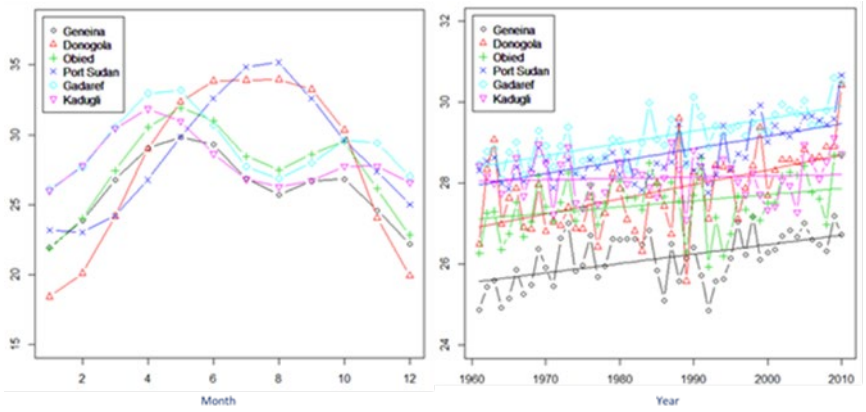
a) Average minimum summer temperature **b) Average minimum winter temperature**



Whilst there were mixed trends (both positive and negative) between stations (for the 1990-2019 period), over 50% of stations show indications of increases in the frequency with which maximum temperatures exceeded 35°C, increases in the length of the dry season, and decreases in SPEI (increasing drought). The CRU data for the longer period (1950-2018), however, clearly indicated that all regions had suffered statistically significant and consistent (between regions) increases in maximum daily temperatures, and decreases in P-ET_0 as an indication of increasing drought risk.

Figure 1-12: Temperature trends (°C) in Sudan average for specific meteorological stations, 1961-2010

a) Average monthly temperature **b) Average annual temperature**



Reductions in rainfall during the shoulder seasons (MAM and SON) are also consistent with the trends for increasing CDD over the recent 1990-2019 period.

Correlations of rainfall and maximum temperatures with sorghum/millet yields shown in Annex 19f suggest that crop yields would have declined in response to the observed trends in climate. This is confirmed in the observed significant declines in crop yields between 1970-2001 (see Annex 19f).

1.3.2. Overview of Sudan's future climatic projections

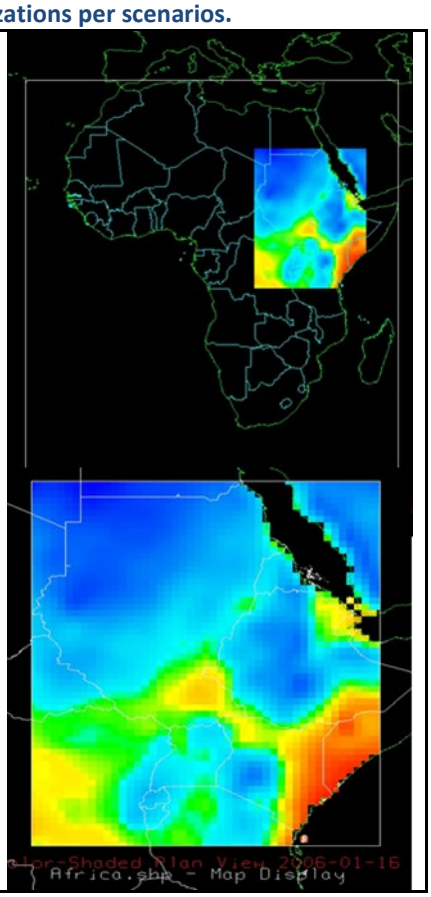
To project Sudan's future climate, the Coupled Model Intercomparison Project, Phase 5 (CMIP-5) data was acquired and processed over a region of Eastern Africa, that includes Sudan and other regions important for Sudan's climate, such as the Ethiopian Plateau. CMIP-5 is a framework for coordinated climate change experiment comparison (http://cmip-pcmdi.llnl.gov/cmip5/), where coupled atmosphere-ocean general circulation models allow the simulated climate to adjust to changes in climate forcing, such as increasing atmospheric carbon dioxide. CMIP began in 1995 by collecting output from model "control runs" in which climate forcing is held constant. Later versions of CMIP have collected output from an idealized scenario of global warming, with atmospheric CO2 increasing at the rate of 1% per year until it doubles at about Year 70.

CMIP-5 adopts the concept of the Representative Concentration Pathway (RCPs). The RCPs describe a wide range of potential futures for the main drivers of climate change: greenhouse gas and air pollutant emissions and land use, consistent with the 2°C global warming target by mid-century. Currently available climate scenarios available at temporal and spatial scales commensurate with regional hydrologic, agriculture and hot-spot modeling for Sudan were collected as shown in Table 1-15, with the spatial extent of the data collection illustrated by the maps on the right side of Table 1-15. Average annual temperature and total annual precipitation were extracted for the grid cell that corresponds to each of the six stations, for the period 1950 to 2100 for the GCMs and RCP scenarios shown in Table 1-15.

The CMIP-5 data have been downscaled for the Sudan region using the Bias Correction and Spatial Disaggregation method (BCSD; Wood et al., 2004) to develop a monthly, gridded time series of CMIP-5 global climate model (GCM) data for the period 1950 to 2100. The BCSD technique resamples a month of historical weather at a time, and was used to generate monthly 50 km grids of precipitation and minimum and maximum temperature over Sudan and portions of Ethiopia to encompass the source water of the Blue Nile River Basin. The Princeton Climate data archive was used to represent "observed" data over Sudan (Sheffield et al. 2006), and compared the generated time series to the six stations near the target localities with relatively long historic records. The Princeton dataset blends reanalysis data with observations and disaggregates those estimates in time and space, thus providing near-surface meteorological data for driving land surface models and other terrestrial modeling systems.

Table 1-15: The CMIP-5 GCMs that were downscaled to 12-km spatial resolution on a monthly timestep. The numbers in each column represent the number of realizations per scenarios.

Model Name CMIP-5	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
ACCESS		1		1
bcc-csm1	1	1	1	1
BNU-ESM	1	1		1
CanESM2	5	5		5
CCSM4	5	5	**5**	5
CESM1-BGC		1		1
CESM1-CAM5	3	3	3	3
CMCC-CM		1		1
CNRM-CM5		1		5
CSIRO-Mk3-6-0	10	10	10	10
EC-EARTH	2	2		2
FGOALS-g2	1	1	1	3
FIO-ESM	3	3	3	3
GFDL-CM3	1	1	1	1
GFDL-ESM2G	1	1	1	1
GFDL-ESM2M	1	1	1	1
GISS-E2-R	1	5	1	1
HadCM3/GEM2	4	8	4	4
IPSL-CM5A-LR	3	3	1	4
MIROC4h/5/E	2	5	2	2
MPI-ESM-LR/MR	4	4		4
NorESM1-ME/M	2	2	2	2



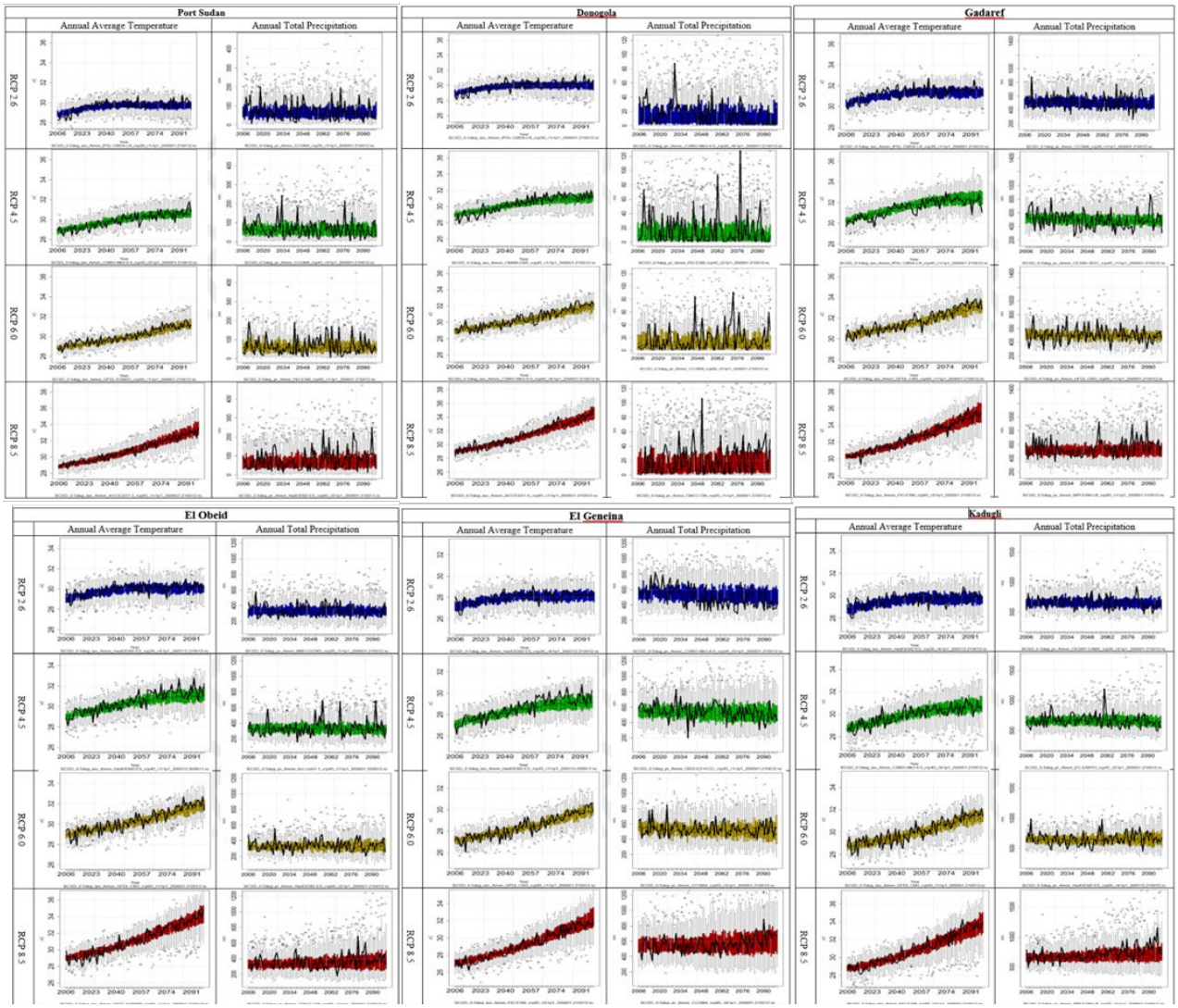
The output of the analysis is maximum and minimum temperature (Tmin and Tmax) and total monthly precipitation (Ptot) data from each GCM cell centered within the study region. Each cell centered value was treated individually for purposes of bias correction. For bias removal, a quantile-based mapping is performed from the GCM model climatology to the observed monthly climatology for each variable (Tmin, Tmax, and Ptot). For the bias correction step, the observed climatology was derived from the Princeton Dataset for the period 1961 through 2010, re-gridded and averaged to the GCM grid resolution. The GCM climatology was taken from modeled temperature and precipitation from the simulations for the same period as the historic period (1961 to 2010). The mapping from GCM to observed climatology was subsequently applied to the GCM raw output, translating it to a plausible range with respect to historical observations. The mapping was performed at the resolution of the GCM output, hence the adjustments vary spatially at the GCM grid scale and by month.

Spatial disaggregation imposed sub-GCM grid scale spatial variability on the bias-corrected, GCM-scale forcings. The monthly time step, bias-corrected GCM- scale scenario time series were spatially interpolated to the 0.5° grid cell centers. Anomaly fields (multiplicative for Ptot, and additive for Tmin and Tmax for each calendar month), were developed from the observed climatological monthly means (for Tavg and Ptot) and were applied to the resulting 1 -degree monthly variable fields as follows: (a) observed monthly mean Tmin and Tmax, and Ptot 1975 to 1995 averages were aggregated to the climate model scale (1.0°), and then interpolated back to the 0.5° scale, exactly as the climate model scale forcings were interpolated; (b) the differences (for Tavg) or ratios (for Ptot) between the 0.5° monthly mean Tavg and Ptot and the interpolated monthly mean fields were calculated to create the

anomaly fields. The mean monthly sets of anomaly fields so constructed, when applied to timeseries of interpolated climate model- derived fields, added spatial variability to the smooth 0.5° field created by the interpolation step. The spatial disaggregation created monthly forcing time series corresponding to the GCM-scale time series, but reflecting 0.5° scale spatial structure.

Figure 1-13 summarizes, for each of the six stations, the full dataset of GCM projections given in Table 1-15, and includes future projections of annual average temperature and annual total precipitation for the period 2006 to 2100. The data are given as box plots, with the colored portion of the plot (blue for the RCP 2.6 scenarios, yellow for the RCP 4.5 scenarios, green for the RCP 6.0 scenarios, and red for the RCP 8.5 scenarios) representing the inter-quartile range of the projected change for each year. The extremes of the box plots are the 5% and 95% interval, while the marks represent outliers of individual models, which suggests some of the extreme conditions that some of the GCM project into the future. The dark line is the projected temperature and precipitation for one of the GCMs, the Community Climate System Model 4.0 (CCSM4) model, as an example. For temperature, there are clear trends regards for temperature increases across all RCPs. For precipitation, the trends are less clear, with some stations showing higher volatility (e.g., Dongola under RCP8.5), other stations

Figure 1-13: Future projected temperature (°C) and precipitation (mm) for 6 stations in Sudan through 2100



showing a decrease in future rainfall (e.g., El Geneima under RCP4.5), and many stations showing flat trends.

1.3.3. Climate change impacts on smallholder livelihoods in targeted areas

The above patterns of projected increasing temperatures and potentially decreasing rainfall in some of the targeted areas could adversely impact soil fertility, water availability, and wind patterns. In turn, these effects are expected to lead to a decrease in future crop and rangeland productivity as the intensity and frequency of droughts, flash floods and dust storms increase. In the absence of effective adaptation, these circumstances will deepen the already high vulnerability of smallholder livelihoods in the targeted areas. Indeed, climatic change and variability are recognized as one of the major factors contributing to land degradation in Sudan. The definition of land degradation in the United Nations Convention to Combat Desertification (UNCCD) gives explicit recognition to climatic variability as one of the major factors contributing to land degradation. In the project areas, impacts from higher frequencies of extreme events such as droughts, sand storms, floods, heat waves, on land degradation has been well demonstrated, and climate change is the primary driver of the land degradation in northern parts of Sudan such as the Red Sea state and Kassala state due to the unusually prolonged drought and increased temperatures that have directly contributed to reduced soil moisture resulting and subsequent land degradation. Moreover, drought conditions and increasing temperatures have had an impact on Sudan's desert belt which has migrated 250 kilometers to the south.

The most serious impacts from climate change on smallholder livelihoods are directly linked to several key impacts, as outlined in the bullets below.

- *Shorter growing seasons:* One of the anticipated impacts of climate change on agriculture in the targeted areas is a shortened growing season. The length of the growing period is the total number of days in a year when there is enough water to support crop growth. On average, the growing season across Sudan has been shortened by about 15% in the 1991-2010 period compared to the 1961-1990 period (Kawkab, 2010). While farming systems across the targeted areas display a wide range of growing periods, around 61% have growing periods shorter than 90 days (ASARECA, 2011). With climate change, the length of the growing season is expected to decrease, potentially forcing large regions of marginal agriculture out of production. As most crops attain the highest yields in areas with prolonged growing seasons, any reduction is likely to have a significant adverse impact on crop productivity.
- *Lower sorghum productivity:* Sorghum is the most important cereal crop in the targeted areas in terms of total area cultivated, annual production and consumption levels. It leads other crops in area, occupying annually about 40% of the entire cropped area and about 80% of this is in rain-fed areas. Studies carried out by the International Crop Research Institute in the Semi-Arid Tropics (ICRISAT) on disaggregated effects of climate change on sorghum yields (table 20) indicated that in sorghum yields in West Africa are reduced by about 14%. As the whole of Sudan exhibits a similar Sahelian climate, reduction in Sorghum yields are expected. In Sudan, initial modeling of projected sorghum yields under climate change have resulted in yields lower by more than 75% (GoS, 2003).
- *Lower wheat productivity:* Wheat, the dominant food crop in Northern State, requires a strict winter temperature range, typically between 5 and 10 degrees Celsius, to initiate or

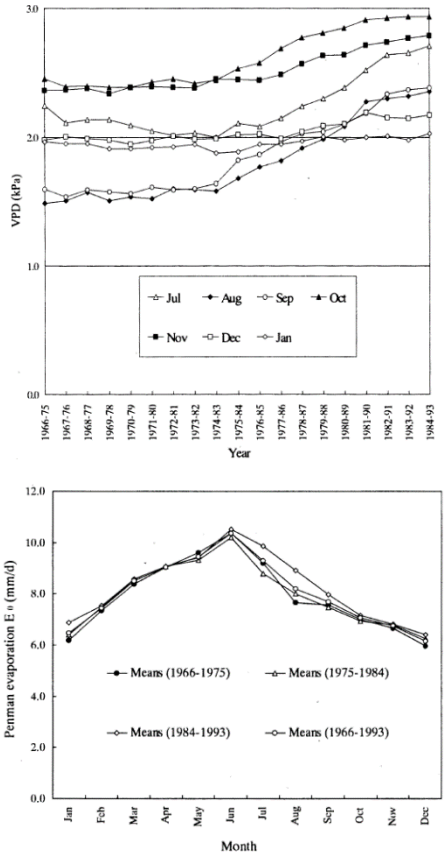
accelerate the flowering process and transition to the reproductive stage. As wheat is highly sensitive to heat, the maximum temperatures that can be tolerated by wheat varieties common in the Northern State are around 25°C, which is limited to November through March. With climate change, both maximum temperatures are projected to rise, presenting a great challenge to the continuation of wheat production. Indeed, without adequate climate change adaptation such as improved seed varieties, wheat production might no longer be possible.

- *Increased incidence of pests and diseases:* While no studies have yet been conducted in the targeted areas, there is clear evidence to suggest climate change is altering the distribution, incidence and intensity of animal and plant pests and diseases. The Old World bollworm (*Helicoverpa armigera*) is an example of a plant pest whose distribution is shifting, most likely due to climatic factors (Cannon, 1998). With climate change, new ecological niches will likely develop in the targeted areas that facilitate the establishment and spread of animal and plant pests and diseases species to new areas.
- *Lower livestock productivity:* Heat stress has direct effect on livestock performance. For females, some common symptoms are delayed maturity, the estrus cycle takes longer, and fertility signs become unapparent. For males, semen quality is adversely affected and overall fertility is reduced. Moreover, heat also affects fertilization if there are sharp temperature increases during the first five days after conception. For both sedentary and transhumant pastoral systems, the impacts over the past several decades are serious, with reductions in offspring per lifetime for cows, sheep and goats of 33%, 50%, and 31%, respectively (Eco-farm, 2012).
- *Increased water requirements:* The combination of increased temperatures and lower rainfall in the targeted areas may require an increasing need for irrigation to sustain rural livelihoods. Abdelhadi et al. (1999) studied the effect of climate variability on the calculation of crop water requirements during the period 1966-1993. During the driest period (i.e., 1984-1993) water requirements increased tremendously as the lack of rainfall and reduced relative humidity increased the vapor deficit and consequently water requirements. In certain regions of the targeted areas, it is likely that additional water will be needed for supplementary irrigation during summers.

  It important to note that the Abdelhadi et al study (1999) presents evidence for the period 1966-1993 that crop water requirements in Sudan increase significantly during dry periods due to reduced relative humidity and increased water vapour deficits (VPD) (increasing potential evapotranspiration (ET0) and hence crop water requirements). The study uses the FAO recommended Penman-Monteith method to calculate ET0 and demonstrates increases in VPD and ET0 during July, August and September (see Figure 1-14). Crop water requirements and crop coefficients are estimated from actual evapotranspiration measurements and it is shown that average ET0 for the whole period underestimates crop water requirements by 4% compared to ET0 for the later 1984-1993 period.

- *Increased land degradation:* While there are many reasons for land degradation in Sudan (e.g., local competition for resources, overgrazing, institutional coordination), land degradation in the targeted areas has been directly linked to climate change (DCG, 2013). Rainfall fluctuates and the range of low rain-fall regions and aridity expanded areas become too dry for grazing, leading to the changes in livestock movements, increasing competition for resources, and over-use of land. At present, more than two thirds of the areas experiencing severe desertification are located within the targeted areas. In the future, climate change is projected to impact desert and semi-desert boundaries by intensifying the shift southwards due to declining precipitation and increasing rainfall variability.

Figure 1-14: Increases in VPD (top) and ET0 (bottom) during July, August and September over 1966-1993



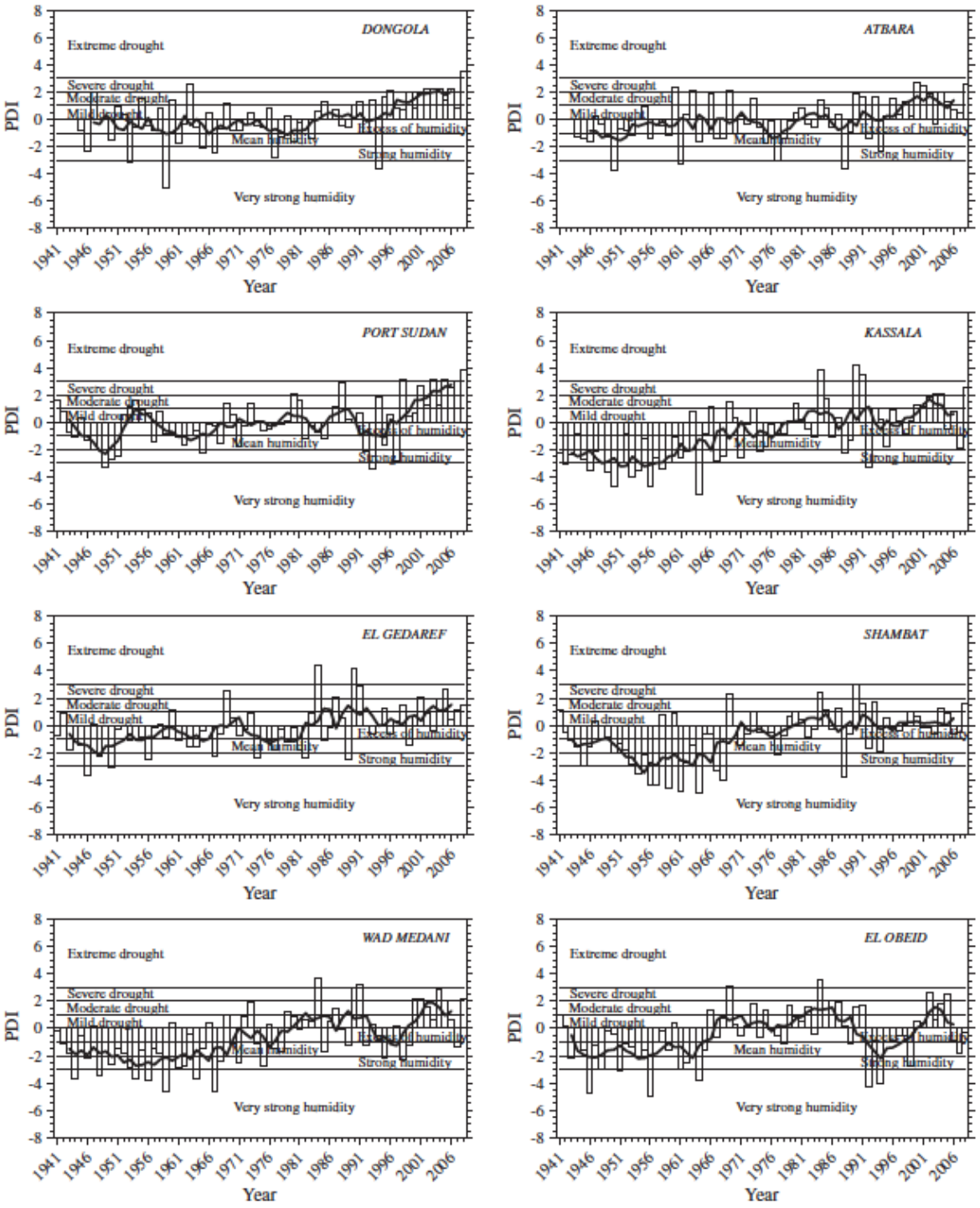
- *Increased conflict over resources:* Competition for resources in the targeted areas is caused in large part by continuing environmental degradation. That is, increasing climatic variability has led to an expansion southward of arid zones. This has been accompanied by new livestock movements which has strained the relationships and precipitated conflicts between pastoralists and farmers, particularly in Darfur (UNEP, 2007), and disrupted livestock grazing on crop by-products depriving the land of needed manure. Human settlements are also spreading to traditional pastoral reserve areas, further exacerbating dry season flexibility among pastoralists.

- *Frequency of extreme climatic shocks:* The time between climatic shocks is becoming shorter and shorter in Sudan. This is based on published observed increases in the Pedj drought index (PDI), which measures the difference between annual standardized anomalies of temperature and rainfall. The PDI was calculated for the period 1941-2008 at 14 stations covering both southern and northern Sudan (Elagib and Elhag, 2011). The timeseries of PDI for a selection of northern meteorological stations are shown in Figure 1-15. All stations show a greater tendency for positive anomalies in the later period – indicating that drought periods have become more frequent/common. This is confirmed in Table 1-16, which shows the spearman test statistic for mean, max and min temperatures, rainfall and PDI, indicating consistent and statistically significant increases (positive trends) in temperatures and PDI between 1940 and 2008.

1.4. Logic of proposed interventions in the targeted areas

The proposed project aims to build resilience of subsistence farmer and pastoral communities and physical assets and livelihoods to climate change risks through a highly innovative set of activities and adaptation measures that also show great promise for subsequent scale-up to other vulnerable communities in Sudan. The underlying logic is outlined in the subsections that follow.

Figure 1-15: Pedj drought index (PDI) over the period 1941-2008 for 8 meteorological stations across northern and southern Sudan (source: Elagib and Elhag, 2011)



1.4.1. Point of departure for proposed interventions

The proposed interventions are closely aligned with and build off Sudan's National Adaptation Programme of Action (NAPA), its forthcoming National Adaptation Plan (NAP), and past adaptation projects. Some of the key lessons from these processes that serve as a point of departure for the proposed project are summarized in the bullets below.

- *Align with local development perceptions:* Focus on grassroots action and activities that are designed to be simple and closely aligned with local needs;
- *Demonstrate clear benefits:* Focus only on those actions that have a visible impact for beneficiaries in the face of a changing climate;
- *Engage state-level intermediaries:* Involve committed State coordinators, embedded in State government, to provide continuous support and to link villages to national Project management;

Table 1-16: Spearman rho statistic (two-tailed) test of the direction of trends in the standardized climatic anomalies SAITx, SAITn, SAITm (daytime, nighttime, and mean temperatures, respectively), SAIRF (rainfall) and Pedj drought index (PDI) (source: Elagib and Elhag, 2011)

Station	SAI_{Tx}	SAI_{Tn}	SAI_{Tm}	SAI_{RF}	PDI
Southern region					
Juba	0.452[d]	0.408[d]	0.480[d]	0.063	0.277[a]
Wau	0.687[d]	0.450[d]	0.678[d]	−0.099	0.446[d]
Malakal	0.565[d]	0.196	0.432[d]	−0.131	0.316[b]
Central region					
Ed Damazin	−0.123	0.294[a]	0.192	−0.090	0.149
Nyala	0.308[a]	0.824[d]	0.693[d]	−0.230	0.599[d]
El Obeid	0.332[b]	0.420[d]	0.424[d]	−0.136	0.317[b]
El Fasher	0.316[b]	0.609[d]	0.588[d]	−0.318[b]	0.547[d]
El Gedaref	0.786[d]	0.682[d]	0.760[d]	0.193	0.452[d]
Wad Medani	0.454[d]	0.617[d]	0.582[d]	−0.335[c]	0.553[d]
Kassala	0.155	0.833[d]	0.697[d]	−0.402 [d]	0.644[d]
Shambat	0.397[d]	0.487[d]	0.431[d]	−0.299[a]	0.480[d]
Northern region					
Atbara	0.559[d]	0.256[a]	0.486[d]	−0.237	0.453[d]
Dongola	0.069	0.443[d]	0.321[a]	−0.329[b]	0.451[d]
Coastal region					
Port Sudan	0.239[a]	0.353[c]	0.376[c]	−0.255[a]	0.398[d]

[a] Significant at $0.01 \leqslant \alpha \leqslant 0.05$.
[b] Significant at $0.005 < \alpha \leqslant 0.009$.
[c] Significant at $0.001 < \alpha \leqslant 0.005$.
[d] Significant at $\alpha \leqslant 0.001$.

- *Ensure local technical oversight and accountability:* Engage multi-sector, State level Technical Committees to ensure good technical backstopping and integration;
- *Promote inter-state experience sharing:* Facilitate exchange of experiences across regions through inter-state dialogue;
- *Develop trust with beneficiaries:* Take the time needed to build trust with communities when working on natural resource management in poor and remote areas; and
- *Engage women in identifying adaptation initiatives:* Work with women in communities in rural Sudan as this can produce positive tangible results even in the more socially conservative areas.

The proposed interventions are also closely aligned with and build off the following recent initiatives:

- *LDCF financing project:* One key lesson was the importance of community dialogue/training in developing an enabling environment for climate change resilient decision-making in local communities. Another lesson was the importance and viability of flexible re-payment mechanisms associated with loan products for adaptation farming and livestock production for farmers and pastoralists.
- *CIDA resilience project:* a key lesson was that field demonstrations of viable and cost-effective adaptation options were able to generate essential knowledge on good practices that have gradually been integrated into State-level food security policies.

Moreover, project structure and proposed activities directly incorporate the lessons learned in past projects that focused on building climate resilience among agro-pastoralists, including women-headed households. Some of the specific lessons that have been directly accounted for in project design are outlined below.

- Rural water supply for domestic and small-scale irrigation using solar pumping has been readily adopted and effective in several rural settings, resulting in availability of water for agriculture and clean water for human an animal use and saving time of getting it;
- Cultivation of drought-resistant horticultural crops (e.g., introduction of new vegetables and practicing cultivation in 3 seasons instead of one season cropping system in Gerf area in Gedarif State) has resulted in improved crop productivity;
- Rehabilitation and improvement in irrigated agricultural production (e.g., in Wad Hassan village of Gedarif State) contributed to the creation of new income sources and labor opportunities, which contributed to improved socio-economic status of communities;
- Shelter belts around some farms in River Nile State demonstrably protected farms from hot wind and also created favorable microclimates, which helped to increase productivity and yields;
- Afforestation in North Kordofan State - where 7 community nurseries were established, and 53,000 trees were planted – effectively protected agricultural lands and residential areas; and
- Awareness-raising and capacity building through demonstration women's farms led to improvement in crop productivity (e.g. faba beans) in river Nile State and led to women being more oriented to climate change adaptation practices.

1.4.2. Framework for proposed interventions

The logic of proposed interventions is bounded by a framework that focuses on a range of measures intended to reduce the vulnerability of small scale farmers and pastoralist under climate change. Currently, the GoS is implementing several actions in the targeted states aimed at improving food security. These activities are summarized from Executive Program for Agricultural Revival in the following bullets for each of the nine (9) targeted states. It is important to note that these government investments do not include a climate change component or seek to address adaptive responses to increasing climatic variability.

Darfur (west, east central) and Kordofan (south, west)

- Enhancing the capacity of technology transfer and extension services using the village as a center for providing services and agricultural knowledge;
- Enhanced research systems and capacity in traditional rainfed sector in western Sudan;
- Improving availability and access to agricultural inputs in traditional rainfed sector;
- Enhancing capacity for women in agriculture by supporting activities of demonstration plots/fields, Farmers' School and Seed Multiplication Farms in conflict-affected areas;
- Legalization and development of pastoralists routes;
- Rehabilitation of the Gum Arabic Belt;
- Preparation of land use maps; and
- Support formation of qualitative producer organizations dealing with production and marketing.

Kassala, Red Sea, and Khartoum states

- Adopt participatory approach for planning and implementation of research involving beneficiaries and other stakeholders;
- Provide women with access to assets and agricultural services through short-term low-cost credit;
- Improving availability and access to agricultural inputs in traditional rainfed sector;
- Enhancing the capacity of technology transfer and extension services using the village as a center for providing services and agricultural knowledge;
- Legalization and development of pastoralists routes;
- Encourage and support formation of qualitative producer organizations dealing with production and marketing; and
- Preparation of land use maps.

The framework for the proposed interventions consists of three major pillars. First, the proposed interventions are designed to *leverage* the above ongoing governmental actions to enhance climate change coping capacity of small holder farmers and pastoralists. Second, the proposed interventions are designed to *spur* future governmental investments toward specific investments on new practices and technologies that prove effective on both cost and cultural grounds. Third, the proposed interventions are designed to *produce synergies* between local sustainable livelihoods and state-level disaster risk management strategies. Specifically, the framework integrates the following key objectives:

- Build adaptive capacity by introducing drought-resistant varieties of crops, access to water for small scale irrigation and domestic using and promoting climate resilient animal production practices.
- Enhance overall resilience of vulnerable communities as first responders of climate change-induced hazards in ways that strengthen government actions intended to increase local resilience to non-climatic risks (e.g., conflicts, lack of infrastructure, overgrazing, soil nutrient depletion);
- Integrate specific proposed climate change adaptation interventions that prove successful into national and state policy development planning frameworks,
- Develop and implement a monitoring, knowledge management and communication strategy in support of wide adoption and upscaling of proposed interventions

1.4.3. Theory of change

As noted earlier, the overall impact of the project is enhanced resilience and adaptive capacity of highly vulnerable subsistence farming and pastoralist communities in selected areas in rural Sudan. The project outcome is reduced climate risks to rural livelihoods through increased food and water security, enhanced livestock productivity, and heightened community resilience. There are three major outputs, as summarized below.

- **Output 1: Resilience of food production systems and food insecure communities improved in the face of climate change in Sudan, benefiting at least 200,000 households of farmers and pastoralists with 35% women.** This will be achieved through four activities, namely improved adoption rate of early maturing seeds, introduce sustainable practices, improve range management, and establish shelterbelts/agroforestry. The total number of people directly benefitting from climate resilient crop production packages implemented by the project will be around 850,000.
- **Output 2: Improved access of water for human, livestock and irrigation to sustain livelihoods in the face of climatic risks in the nine targeted states benefiting at least 200,000 households.** This will be achieved through three activities, namely construction of improved water storage units (i.e. water yards), establishment of sand storage dams, and construction/rehabilitation of water infrastructure (i.e., hafirs). The total number of people benefitting from water resource development packages implemented by the project will be nearly 331,000.

Output 3: Strengthened capacities and knowledge of institutions and communities on climate change resilience and adaptation. The project is designed to incorporate a sizeable training component, considered essential for realizing the paradigm-shifting potential of project activities. The training component incorporates capacity building, consultations/participation, guidance material development and will leave behind strengthened capacities for development and use of these materials (see Box 1-1). Training will be achieved through two activities, namely a) development of technical guidance documents and training of extension workers and other stakeholders regarding climate change adaptation; and b) building capacity of households regarding resilience-building practices. The total number of people benefitting from project activities are already included in the estimates for Outputs 1 and 2.The theory of change diagram (Figure 1-16) illustrates how each of the three outputs of the project contribute to the long-term objective. It also demonstrates how the resulting project impacts can be sustained, replicated and scaled up to other subsistence agricultural communities to enhance climate-proofing activities in Sudan.

Box 1-1: Training standards in Sudan

It is important to note that there are no national standards, per se, regarding the development of technical manuals/technical guidelines. Nevertheless, there is a long history in Sudan of the development of technical/training materials through project-government partnerships. Prominent national organizations that have been involved in such efforts include the Agricultural Research Corporation (ARC) research stations, the Sudanese Standards and Metrology Organization (SSMO), State Universities and colleges, and local consultancy firms. Moreover, national terms, conditions and standards set to ensure quality and effective training include:

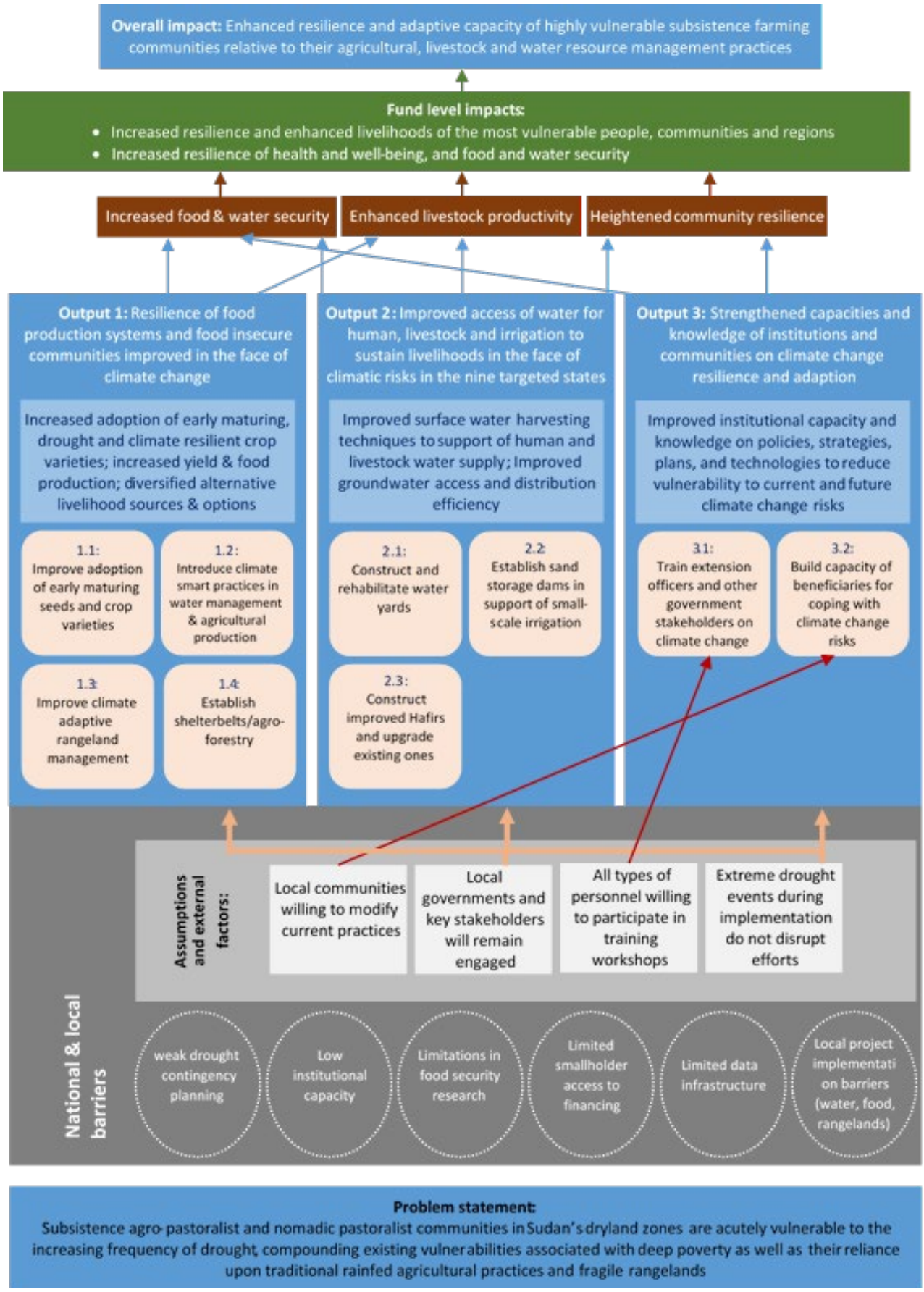
- The training will be conducted by recognized institution or authorized (registered) consultancy firms with qualified staff.
- A list of training institution staff qualifications (CVs) is available.
- The responsible or delegated organization will define the required training in accordance with the activities and tasks to be performed.
- The training institution will make every effort to provide participants with all important knowledge during training sessions, as per a previously developed training plan.
- Training is to be conducted during the dates specified and confirmed by the client.
- Training to be conducted in training institution premises, on the participant's premises, or at another mutually agreed upon location.
- The training institution will provide the infrastructure necessary for training including documents, presentations, hand-outs, reports, and studies.
- Choice of national consultants to develop technical/training materials will be subject to a rigorous competitive bidding process with well-established and transparent technical evaluation criteria.

1.5. Conclusions

1.5.1. Priority interventions

The proposed interventions focus on implementation of a set of adaptation measures that will enhance food security of smallholder livelihoods in the face of climate change. All measures aim to empower

Figure 1-16: Theory of change diagram



women and promote gender mainstreaming. Specifically, priority areas of intervention in the targeted localities and village communities are identified in the bullets that follow. Overall, the technical feasibility of each of the measures has been validated through a record of successful implementation in other rural areas of Sudan, as discussed in Section 2 Situation Analysis. A theory of change analysis has been conducted.

- Improved crop seed technologies encompassing both drought-tolerant and early-maturing seed varieties
- Improved farming practices including seed priming, fertilizer micro-dosing at time of sowing, intercropping systems, planting time adjustment, and introduction of alternative and dual-purpose crops
- Increased crop productivity through mulching, agro-forestry, intercropping, windbreaks, and increased planting concentrations.
- Better water management including drip irrigation, water storage, rainwater harvesting techniques in households and in rangelands
- Range and pasture development and management, including range reseeding, range enclosures, introduction of improved range species, water harvesting
- Livelihood support systems targeting vulnerable communities in terms of their skills development, social empowerment and income support, etc.

1.5.2. Target beneficiaries

The location and number of households (i.e., beneficiaries) have been developed on the basis on a series of consultative workshops held in areas of rural Sudan. The proposed project aims to improve the resilience against climate change of 211,773 directly-benefitting households distributed throughout the targeted localities. The duration of the effort is 5 years, with activities sequenced to maximize sharing of lessons learned from the implementation location across the targeted areas. A breakdown of direct and indirect beneficiaries per state, locality, and village cluster is provided in Table 1-17. Roughly 35% of all beneficiaries of the project are women.

Table 1-17: Breakdown of beneficiaries in targeted localities and village communities

Region	State		Project Locality		Villages	Direct beneficiaries		Indirect beneficiaries		All beneficiaries	
	#	Name	#	Name		households	Population	households	Population	households	Population
Darfur States	1	West Darfur State	1	Genana	4	1,629	10,934	3,616	24,271	5,245	35,205
			2	Krenik	1	1,200	8,400	2,664	18,648	3,864	27,048
			Subtotal		*5*	2,829	19,334	6,280	42,919	9,109	62,253
	2	Central Darfur State	3	Zalingi	9	3,065	18,388	6,804	40,820	9,869	59,208
			4	Azoom	4	4,662	27,972	10,350	62,100	15,012	90,072
			Subtotal		*13*	*7,727*	*46,360*	17,154	102,920	24,881	149,280
	3	East Darfur State	5	ELdain	3	22,100	110,500	49,062	245,310	71,162	355,810
			6	Firdous	2	16,400	82,000	36,408	182,040	52,808	264,040
			7	Asalia	5	9,200	46,000	20,424	102,120	29,624	148,120
			Subtotal		*10*	47,700	238,500	105,894	529,470	153,594	767,970
Kordofan States	4	West Kordofan State	8	Asalam	9	688	5,219	5,518	41,858	6,206	47,077
			9	Al Nohoud	9	649	3,894	5,205	31,230	5,854	35,124
			10	Alsunut	10	4,346	29,353	34,855	235,412	39,201	264,765
			Subtotal		*28*	*5,683*	*38,466*	45,578	308,500	51,261	346,966
	5	South Kordofan State	11	El Goz	12	3,000	15,000	24,060	120,300	27,060	135,300
			12	Dilling	12	7,350	36,750	58,947	294,735	66,297	331,485
			Subtotal		*24*	*10,350*	*51,750*	83,007	415,035	93,357	466,785
Eastern States	6	Kassala State	13	Kassala	6	30,000	180,000	19,500	117,000	49,500	297,000
			14	Telkuk	5	17,708	106,248	11,510	69,060	29,218	175,308
			15	Rural Nhr	5	26,500	132,500	17,225	86,125	43,725	218,625
			Subtotal		*16*	*74,208*	*418,748*	48,235	272,185	122,443	690,933
	7	Red Sea State	16	Agig	6	7,000	42,000	6,790	40,740	13,790	82,740
			17	Dordaib/Haya	3	30,000	180,000	29,100	174,600	59,100	354,600
			18	Guneb Olib	6	15,000	90,000	14,550	87,300	29,550	177,300
			Subtotal		*15*	*52,000*	*312,000*	50,440	302,640	102,440	614,640
Nile States	8	Northern State	19	Dongala	7	1,729	8,645	15,941	79,705	17,670	88,350
			20	Marawi	7	4,600	23,000	42,412	212,060	47,012	235,060
			21	AlDabaha	4	2,600	13,000	23,972	119,860	26,572	132,860
			Subtotal		*18*	*8,929*	*44,645*	82,325	411,625	91,254	456,270
	9	Khartoum State	22	Omdorman	5	1,115	5,575	10,871	54,355	11,986	59,930
			23	Sharg ElNil	4	1,232	6,160	12,012	60,060	13,244	66,220
			Subtotal		*9*	*2,347*	*11,735*	22,883	114,415	25,230	126,150
GRAND TOTAL					**138**	**211,773**	**1,181,538**	461,797	2,499,712	673,570	3,681,250

1.5.3. Target areas

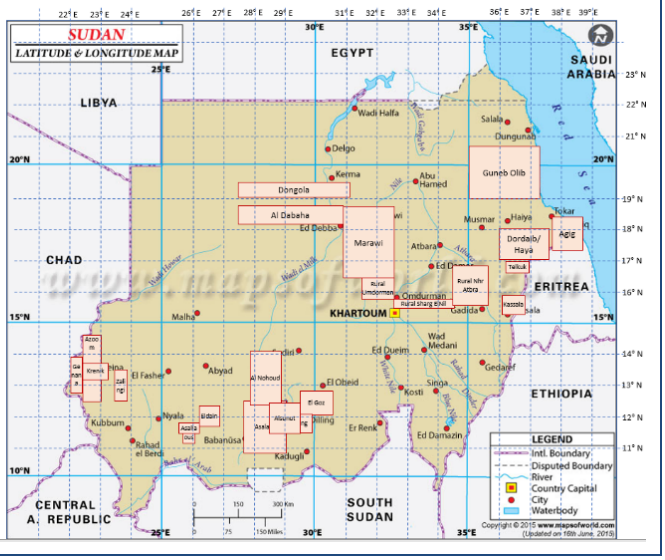
The spatial distribution of the target areas for project interventions are illustrated in Figure 1-17. The distribution of interventions within each of these project areas is summarized in Annex E.

1.5.4. Key value chains to strengthen resilience to climate variability and change.

The overwhelming majority of beneficiaries are subsistence farmers and pastoralists who are preoccupied with providing food for the household. The changing climatic and socio-economic conditions is putting pressure on subsistence farmers/pastoralists to improve their access to markets to ameliorate food insecurity and generate income to support their families.

Figure 1-17: Spatial distribution of the target areas for project interventions

State #	State Name	Locality #	Locality Name	Longitude	Latitude	Aridity Classification	Rangeland classification
1	West Darfur State	1	Genana	22° 32' E to 22° 5' E	12° 47' N to 13° 57' N	Arid	Poor savanna
		2	Krenik	22° 32' E to 23° 16' E	13° 38' N to 13° 10' N	Arid	Poor savanna
2	Central Darfur State	3	Zalingi	23° 30' E to 23° 45'E	12° 30' N to 13° 30'N	Arid	Poor savanna
		4	Azoom	23° E to 22°30' E	12° 30' N to 14° 30' N	Arid	Poor savanna
3	East Darfur State	5	Eldain	26° 15' E to 26° 40' E	11° 46' N to 12° 18' N	Semi-arid	Rich savanna
		6	Firdous	25° 46' E to 26° 8' E	11° 10' N to 11° 45' N	Semi-arid	Rich savanna
		7	Asalia	26° 15' E to 27° 15'E	11° 30' E to 11° 30' E	Semi-arid	Rich savanna
4	West Kordofan State	8	Asalam	27° 42' E to 29° 01' E	10° 50' N to 12° 30' N	Semi-arid	Poor savanna
		9	Al Nohoud	27° 56' E to 28° 52' E	12° 20' N to 14° 07' N	Semi-arid	Poor savanna
		10	Alsunut	28° 42' E to 29° 35' E	11° 28' N to 12° 27' N	Semi-arid	Poor savanna
5	South Kordofan State	11	El Goz	29° 29' E to 30° 34' E	12° 06' N to 12° 45' N	Semi-arid	Poor savanna
		12	Dilling	29° 12' E to 29° 58' E	11° 39' N to 12° 11' N	Semi-arid	Poor savanna
6	Kassala State	13	Kassala	36° 11' E to 36° 48' E	15° 20'N to 16° N	Arid	Semi-desert
		14	Telkuk	37° E to 36° 18' E	15° 37'N to 16° 40'N	Arid	Semi-desert
		15	Rural Nhr Atbra	34° 36' E to 35° 35' E	15° 40'N to 16° 40'N	Arid	Semi-desert
7	Red Sea State	16	Agig	37° 45' E to 38° 45' E	17° 22' to 18° 32' N	Arid	Semi-desert
		17	Dordaib/Haya	35° 0' E to 36° 45' E	17° to 18° 3' N	Arid	Semi-desert
		18	Guneb Olib	35° E to 37°15' E	18° 58' to 20° 40' N	Arid	Semi-desert
8	Northern State	18	Dongala	27° 36' E to 31° 15' E	19° N to 19° 30'N	Hyper-arid	Desert
		20	Marawi	31° E to 32° 48' E	16° 35'N to 18° 45'N	Hyper-arid	Desert
		21	AlDabaha	27° 36' E to 31° E	18° 15'N to 18° 40'N	Hyper-arid	Desert
9	Khartoum State	22	Rural Umdorman	31° 35' E to 32° 30' E	15° 45'N to 16° 35'N	Semi-arid	Semi-desert
		23	Rural Sharg ElNil	32° 30' E to 34° 30' E	15° 30'N to 15° 45'N	Semi-arid	Semi-desert



2. Situation Analysis – Institutional and climate change policy profile

2.1. Country Background: Institutional and policy context

2.1.1. Multi-lateral Environmental Agreements

In addition to the Climate Change Convention itself, Sudan has ratified two multilateral environmental agreements (MEAs), the Conventions on Biological Diversity and Combating Desertification, that have direct links to climate change adaptation. Many of the issues concerning climate change adaptation – ecosystem resilience, reforestation, sustainable agriculture, and increased risk from drought – are also of central concern in Sudan in the context of these MEAs. A summary of the status of each of these MEAs, together with a list of their associated national submissions is provided in Table 2-1.

Implementing the MEAs have led to activities, either in place or in development, that are potentially relevant to the institutional and climate change adaptation policy profile. The major types of initiatives are as follows:

- *Government Policies and Strategies:* These are policy responses to environmental challenges motivated by either Sudan's commitments under the MEAs or national sustainable development objectives;
- *National Programs:* these are specific measures designed to meet specific needs and objectives of national policies related to climate change, to be funded by national budget and/or bilateral donors;
- *Intergovernmental/Multilateral Processes:* these are scoping studies that address critical areas affecting or impeding adaptation within national sustainable development priorities; and

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

Table 2-1: Status of multilateral environment agreements

MEA	Ratified	Communications
Framework Convention on Climate Change (UNFCCC)	1993	• First National Communication (2003) • Second National Communication (2013) • Assessments of Impacts and Adaptation to Climate Change project (2005) • National Adaptation Programme of Action (NAPA) (2007) • National Adaptation Plan (NAP) (2015)
Convention on Biological Diversity (UNCBD)	1995	• National Biodiversity Strategy & Action Plan (1999) • 4 national reports (2009)
Convention to Combat Desertification (UNCCD)	1995	• National Action Programme to Combat Desertification (2006) • First National Implementation Report (1999) • Second National Implementation Report (2004)

2.1.2. National policies complementary to climate change adaptation

In Sudan, there are two main legislative instruments that provide a framework for climate change adaptation initiatives. These are briefly summarized in the bullets below.

- *Environmental Protection Act:* The objective of the Act is the protection of the environment and conservation of natural resources through enhancing coordination between government and other national institutions including private sectors. It was enacted in 2001 and provides a framework law governing policy formulation, subsequent legislative initiatives, and executive actions by federal and state institutions (GoS, 2007).
- *25-Year Strategy:* This Strategy sets the policy direction for all economic and social sectors, including the country's environmental strategy. The Strategy mandates that environmental issues must be embodied in all development projects (GoS, 2007). This strategy – and the ongoing/planned governmental activities in the targeted areas - is the basis by which the proposed project yields incremental benefits that are additional to current development objectives.

2.1.3. National programmes complementary to climate change adaptation

In Sudan, there are numerous programmes whose objectives are closely linked with national development priorities. These are briefly summarized in the bullets below and their mandates are described in Annex C. It is important to note that each of the programmes address sustainable development in a general sense. None of the programmes directly address climate change risks or potential adaptation responses. Hence, they are essential in characterizing the baseline situation in Sudan upon which the proposed interventions will build.

- *The Agricultural Revival Program (ARP) 2008-2011:* This is a comprehensive agricultural development package. All nine of its success pillars overlap with climate change adaptation success indicators (e.g., Addressing land tenure and land rights problems; improving agricultural support services; protecting and developing natural resources).
- *Sudan's Poverty Reduction Strategy Paper (2011-2016):* This Paper consists of four pillars: (i) strengthening governance and institutional capacity of the public sector; (ii) reintegrating internally displaced persons and other displaced populations; (iii)

developing human resources; and (iv) promoting economic growth and employment creation.

- *Five-Year Development Plans (2007–2011; 2012–2016):* The two Five-Year Development Plans serve as growth-oriented strategies with primary focus on sustainable development and poverty reduction in the medium-term. Revise
- *Three-Year Economic Salvation Programme (2012-2014):* This programme was designed to absorb the resulting shocks and impacts on the economy by implementing a package of financial and monitory policies, production improvement policies, import substitution policies and social protection policies to mitigate the effect on vulnerable communities.
- *Five–Year Development Strategy (2015–2019):* The strategic objective of this Strategy is to support realization of a sustainable and stable economy and accordingly high comprehensive and sustainable growth, which would lead to opening more employment opportunities and transforming the economy into an extensive and diversified production base. In line with this strategy the project is aligned with the current Government Economic Reform Program (2014-2019) objectives which aim to increase and diversify rural income and employment opportunities for men, women and youth. It is also in line with the overall objectives of the former Agricultural Revival Program and the Federal Government of Sudan's thrust to promote adoption of improved inputs agricultural technology by small farmers for increasing production and rural development focus. These factors will provide the project with adequate supportive conditions for successful implementation. Small scale farmers are more often than not averse to taking risks with the little resources they have such as buying inputs for a crop that may fail for lack of water. Hence, buffering the agricultural management of water resources provides viable options to these challenges while unlocking the food security potential in the target areas. The project seeks to foster sustainable agricultural water management (AWM) for increased productivity, incomes and food security in the selected landscapes of the 9 target states with innovative integrated approaches that take into consideration environmental integrity and sustainable agriculture principles. Sustainable Agriculture (CSA) seeks to enhance sustainable productivity, strengthen farmers' resilience to climate change shocks.
- *Comprehensive Africa Agriculture Development Programme (CAADP):* This Programme aims to establish strong economic growth through agriculture-led Development that emphasizes sustainable land and water management, improving market access, reducing food insecurity, and technology-related initiatives

2.1.4. National lead institutions for climate change adaptation policy coordination

The Higher Council for Environment and Natural Resources (HCENR) conducts and coordinates programmatic and policy development activities related to climate change adaptation. The Ministry of Environment and Physical Development oversees environmental policy integration and coordinates activities across governmental and non-governmental organizations.

The HCENR is the Government of Sudan's national focal point for the UNFCCC and plays an advisory policymaking role with regard to climate change-related initiatives within government, with a mandate that spans both coordination and institutional implementation activities, the HCENR is the lead agency charged with the formulation of medium- to long-

term actions that not only mitigate the impacts of climate change related disasters such as drought, flash flooding, vector-borne disease outbreaks, but also reduce the vulnerability of communities most exposed to natural phenomena. The range of HCENR-implemented climate change-related initiatives include the First and Second National Communications under the UNFCCC, the National Adaptation Programme of Action, and the National Adaptation Plan.

The Ministry of Agriculture is the main implementing partner in the State Level through financing and direct implantation of the project activities. In the federal level, HCENR will take a lead role in consultation with ministry of agriculture (federal level agriculture minister office).

2.2. Targeted area background: Institutional and policy context

2.2.1. State-federal policy coordination

The 18 states of Sudan each have state-level agencies that carry out functions and provide services consistent with national policies. That is, at the national level, federal ministries and agencies exercise power over planning, legislation and execution on federal lands, natural resources, mineral and subterranean wealth, inter-state waters, national electricity projects, epidemics and disasters. At the state level, local ministries and agencies exercise power, within state borders, over state lands, natural resources, animal wealth, wildlife, non-Nile water and electric power. States in turn are divided into localities governed by local councils. Members of councils are directly elected and are intended as essential links between state and federal governance. There are concurrent powers where federal and state organs exercise power over activities that are related to climate change adaptation. Project designed emphasized coordination across state and federal agencies.

2.2.2. State institutional context for climate change adaptation

Public sector adaptation-related planning institutions exist in each of Sudan's 18 states. These state institutions are patterned after their national counterparts (e.g., state ministries of agriculture, state ministries of health). Regarding climate change, a focal point and inter-agency technical team of experts from related government, research, academia and civil society organization, have been established to coordinate the implementation of federal climate change policies and to provide grassroots inputs to inform federal decision-making. The capacity of these units has been strengthened through a range of activities over the past several years including for example, targeted training sessions; learning-by-doing programmes; and network building to exchange knowledge and experience.

2.2.3. State lead institutions for climate change adaptation policy coordination

As part of the NAPA and NAP processes, these units were tasked with data collection, undertaking vulnerability assessments, adaptation strategy formulation, policy review, institutional appraisal, and the identification/prioritization of specific adaptation initiatives. State lead institutions participated throughout the entire consultation process and took part in numerous organized workshops held throughout the country. This was an indication of the level of regional ownership engendered by project design activities and reflects strong state-federal-local coordination. Table 2-2 provides a summary of the range of governmental, para-state organizations, civil society organizations, and academic/research organizations that

Table 2-2: Institutions involved in climate change adaptation initiatives in targeted areas (GoS, 2015)

State	State-level ministries	Para-state organizations	Civil Society groups	Academic & Research institutions
West Darfur	• Ministry of Agriculture • Ministry of Health • Water Corporation • Meteorology Authority	• **Forest National Corporation**	• Farmer's Union • Pastoralist Union	• West Darfur Research Station
East Darfur	• Ministry of Agriculture • Council for Environment • Water Corporation • Range & Pasture Corporation • Ministry of Health	• **Forest National Corporation** • Animal Research Administration	NA	NA
Central Darfur	• **Ministry of Agriculture** • Meteorology Authority • Ministry of Health • Water Corporation	• Forest National Corporation	• Farmer's Union • Pastoralist Union • Environment Conservation Society	• University of Zalingi • Jebel Mara Rural Development Project
South Kordofan	• Ministry of Agriculture • Ministry of Health • Ministry of Water Resources	• Forest National Corporation	NA	• **Agricultural Research Station** • University of Dilling
West Kordofan	• **Ministry of Agriculture** • Ministry of Health • Ministry of Animal Wealth • Water Corporation	• Forest National Corporation • Natural Resource Programme	• Agriculture Engineering Union	• Elsalam University • Sudan University
Kassala	• Ministry of Animal Wealth • Range & Pasture Corporation • Meteorology Authority • Ministry of Health • Water Corporation • **Environment Council**	• Forest National Corporation	NA	• Agriculture Research Corporation - New Halfa
Red Sea	• Ministry of Agriculture • **Ministry of Environment & Tourism** • Water Corporation • Ministry of Health	• Survey Corporation • Forest National Corporation	NA	• Red Sea University
Northern	• Ministry of Agriculture • Water Corporation • Ministry of Health	• **Forest National Corporation**	• Farmers Union	• Dongola Research Station • Dongola University
River Nile	• **Environment Council** • Water Corporation • Ministry of Animal Wealth • Meteorology Authority • Ministry of Health	• Forest National Corporation	• Pastoralist Union • Farmers Union	• University of Wadi El Nile • Agricultural Research Station El Hudeiba
Khartoum	• Ministry of Agriculture • **Environment Council** • Water Corporation	• Forest National Corporation	NA	• Ahlia University

participated is developing climate change adaptation recommendations in the targeted areas. The lead agency for climate change adaptation activities under the proposed project is identified in bolded text.

2.3. Technical feasibility of proposed measures, technologies, and practices

There have been a number of small-scale projects to assess the feasibility of a set of measures, technologies and practices that could perform well under the range of climatic stresses facing rural communities in Sudan. Each of the subsections below describe a specific activity whose implementation record suggests there would be clear benefits to local communities for them

to be part of a climate change adaptation package. Notably, none of the activities described below have been incorporated at large scales with the GoS rural development activities. As such, they represent core, additional measures that can leverage ongoing governmental extension services.

The approach to the technical feasibility assessment focused on a review of measures, technologies, and practices that a) can build climate resiliency among small holder farmers and pastoralists and b) have been successfully implemented in similar locales throughout rural Sudan. The criteria that were applied to evaluate the potential of measures, technologies, and practices have emerged from previous adaptation interventions in rural areas and are summarized in the NAPA and NAP reports submitted to the UNFCCC Secretariat. Interventions were evaluated regarding their success or lack thereof relative to the degree of uptake beyond direct beneficiaries. An adaptation intervention was deemed successful if there was widespread adoption or progress toward adoption after a period of a few years by surrounding households/communities not directly involved in project activities. A review of the record of project intervention revealed that there have been several climate resilience-building efforts in Sudan (see UNFCCC entries in the previous Table 2-1). In the process of completing these activities, there were some key underlying premises to a) establish state-federal coordination arrangements on adaptation, b) strengthen the technical capacity of local research organizations, and c) define effective adaptation at the local level through extensive grassroots consultations. These premises overlap with project objectives.

A review of the mid-term and terminal evaluations of these projects shows that, because of the successful realization of these premises, several best practices and lessons have emerged that have been directly applied to the LDCF financed, NAPA follow-up project "Implementing NAPA Priority Interventions to Build Resilience in the Agriculture and Water Sectors to the Adverse Impacts of Climate Change in Sudan", a $3.3 million project.

The aim of the project was "to implement an urgent set of adaptation-focused measures that will minimize and reverse the food insecurity of small-scale farmers and pastoralists, thereby reducing vulnerability of rural communities resulting from climate change, including variability". Several adaptation interventions were implemented from 2009 to 2014 in selected communities within each of Sudan's five ecological zones. The main best practices and lessons learned from these interventions is described in the initial subsections below (Faisal et al, 2012). Additional best practices and lessons learned from selected other interventions are provide in the latter subsections (sources as noted). A complete set of adaptation-related projects, both completed and ongoing, are shown in Annex D.

2.3.1. Drought tolerant and early maturing seeds

Background

One of the main focuses for adaptation to climate change has been the development of crop varieties that can cope with heat, drought, flood and other extremes and help farmers adapt to the changes and sustain increase in agricultural production and productivity. In Sudan, participatory research has identified and released several adapted food and cash crops varieties with desirable traits that allow them to achieve optimum yields while withstanding stresses, such as drought, heat, and water-logging.

Technical characteristics

The released varieties are short maturing, drought tolerant with high yield and having the following merits:

- Being early, they do escape terminal dry spells and late season pests.
- Have shown adaptable performance under unfavorable environments.
- Good quality (consumer and market preferred).

As part of a previous project (2009-14) unrelated to the technical feasibility assessment process for proposed activities, the feasibility of crop varieties was evaluated to explore long-term viability under climate change (Osman et al, 2010). Short (70-75 days), and medium maturing (95-105 days), seed varieties that are more resistant to drought, heat and disease than traditional varieties were considered. Some of the key findings are summarized in the following bullets. Additionally, Table 2-3 summarizes results of intensive on-station and on-farm testing of local and improved seed varieties of sorghum, millet, cowpeas, groundnuts, and wheat in Sudan.

- For sorghum, Yarwasha, Aroselrimal, Wad Ahmed, Butana, and Arfagadmk seed varieties showed minimum potential yields that were over two that of traditional varieties
- For millet, Ugandi and Ashana seed varieties showed minimum potential yields that were nearly two times the yield of traditional varieties
- For groundnuts, Sodiri and Gubeish seed varieties showed minimum potential yields that were over 1.3 times the yield of traditional varieties
- For wheat, Condor and Dibera seed varieties showed minimum potential yields that were double the yield of traditional varieties

Performance feasibility

In South Darfur, an early maturing drought tolerant crop varieties (i.e., Yarwasha) was combined with water harvesting techniques. Quality improved and productivity more than doubled for grain and fodder compared to traditional practices. Some of the key successes are summarized in the following bullets. The figures correspond to one-season averages.

- Average grain yields increased from 0.4 to 1.0 tonnes per feddan due to the perceived higher quality of grain from the new drought tolerant seeds certified by the Agriculture Research Center, Sudan
- Average grain prices increased by 18%, from 220 to 260 SDG per sack ($36 to $43 per sack)
- Average fodder yields increased from 1.0 to 2.1 tonnes per feddan

Table 2-3: Performance of local and drought-resistant crop varieties

Crop	Variety	Days to maturity	Yield kg/ha	% Yield increase over local variety	Source
Sorghum	Yarwasha	85	1,319	88%	ARC-El Obeid Research Station Reports (2009-2011)
	Zinnari (Local variety)	117	703		
Groundnut	Gubiesh	85	1,115	19%	
	Barberton (local variety)	100-110	938		
Cowpea	Einelgazal	55	596	177%	
	Baffa (Local variety)	112	215		
Wheat	Debeira	NA	5.50	13%	Hussein et al, 2005
	Sasaraibe	NA	4.92	1%	
	Condor	NA	5.51	13%	
	Giza 168 (local variety)	NA	4.87		
Millet	Ashana	NA	483	829%	CCAPT Project, 2012
	Local variety	NA	52		

Operations & maintenance

There are no applicable ongoing operations and maintenance requirements post-project.

2.3.2. Women-run farms and gardens

Background

In rural Sudan, there is high potential for horticulture development using small scale irrigation facilities, as well as high potential for marketing opportunities that could be directly accessed by women (source). Implementation involved organizing women into formal groups with a micro credit scheme predicated on their own contributions to establish their own horticultural farms. The women's groups were provided with an irrigation facility, vegetable seeds, agricultural hand tools, and training on horticulture farming. With the available water supply, women could irrigate their tomatoes, onions, pepper, leafy vegetables, potatoes, spices, eggplant, lemon/orange trees. Some of the key successes are summarized in the following bullets.

- Improved nutritional status of households, particularly women and children, and increase their income by selling produce in local markets
- Year-round access to water for human and livestock consumption.
- Strengthened of local saving system and enhanced women economic capabilities.
- Promoted women's participation in income generating activities, thus encouraging them making small investment (uplifting the status of women).
- Established a micro credit scheme, based on a local revolving fund contribution of 30 SDG per month per women ($5/month/woman) from which loans were made for sheep fattening, small business, agro-inputs, and others. The average return was 625 SDG/woman ($103/woman).

It is important to note that these schemes are currently limited due to lack of governmental support. They have been included here with a focus on productive activities that are directly at risk from climatic threats. They represent potentially high value-added outcomes against modest investments.

Technical characteristics

Women's farms are distinct from women's home gardens as outlined below:

- Women's farms are larger plots of land (up to 4.2 hectares) compared to women's gardens (typically up to 0.2 hectares);
- Women's farms are located further away from the home as compared to women's gardens which are located in the immediate vicinity of the home;
- Women's farms are cultivated collectively by a group of women whereas women's gardens are cultivated by the individual owner;

- Women's farms are essentially commercial enterprises that provide a source of income from selling produce in local markets whereas women's gardens serve primarily as a supplementary source of food, with lower income generation potential;

Women's farms and gardens have proven to be a promising approach to enhance food security and wellbeing of resources-poor households in vulnerable areas, particularly women-headed households. Household gardens refer to the cultivation of a small portion of land which may be around the household or within walking distance from the residence. This offers benefits of security, convenience, and special care. They can be planted with vegetables and fruits and as well as extra-early maturing crops that can serve as a supplementary and urgent source of food and income during period of food scarcity. Some of the key successes are summarized in the following bullets. As with the other activities described in this section, they perform well under a range of climatic stresses (i.e., sustained extremes temperatures, low rainfall) and are not part of governmental extension activities. Hence, their incremental benefits to baseline sustainable development efforts are high.

- Yields from the first and second harvest were about 8 and 13 sacks on average, respectively, from an area of 1.3 feddan (sack weight is 50 kg and price per sack is 320 to 350 SDG).
- After accounting for the costs of all inputs (e.g., materials and labour) and revenues from selling the produce at local markets, the average net economic benefit is 17,692 SDG per feddan (or $6,906 per hectare at an exchange rate of 6.10 SDG per $).
- Home gardens contribute to income generation, improved livelihoods, and household economic welfare as well as promoting entrepreneurship

Performance feasibility

Household garden may be the single most effective and feasible adaptation intervention for rural, women-led households. They represent both a niche activity not addressed in governmental outreach/extension services and a high value-added activity requiring only modest investment.

Operations & maintenance

There are no applicable ongoing operations and maintenance requirements/costs post-project. Women-run gardens will continue to operate and are self-sustaining post-project

2.3.3. Shelterbelts with drip irrigation system

Background

Shelterbelts of trees have been installed in fragile ecosystems in other areas of Sudan to act as a barrier to reduce the harmful effect of wind velocities, wind erosion and sand drift and heat wave and improving the existing harsh environmental condition. Sustainable management of shelterbelts has relied on community mobilization/engagement, awareness-raising, and village institutional capacity building Some of the key successes are summarized in the following bullets.

- Year-round protection of cultivated land from recurring dust storms
- Establish of local procedures for shelterbelt maintenance and protection

Technical characteristics

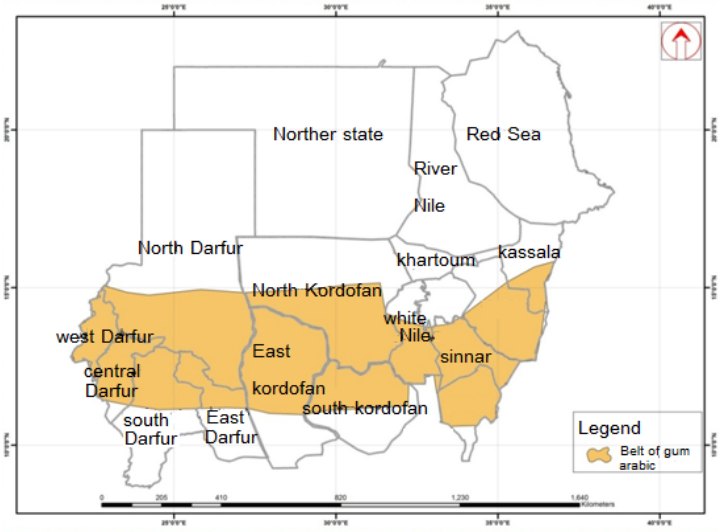
As in most of the arid zones wind erosion, sand dust, higher wind speed and desertification are serious problems in the fragile ecosystem. Shelterbelt has been defined as single or multiple rows of vegetation, usually trees and/or shrubs, placed to protect against wind. In the establishing shelterbelt, indigenous species such as African acacias (i.e. Acacia seyal), fast growing trees can be used. Other indigenous woody fruit trees (i.e. Zisyphus spina-christi) can also be used for providing wild edible fruits and non-timber products that serve as alternative food during period of deficit for the local community. In addition, the trees in shelterbelt can buffer temperatures, reduces incident solar radiation and improves water status and thereby they have a potential to improve resilience to uncertain climates. Moreover, the trees can meaningfully reduce the pressure on natural forests for energy needs.

Performance feasibility

Shelterbelts can buffer temperatures, reduces incident solar radiation and improves water status and thereby they have a potential to improve resilience to climatic variability. Moreover, the trees within shelterbelts can meaningfully reduce the pressure on natural forests for energy needs, slow soil erosion, reduce damage to crops and increase crop yield. At the planning stage, establishment of a properly functioning shelterbelt system requires attention to three major factors: 1) appropriate tree species; 2) proper spacing between trees; and 3) adequate number and density of trees to provide the desired sheltering services. In addition to increasing resiliency against climate-related impacts, irrigated shelterbelts provide an important co-benefit of carbon sequestration. Principal species to be planted include Acacia Senegal with other Acacia species planted as needed, with a rotation of about 15 years and an uptake period of 30 years..

There are several advantages associated with Acacia senegal (Hashab tree) plantations. It is a hardy species under Sudan's climatological conditions, as evidence by the fact that it occurs naturally in a belt that lies between latitudes 12–14 North (see Figure 2-1). In the sandy areas of western Sudan (part of the project target area) the pattern of land-use, which involves Hashab, is frequently referred to as "gum cultivation cycle". Recently, Hashab plantations have also been readily established in the central clay plains of Sudan where rain-fed mechanized crop production is practiced. The acacia tree is linked with the sandy soil because of its capacity to stretch its roots vertically, but also it grows in the light clay soil and it bears up well under hot temperatures. Moreover, it is a nitrogen-fixing tree. Gum Arabic trees have gained the interest of various international and regional organizations which work in the reconstruction of belts because it's one of the places which witnessed deterioration in its ecological systems as a result of droughts,

Figure 2-1: Gum Arabic, Acacia Senegal, belt in the Sudan



desertification and misuse of lands which led to negative impacts on human life and environment.

Annex G provides an estimate of the carbon sequestration benefits for shelterbelts with drip irrigation system.

Operations & maintenance

Shelterbelts need proper care and sustainable management to provide the planned benefits for which they are established. The ongoing engagement of local communities is essential to the sustainable management of shelterbelts. To ensure that communities are able to properly manage shelterbelt protection activities, the project will work through CBOs and will provide them with the necessary training on sustainable management of forest resources and responsibilities of communities, including benefit sharing arrangements and minimum environmental standards.

Shelterbelts are at their most vulnerable during the period just after establishment as they are highly susceptible to grazing by animals, dry conditions and weed competition. The level of management required to maintain a belt generally decreases as the belt becomes established. Sustainable shelterbelt management incorporates several key activities including pruning, weed control, insect/disease control, control of destructive animals and replacement of dead or wilted trees. A maintenance checklist and inspection plan for shelterbelt management is outlined in Table 2-4.

Table 2-4: Shelterbelt maintenance checklist and inspection frequency plan

Maintenance Task	Minimum Frequency of Task	Responsibility	Results expected when maintenance is performed
Replacing dead seedlings and trees	Once per year up to second year	Forest User Group	100% survival of seedlings
Weeding	Once per year up to third year	Forest User Group	High growth rate
Watering	As needed in summer period up to third year	Forest User Group	High growth rate
Pruning	Once per year from 3rd to 5th year	Forest User Group	Girth Breast High increase
Protection from animals	As needed in year one and two	Forest User Group	Good survival rate
Inspection and early control to prevent insect/disease damage	As needed throughout of the plantation life	Forest User Group	Good survival rate
Replanting and renovation	As needed after 5 year	Forest User Group	100% survival of seedlings

2.3.4. Seed multiplication farms

Background

Seeds of climate-smart varieties are the most important agricultural input, particularly, for small-scale farmers in the project area. Compared to other agricultural inputs, improved seed has been shown to have the greatest potential to increase on-farm productivity and enhance food security. To promote the role of the local farmers in provision of quality seeds of climate-smart varieties at household and community levels, the project will conduct several trainings to strengthen farmers' capacity and knowledge regarding technical aspects of seeds: Importance, quality, testing, storage, multiplication, and certification. Researchers and specialist from seed inspection services will participate in these trainings. As a result, farmers will become more aware of the importance of high quality seeds, new varieties, and seed

multiplication. Selected farmers farms will be inspected by seed inspection services. These farmers will become a source of quality seeds of improved climate-smart varieties to the communities.

Technical characteristics

The project has a good potential in establishing community-based seed supply. The community –based seed supply can be a reliable and efficient way to access and avail quality seeds of the improved adopted crop varieties. The most important factors for the sustainability this system is:

1. Formation and capacity building of the community-based organizations.
2. Less dependency on external sources.
3. Increase the involvement and interaction of government counterparts and strengthening their linkages with the communities (Research-Extension-Federal Seed Administration).

Performance feasibility

During the field visits, majority of farmers indicated that seed security in the area has been limited and they use local cultivars. This intervention will make:

1. Local purchase possible instead of external.
2. Reduced transport and seed distribution cost.
3. Incentive for the informal seed production sector.
4. Improved local community income and capacity

Operations & maintenance

Communities' mobilization and capacity building of village community institutions is necessary in ensuring the ongoing effectiveness of seed multiplication farms post-project.

2.3.5. Community-based procurement

Background

Seed supply from the formal sector could not reach and meet traditional farmers demand. This activity is designed to promote the role of the local farmers in procurement of quality seeds of improved varieties at household and community levels. This can be done through:

- Local purchase possible instead of external.
- Procurement within seed administration using the guiding principles
- Reduced transport and seed distribution cost

Technical characteristics

- Training that strengthening farmer's capacity and knowledge regarding technical aspects of seed production, handling and exchange.
- Establishment of seed multiplication farm at the village level.
- Inspection and supervision of potential seed supply source farms.

Performance feasibility

The performance feasibility of community based programs is well established in rural Sudan thanks to past projects and local resource management practices .Seed supply from the formal sector could not reach and meet traditional farmers demand.

- Local purchases have been demonstrated as possible instead of external inputs.
- Local purchases result in reduced transport and seed distribution costs

Operations & maintenance

Seed maintenance activities at farms are closely monitored and examined under testing conditions and regulations set by national seed administration.

2.3.6. Climate-smart technologies and practices

Background

Climate-smart technologies and practices for agricultural production address the challenge of how to transition to a climate-smart agriculture at needed scales for enabling agricultural systems to be transformed and reoriented to support food security under the new realities of climate change. In Sudan, there are several adaptation measures and climate-smart technologies and practices that the traditional drylands farmers can undertake to alleviate the effects of present and future climate changes. These technologies, as described in the next sub-section, should be promoted and disseminated to help poor people live in the fragile rural environment enhancing food security and reduce their vulnerability.

Technical characteristics

Two main categories of sustainable agriculture that are the focus of the project are outlined below:

1. Improving farm management practices
    - Water management (water harvesting techniques, small scale irrigation, implementing new or improving existing irrigation systems contour bands, ridges)
    - Soil management practices (mulching, conservation tillage, fallowing,)
    - Crop management practices (high yielding, early maturing, drought tolerant and heat-resistant crop varieties, alternative crops / IPM)
2. Crop production practices (seed priming and fertilizers micro dosing, planting density and changing planting dates, diversification (Planting different varieties or crop species), intercropping, Improved crop residue and weed management, agroforestry.

Performance feasibility

The main features of these adaptation technologies agree with Climate-Smart Agriculture four-pillars identified by (FAO, 2013), namely:

1. Sustainably increases productivity and incomes (adaptation);
2. Reduces or removes greenhouse gases (mitigation);

3. Adapting and building resilience to climate change and
4. Enhances achievement of national food security and development goals (development).

Operations & maintenance

There are no applicable ongoing operations and maintenance requirements/costs post-project.

2.3.7. Farmers' Field Schools

Background

In recent years, Farmer Field Schools (FFS) approach is being used as an agricultural extension method in many developing countries in Asia and Africa. Experiences with IPM-FFS in Asia have been documented and used to promote and expand FFS to other countries and other disciplines. The FFS is a non-formal training programme for selected farmers within a locality, usually a village.

Technical characteristics

Technical characteristics for farmer schools are based on the FAO's Farmer Field School methodology, a "Climate Field School"(CFS) available at http://www.fao.org/agriculture/ippm/programme/ffs-approach/en/. This methodology will be applied with farmers to increase farmers awareness about climate change and climate-smart technologies.

Performance feasibility

The performance feasibility of a CFS program are directly related to success in achieving the following actions:

- Enabling farmers to understand climate related risks in agriculture;
- Familiarizing the participants on forecast implementation, climate parameters and instruments;
- Helping farmers learn to integrate weather and climate information with disaster management and agricultural planning; and
- Creating awareness of participants on disaster risk reduction and climate change adaptation.

Operations & maintenance

The CFS will operated and maintained by the extension and research departments using technical *Manual* for farmers and Field Extension.

2.3.8. Climate adaptive rangeland management

Background

Rangelands are a crucial resource for the poorest people in dry areas. They represent the major source of feed in the livestock production systems. Today, however, these areas are threatened by severe human and livestock population pressure, degradation and eventual

desertification.Degradation of rangelands in Sudan is occurring at an alarming rate. Rangelands of Sudan support about 80 million heads of cattle, sheep, goats, and camels Nearly 80% of all rangelands are located in low rainfall savannah ecological zones that characterized by variable and unpredictable rainfall. Recent assessments showed that severe and very severe soil degradation covers, degraded land is estimated at 17 million hectares. Most of the population of the affected states is poor and relies heavily on the natural range for subsistence. Regions of severe land degradation coincide with regions of severe food insecurity.

Technical characteristics

Effective rangeland management practices (rotation grazing ,reduced burning, reseeding, brush control, scheduled rest periods) need to be practiced, in order to provide a supportive and enabling environment for pastoralists. Rested pastures provide forage for emergency use during drought.

Performance feasibility

Range management provides an opportunity for vegetation and soils to recover. Its performance feasibility has been well established through numerous project interventions in rural Sudan.

Operations & maintenance

There are no applicable ongoing operations and maintenance requirements/costs post-project.

2.3.9. Rangeland rehabilitation

Background

Rangeland rehabilitation activities attempt to put back most of what existed in the ecosystem prior to the disturbance and the land has been made productive once again for nurturing livestock herds of nomadic pastoralists and agro-pastoralists.

Technical characteristics

The practice of rangeland rehabilitation consists of four main activities: reseeding, water harvesting, grazing management, and fire control.

Performance feasibility

Improve the range–livestock production system by reducing the feed gap – the scarcity of animal feed and managing of severely degraded rangelands.

In addition to improving the resilience against climate-related impacts of pasture lands, rehabilitated rangelands provide an important co-benefit of carbon sequestration. Annex G provides an estimate of the carbon sequestration benefits for rangeland rehabilitation.

Operations & maintenance

There are no applicable ongoing operations and maintenance requirements/costs post-project.

2.3.10. Community based afforestation

Background

Forests play a vital role in maintaining an ecological balance, biodiversity conservation and improving the livelihood of people across all zones in Sudan. Forestry resources provide energy needs (firewood and charcoal), timber for construction and building material, forage for livestock, foodstuff and income opportunities for rural people.

Technical characteristics

Community-based afforestation refers to the planting of climate resilient tree species and greater and continued community participation in the management and long-term protection of the new forest.

Performance feasibility

The performance feasibility of community-based afforestation is directly linked to the success in recruiting local communities to become actively involved with forest management and adaptation activities. There are numerous good examples of where this has been achieved in rural Sudan. Lessons learned from these activities will be applied to the project.

In addition to increasing resiliency against climate-related impacts, afforested areas provide an important co-benefit of carbon sequestration. Principal species to be planted include Acacia Senegal with other Acacia species planted as needed, with a rotation of about 15 years and an uptake period of 30 years. Annex G provides an estimate of the carbon sequestration benefits for community based afforestation.

Operations & maintenance

Afforested areas will be established and sustainably managed by communities giving due consideration to seedling fragility, seasonal conditions, harvesting limitations, and access restrictions. Meeting sustainable management objectives will require strong elements of community engagement in seedlings follow-up (from nursery to field) including irrigation, community-defined access protocols (in lieu of fencing) and harvesting practices. Expertise will be provided in terms of technical guidance developed during the project and community capacity building by local extension officers. Other than this, there are no applicable ongoing operations and maintenance requirements/costs post-project.

2.3.11. “Sandug” micro-financing system

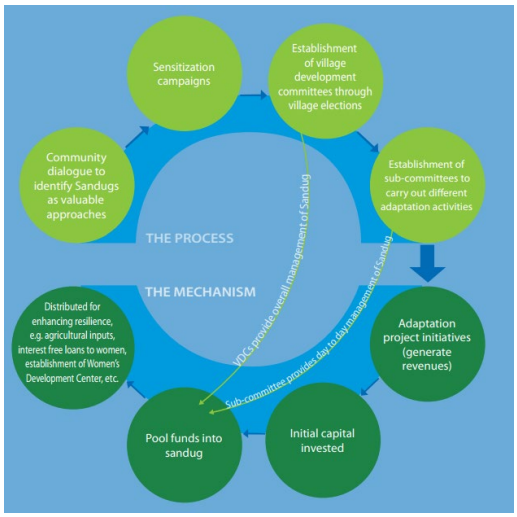
Background

Coping with climate change impacts requires a strengthening rural finance in a way that incorporates traditional knowledge into adaptation interventions. In Sudan, a validated mechanism for achieving this is the “Sandug” micro-financing system for small-scale loans and savings. A “Sandug”, which literally means a box for holding money, is a revolving fund that typically involves a group of 10 to 20 women who contribute an agreed upon amount of money or commodity to a group fund, at regular periods of time. The collected funds are then handed over to one member of the group on a rotating basis, until each one in the group has received the same service. Any GCF funds to support microfinance needs will be applied only

to a) capacity building at the village level and b) promoting links between sandugs and existing microfinance institutions.

Setting up a Sandug involves a series of initial sensitization campaigns and the establishment of Village Development Committees (VDCs) in each participating village. These VDCs are elected by the villagers and provide an overall managerial role of the Sandug, and in most cases women from the VDCs take the responsibility of the day to day running of the fund. This approach has been used in all four agro ecological zones of Sudan. Figure 2-2 illustrates the steps involved in the operation of a Sandug. Case study information on sandugs is provided in Annexes 19g and 19h of the full proposal.

Figure 2-2: Operation of a "Sandug"



Technical characteristics

The Sandug revolving credit system will be undertaken in the target villages through Women's Savings and Credit Groups (SCGs). These are village-based entities for accessing credit and for savings. They are a mechanism to link small farmers and women groups with existing microfinance institutions at the state level. SCGs are also capable of supporting the creation of similar community and village level rural credit initiatives, building on revolving funds supported by the project. The GCF Project will promote linking small farmers and women groups with existing microfinance institutions. Training and community mobilization will be organized by the project as a prerequisite for any well-informed rural financial system. The training will cover technical, organizational and management aspect of the saving mechanism as a rural micro-finance system. SCGs are characterized by the following key features.

1. It is a saving–based micro-financial service with no external borrowing or donations to loan portfolio.
2. Self–managed intervention.
3. Characterized by simplicity and transparency of operations.
4. Flexibility in loan size and terms
5. Very low group management cost met through group earnings.
6. Earnings retention in the group and local community.
7. Efficient and reliable financial intermediation.
8. Individual saving and credit groups providing extraordinary and always positive real rates of return on clients' savings.
9. Meeting the basic needs of clients for simple, accessible savings and credit and insure facilities.
10. Very low cost per client.

Performance feasibility

"Sandugs" are currently being used as essential tools to scale up a variety of adaptation interventions across the different states of the country.[1] In North Kordofan, small farms were established in the participating villages, jointly managed by Village Development Committees (VDCs) and women groups (354 women in total). The women groups allocate part of their revenues to their own *"Sandug"*- which is managed by themselves separately from the village *"Sandug"*. This money is later used to procure agricultural inputs and provide interest free loans to the women. The VDCs established by the project are now officially registered as civil society organizations and linked to a local micro credit institution to expand the *"Sandug"* activities to other areas, such as livestock (e.g. sheep fattening, increasing twinning and increasing goats' milk production).

In the River Nile state, where water pumps are being installed to irrigate agricultural crops, each pump serves 15 farmers who pay back the cost of the pump in installments over three years. The money collected through these payments is saved in the village *"Sandug"* and used to purchase additional pumps and to procure agricultural inputs. The project provided 96 pumps and the VDCs purchased additional 17 units from their own *"Sandug"*. A total of 1,685 butane gas units (cylinder and stove) have been provided to households who pay back the cost in installments, and the *"Sandug"* procured an additional 520 units. As a result, all of the households in three villages have acquired butane gas units and shifted from biomass to butane gas energy.

In the state of Gedarif, a *"Sandug"* was initiated for the distribution of butane gas units on a revolving basis, in addition to providing ovens for bread production. Seven ovens were provided by the project to five women groups (with ten women each). The Women Committee, which is a sub-committee of the VDC, manages these activities and has their own *"Sandug"*. This *"Sandug"* provides interest free loans to women, which is used to purchase production inputs, such as seeds, agricultural appliances, etc. This *"Sandug"* also contributed approximately US$ 760 out of US$ 2,200 for the establishment of a Woman Development Centre (WDC) for the village. The WDC now houses literacy classes and training activities for women.

Operations & maintenance

There are no operations and maintenance costs associated with the SCGs.

2.3.12. Hafirs

Background

Several target localities are water-scarce, regularly experiencing extreme water shortage during periodic dry spells. Harvesting rainwater in reliable water storage structures represent opportunities to address water scarcity for both livestock and domestic purposes. One of the main water supply infrastructure proposed in this project is the "hafir". They are selected because rain is the only water source and there are no or limited underground or surface water sources available.

[1] Source for the information in this section comes from: Canada-UNDP, "Case Study: Using a Rural Financing Mechanism – Sandug – to Scale up Climate Change Adaptation in Sudan", available at http://adaptation-undp.org/sites/default/files/downloads/ccaf_cs_sudan_final_eng_0.pdf

A hafir is an artificial excavation (dugout enlargements) designed for harvesting rain water, carried during the rainy season by seasonal streams, to enhance the access of vulnerable communities to drinking water. Hafirs are usually constructed big enough to cater for the needs of the villagers/nomads and their livestock during the dry season. The average capacity of an existing hafir varies from 15,000 to 250,000 m3. Each new hafir is designed for an annual water storage capacity of 50,000 cubic meters. The hafir is surrounded by a fence for protection from animals. Pictures of actual hafirs located in rural Sudan are shown in Figure 2-3.

Figure 2-3: Pictures of a hafir under construction (left) and an operation hafir (right)

Technical characteristics

The dimensions and other design details of the hafirs to be installed at the target sites are shown in Annex H. The main steps in hafir establishment include: construction, community organization and management structures, capacity building, operation and maintenance and monitoring and evaluation. Recently, communities have a greater role and responsibility in the management and operation of their water supplies. However, the operation and management of a water supply requires awareness, skills and experience. The capacity of the community may need strengthening so they can manage their water supply. Capacity building should result in that the committees selected by the community gains skills on leadership, financial management and technical operation and management and water hygiene and sanitation.

Performance feasibility

The presence of a trained and functional management committee, or Water Management Committee (WMC) is the first step towards establishing a sustainable and well-performing hafir facility. The WMCs must represent the key stakeholders: representatives of the locality government and members from the communities using the hafir, including permanent residents and nomadic pastoralists passing through. However, the management committee should have clear roles and responsibilities and should receive proper training. WMCs will be actively linked to the relevant government departments. In the target areas, women play a critical role when it comes to water, sanitation and hygiene, their representation and voices must be heard in WMCs and WASH Committees.

The training of WMCs is the key factor for efficient shouldering of O&M. After the WMCs have been established, they will have a comprehensive training on management, O&M. Topics covered include participatory decision making, management of conflicts over natural resources, understanding basic concepts related to catchment management, gender issues related to water resources management, hygiene and sanitation practices and Participatory Action Plan Development (management of water stations, collection of money, follow up and evaluation and water uses, organizing meetings, taking decisions and writing reports). The availability of trained technical personnel within the community is important for the O&M of

the system. Hence, training of such technical people and provision of continuous support is very critical for sustainability.

Lessons learned from previously constructed Hafirs revealed that the benefiting communities managed to establish a water tariff system for O&M. Based on this system, and in consultation with communities; the WMCs were actively involved in the determination of the revenue collection systems to meet at least the future maintenance expenses. To avoid such lack and delays of maintenance, heavily investment was made in training, organization, intensive mobilization and awareness campaign to improve knowledge and skills to create a conducive environment for sustainable functioning of Hafir. There are always a Hafir guard and operator with good management skills who is in charge of operation and day-to-day management including collecting fees, organizing watering operation and care for the facilities; under the supervision of the Water Management Committee (WMC).

Preventative maintenance is the key to ensuring a long life for hafir. Regular monitoring of the embankments, reservoir and catchment area should be carried out to make sure that maintenance needs are identified early enough to take action. Monitoring should be carried out by the individual or committee responsible for management and needs to be more frequent in the first year after construction, preferably once a month. Ideally a technician should assist in the monitoring for the first year. After the first-year monitoring can be carried out twice per year, preferably just after and before the rainy season.

Inspection forms should include, at a minimum, the following information: -

- Type of inspection (annual, seasonal, monthly, special conditions)
- Date of inspection
- Items to be inspected
- Record of any problems noted during inspection and follow-up actions that are required

Operations & maintenance

O&M costs associated with these activities are low, estimated at about $2,500 per year, mostly for fuel, lubricants, and spare parts. In addition, major maintenance outlays are assumed to occur every 5 years at a cost of $5,000. Underlying the operations and maintenance costs of hafirs are several key elements. These are summarized in Box 2-1. There are six (6) essential operation and maintenance activities of Hafirs, as described in the bullets below.

1. *Desilting.* Removal of slit (desilting) is the most important maintenance operation, as silt and soil will fill up the storage system and hafir becomes shallow and reduce the volume of water and the evaporation loss increases as well. Desilting (by excavation) can be done using any of the techniques suitable (manual, draught animal traction or mechanical).

Box 2-1: Key elements in hafir operation and maintenance (O&M) plan include:

- Community-Based Operation and Maintenance
- Infrastructure designs will be chosen that have minimal operation and maintenance requirements.
- Development of local water management committees(WMCs)
- Comprehensive training programmes for O&M staff
- Hiring of local community members as clerk and operators
- Setting of realistic water tariffs
- Hafir should be inspected periodically: monthly, quarterly and annually and prior to the season and after every heavy rain.
- Linking the WMCs to the local authorities and rural water administration to strengthen sustainability of the service
- Reporting system for breakdowns.

Desilting should be done regularly, preferably once a year in areas where heavy siltation occurs. The depth of silt deposited (and hence the quantity to be removed) can be measured easily if a marked post is installed in the bottom layer at the time of construction.

2. *Rectification of the fencing.* Fencing regular checking is very important as it keeps livestock out and helps to maintain better quality of water. When fencing is in a poor state of repair, animals enter freely, accelerating bank erosion, increasing turbidity of the water and adding to the pollution hazards.
3. *Plant windbreaks.* Evaporation losses from hafir can be high in dry, windy areas. A dense stand of trees such as neem or other native species on the windward side of the hahir reduces evaporation. Windbreak trees stand need to be followed-up and maintained periodically (during the rainy season).
4. *Preventing leakage.* leaks through structure walls can occur due to inadequate compaction or old tree roots. Compaction of eroded parts of embankment must be done.
5. *Maintenance of inlets and outlets and obstructions removal*. Obstructions such as trees and bushes, carried by seasonal streams can block the way and water entrances. Inlets and outlets should be cleared from silt and debris before and during the rainy season. Separate gates or entrances for people and livestock should be established and controlled.
6. *Establishment of a community based revolving fund and the setting of realistic water water user fees.* User contributions towards operation and maintenance costs should be clearly understood and agreed upon by the community. The user fee amount should be agreed upon by the community and management committee (e.g. in cash per animal watering or per jerrycan collected). WMCs will be actively involved in the determination of the revenue collection systems to meet future maintenance expenses. Fees can be gradually increased once the community consolidates a sense of ownership. Such fees can be used for the maintenance of hafir and necessary accessories.

   Generally, across Sudan, rural water tariffs are low but historically there have existed tensions between farmers' willingness to pay and their ability to pay. To address this, national policies have been established by the Ministry of Water Resources/Public Water Corporation to ensure that access to affordable rural water supply is guaranteed to all. Specifically, these policies and regulations specify that:

   - Water is a fundamental human necessity. Water -> Life -> A Human Right.
   - Water use priority - Domestic water use has the highest priority.
   - Water has social and economic values and should be accordingly considered. Thus - water costing should consider social needs.
   - The tariff structure shall be responsive to the low income and the poor segments of the urban communities. It shall have cross-subsidy structure whereby high- volume consumers pay higher rates and low quantity consumers are charged at the minimum tariff rate.
   - For water users that are genuinely found unable to pay, the community shall make considerations to cover the cost from the charges collected from the rest of the

community members and the water tariff shall be established making these social considerations.

Moreover, the above process for setting of water tariffs has proven effective throughout rural Sudan, meaning the proposed water user fee setting process is a proven approach to meet water user needs in the project localities. The process of setting water tariffs was discussed during the stakeholder consultative process in the project design phase there was consensus agreement among stakeholders of the viability of this approach. As part of the community training programmes to be developed and implemented to ensure effective long-term maintenance of the water yards, there will be stakeholder consultations on the magnitude of the water user fee.

Regarding water supply fees for nomadic areas, livestock owners shall be charged for the water used by the herds of livestock based on an established tariff rate for the specific area using cost per head of watered animal. This is consistent with traditional practice in which pastoralists have adequate willingness to pay as well as the ability to pay. All O&M costs associated with maintaining installed water infrastructure will be part of co-financing from Ministry of Irrigation and Water Resources.

Maintaining a well-functioning hafir requires the involvement of all stakeholders and skilled personnel. To ensure a strong and capable community management system, capacity of the community members will be carried out. The size and makeup of the management committee should ensure gender balance and representation of main stakeholders. A community-based management system that is enforced by viable tariff and strong legislations is recommended. The WMCs and other stakeholders will be engaged to work out appropriate tariff levels. Revenue should be allocated to maintain and improve the facilities. Extensive training of communities and local authorities together with awareness campaigns on water sanitation must be carried out. The main stakeholders responsible for O&M are identified in Box 2-2.

The principal maintenance objective is to prevent sediment build up and clogging, which reduce hafir capacity. Inspection for maintenance can be: monthly, pre-rainy Season, after heavy rain, end of rainy Season or (annual, seasonal, monthly, special conditions). The maintenance plan, including a description of activities and frequency at which they will be conducted, is summarized in Table 2-5.

Moreover, included in the design of hafirs is a dense perimeter of trees (i.e., windbreak) such as neem *(Azadirachta Indica)* or other native species on the windward side of the hafir to reduce evaporation. Trees contribute to lower evaporation rates in two major ways, as briefly described in the bullets below:

- *Wind speed reduction:* Trees within a windbreak will help to reduce wind speed over the hafirs. As air moves over water surfaces, it generates waves which increase evaporation losses. Strategic tree planting - either in single, double or triple rows – helps to reduce the wind speed reaching the water surface and will lead to reduced evaporative losses.

Box 2-2: Key stakeholders who will be recruited to maintain hafirs include:

- ✓ Rural communities (farming and ago-pastoralist households)
- Pastoralist communities that seasonally migrate through the areas
- Community-based organizations(CBOs)
- Traditional local governance (Native Administration)
- Rural Water Management Authority (are responsible for the policy and strategy development, coordination, planning, management, monitoring and evaluation of water supply and sanitation facilities).
- State and Locality authorities and institutions
- NGOs working in the area

Table 2-5: Hafir maintenance checklist and inspection frequency plan

Maintenance Task	Minimum Frequency of Task	Responsibility	Results expected when maintenance is performed
Removal of slit (De-silting) can be (manual, draught animal traction or mechanical).	Annually, before the rainy season	Community/RWA	Water flow and storage improved
Inspect and remove debris from hafir entrance point	A head before the rainy season and after heavy rain	Guard and operator /community	Water flow improved
Inspect seasonal stream systems and facilitate water flow/ inspect and prevent any backflow	Annually	WMCs/ RWA community	flow is normal and no backflow
Inspect and repair leaks if any for cracks (Compaction of eroded parts of embankment)	Every 3 months	WRMCs/ community	No leaking from water system
Inspect and clean water outlets (should be cleared from silt and debris).	Community/ Guard and operator	community/RWA	water flow and water quality are normal
Checking and controlling livestock and human separate gates or entrances for water access	Daily-basis	Guard and operator	organized water access and minimum water quality requirement kept
Rectification of thorny wire fencing	Every 3-6 months	Community	Pollution hazards reduced, and minimum water quality maintained
Windbreak trees stand need to be followed-up and maintained periodically	(during the rainy season).	Community	Reduced water evaporation

- *Microclimate generation:* Windbreaks humidify the air passing through the trees due to their transpiration, thus creating a microclimate in the vicinity of the hafirs. This enhances the moisture blanket over the water surface and decreases temperature and solar energy while increasing the relative humidity gradient between hafirs and the surrounding area. Combined, this results in a microclimate exhibiting lower evaporation. Past field tests in northern Sudan have validated the impact of windbreak in creating a microclimate, as summarized in the bullets below.
  - ✓ For hafirs without windbreaks, maximum temperatures reach 41.5°C, relative humidity reaches 42%, and solar insolation reaches 0.354 kWh/m^2.
  - ✓ For hafirs with windbreaks of *acacia stenophylla*, maximum temperatures reach 39.6°C (reduction of 1.9°C), relative humidity reaches 56% (increase of 14%), and solar insolation reaches 0.163 kWh/m^2 (reduction of 0.191 kWh/m2).
  - ✓ For hafirs with windbreaks of *acacia ampliceps*, maximum temperatures reach 39.8°C (reduction of 1.7°C), relative humidity reaches 52% (increase of 10%), and solar insolation reaches 0.191 kWh/m^2 (reduction of 0.163 kWh/m2).

2.3.13. Water yards

Background

Due to lack of surface water resources in many areas of the project target states the population relies on groundwater pumped from considerable depths. “Water yards”, as they are known locally, are essentially a water extraction and distribution complex which includes borehole, storage tank, animal watering basins and tap stands. The borehole is equipped with a pump, typically powered by a diesel engine. In the proposed project, solar-powered pumping is the chosen alternative. Pictures of typical water yards appear in Figure 2-4.

Figure 2-4: Pictures of water yards

Technical characteristics

The dimensions and other design details of the water yards to be installed at the target sites are shown in Annex H. The water yard is contained within a fenced compound, and under the control of a water yard clerk and pump operator. Mostly livestock basin is separate from the tap stands for human consumption by internal cross-fencing. Water is pumped into the elevated storage tank, which is usually constructed from prefabricated steel sections. The average nominal daily tank capacity is 50 m^3. From the storage tank, water is distributed by gravity to tap stands for filling containers for human consumption, and to metal basin for watering livestock.

Water for human use is drawn from the water yard to the home by a variety of means. Jerrycans of 18 litre (4 imperial gallons) capacity are commonly used and are carried to the home if the distance is short. For the longer distances, the jerrycans are loaded on donkey carts. Larger metal tanks on carts dragged by donkeys are also used. Children and women are the primary water providers.

Performance feasibility

A water yard is a proven low-tech option for providing water to meet household and livestock needs in rural Sudan. Historically, rural water yards are maintained by the Rural Water Corporation (RWC). A water yard operator is also employed by the RWC at each water yard. The operator's job is to start and stop the pump, perform routine and preventative maintenance to water yard equipment, and to notify the RWC when a major overhaul or repair of equipment is required. The water yard operator is frequently unable to perform routine and preventative water yard equipment maintenance, since he is not supplied with the necessary spare parts, lubricants and tools. The RWC considers that lack of preventative maintenance and lack of operator training are the major technical reasons for the breakdown of water yards when they occur. Key technical issues that constrain and hinder the operation and maintenance of water yards are as follows:

- Availability of diesel fuel and spare parts
- Aging of facilities
- Tariffs and cost recovery

Regarding water supply fees for nomadic areas, livestock owners shall be charged for the water used by the herds of livestock based on an established tariff rate for the specific area using cost per head of watered animal. This is consistent with traditional practice in which pastoralists have adequate willingness to pay as well as ability to pay.Regarding the last bullet above, tariffs should be sufficient to pay for long term operation and maintenance including major equipment replacement, with a reserve for future improvement. Lessons learned have shown that the beneficiaries are willing and able to pay for good service. Previous experience indicated the essentially of community-based operations and maintenance system and community-based operation and maintenance system is already operating quite successfully in several rural water yards (see Box 2-3).

Box 2-3: Water tariffs

Generally, across Sudan, rural water tariffs are low but historically there have existed tensions between farmers' willingness to pay and their ability to pay. To address this, national policies have been established by the Ministry of Water Resources/Public Water Corporation to ensure that access to affordable rural water supply is guaranteed to all, as follows:

- Water is a fundamental human necessity. Water -> Life -> A Human Right.
- Domestic water use has highest priority.
- Water has social and economic values and should be accordingly considered.
- Tariff structure shall be responsive to the low income and the poor segments of the urban communities, with high-volume consumers pay higher rates to subsidize low quantity consumers.
- For water users genuinely unable to pay, the community shall make considerations to cover the cost from the charges collected from the rest of the community members.

The proposed water user fee setting process is a proven approach to meet water user needs in the project localities. The process of setting water tariffs was discussed during the stakeholder consultative process in the project design phase there was consensus agreement among stakeholders of the viability of this approach.

Operations & maintenance

Lessons learned from previously constructed water yards have been integrated into the post-project O&M plan. O&M costs are low, estimated at about $1,500 per year. In addition, major maintenance outlays are assumed to occur every 5 years at a cost of $5,000. There are several key elements involved in proper operations and maintenance of the water yards to be installed in the target villages, as described in the bullets below.

- *Development of local water committees.* An effective water committee will be formed in each community, with representation of the locality government and members from the communities using the water yard, including permanent residents and nomadic pastoralists passing through. Responsibilities of WMC include: imposing reasonable water charges to cover the costs of fuel and lubricants, to contribute in providing spare parts and to assist in minor repairs and general maintenance for fencing. WMC should receive proper training and actively linked to the relevant government departments. In the target areas, women play a critical role when it comes to water, sanitation and hygiene, their representation and voices must be heard in WMCs and WASH Committees
- *Training of Water Management Committees (WMCs).* The training of WMCs is the key factor for efficient shouldering of the O & M. After the WMCs have been established, they will have a comprehensive training on management, O&M. Topics covered include participatory decision making, management of conflicts over natural resources, understanding basic concepts related to water yard management, gender issues related to water resources management, hygiene and sanitation practices and Participatory Action Plan Development (management of water stations, collection of money, follow up and evaluation and water uses, organizing meetings, taking decisions and writing reports). The availability of trained technical personnel within the community is important for the

O&M of the system. Hence, training of such technical people and provision of continuous support is very critical for sustainability.

- *Establishment of a community based revolving fund and the setting of realistic water tariffs.* Benefiting communities will establish a water tariff system for O&M. Based on this system, and in consultation with communities; the WMCs will be actively involved in the determination of the revenue collection systems to meet future maintenance expenses.
- *Hiring of local community members as clerk and operators.* Local clerks and operators will be hired from within the community and paid by the water committee out of community water revenues in the revolving fund. This will permit direct and effective supervision of the daily operations of the water yard and routine preventative maintenance of the equipment. The clerk will be trained in basic bookkeeping and report preparation and the operator in pump and engine operation, lubrication, preventative maintenance, and pipe repair.
- *Establishment of a supply of spare parts at each water yard.* A stock of lubricants such as oil and grease, and other supplies such as pump and engine gaskets and seals, filters, pipes and pipe fittings will be kept at each water yard. This will allow the pump operator to maintain the equipment and perform minor repairs. A portion of the revolving fund will be used to procure an adequate supply of water yard equipment, spare parts and replacements.
- *Development of a monitoring system for major breakdowns and water abstraction rates.* Preventative maintenance is the key to ensuring a long life for a water yard. Regular monitoring will be carried out to make sure that maintenance needs are identified early enough to take appropriate action. The proposed inspection protocols are outlined in Box 2-4. Regular monitoring will also be carried out to ensure that water abstraction rates are maintained at a sustainable level.
- *Implementation of a maintenance checklist and plan.* A maintenance checklist and inspection plan is outlined in Table 2-6. Upon learning of a maintenance issue, the water committee will be responsible for reporting any serious breakdowns to the RWC/private services. The RWC will react by dispatching a repair team. The costs of providing this service, including vehicle operating costs, personnel costs, costs of spare parts and supplies will be paid for by debiting the community's account within the revolving fund. The RWC will also provide periodic water yard equipment inspections for a fee.

Box 2-4: Water yard inspection protocols

Monitoring should be carried out by the individual or committee responsible for management and needs to be more frequent in the first year after construction, preferably once a month. Ideally a technician should assist in the monitoring for the first year. After the first-year monitoring can be carried out thrice per year. Inspection forms should include, at a minimum, the following information:

- Type of inspection (annual, seasonal, monthly, special conditions)
- Date of inspection
- Items to be inspected
- Record of any problems noted during inspection and follow-up actions that are required.

2.3.14. Sand water storage dams

Background

Sand dams are cost-effective rain water harvesting structures which are used as a response to conditions of water scarcity due to severe drought and climate extremes in drylands. A sand dam is a reinforced concrete wall built up to 5 meters high across a seasonal water stream valleys (wadis) that transport runoff-water from catchment areas to streambeds. They are designed like ordinary earth

Table 2-6: Water yard maintenance checklist and inspection frequency plan

Maintenance Task	Minimum Frequency of Task	Responsibility	Results expected when maintenance is performed
Rehabilitation of drilling	Annually	Community/RWA	Water supply and storage started and normal
Change of pump spare parts	When needed	Guard and Operator/WMCs	Water yard is operational
Inspect and repair if any for water leaks	Daily-basis	Guard and operator	No leaking from water system
Inspect water outlets	Daily-basis	Guard and operator	water supply and quality is normal
Checking and controlling livestock and human separate water supply	Daily-basis	Guard and operator	organized water access and minimum water quality requirement kept
Rectification of the water yard compound fencing	Every week- months	Guard and operator /Community	Damage and pollution hazards reduced
Emergency maintenance	When needed	Community/RWA	Water yard is operational
Groundwater abstraction	Quarterly	Guard and operator	Water abstraction rates are at or below 70% of the quarterly recharge rate

dams, but the spillway is raised to enable sediments to sit in the dam. Pictures of typical sand dams appear in Figure 2-5.

Technical characteristics

The dimensions and other design details of the sand dams to be installed at the target sites are shown in Annex H. The sand dam is comprised of four main parts: the dam, spillway, wing walls and stilling basin. A sand dam is built to last over 20 years and has an annual design water storage capacity of 20,000 cubic meters. Once construction is complete further operation costs are negligible and requires little maintenance. After construction, the dam must mature (which can take 2 to 7 years depending on the geologic and hydrologic conditions), as well as other conditions at the location and then water can start being extracted from the newly created aquifer. They provide a clean, local water supply for domestic and farming use.

There are two essential conditions for the choice of a suitable sand dam site, namely a) the presence of a seasonal river with sufficiently sandy sediment, and b) accessible bedrock in the river bed. Moreover, it is important that river sediment is suitable, with a high percentage of poorly graded coarse sand as this promote greater storage and water abstraction potential from the dam.

To ensure that a sans dam prevents water flowing underneath the dam, they are built on bedrock to a point at least 1.5 metres wider than the typical flood width of the river. This prevents excessive seepage of water which, if not prevented, can become a steady flow that undermine the dam's foundation and/or divert the river's course around the dam. In addition,

Figure 2-5: Pictures of sand water-storage dams

in the river does not continue to flow it its original course, the river may cause erosion upstream or downstream or even change course completely rendering the dam useless.

Performance feasibility

After construction, the first seasonal rains fill the dam area with water, silt and sand in both upstream and downstream directions. The coarser sand has the highest settling velocity and deposits upstream of the dam. The newly deposited sand provides additional water storage capacity. Suspended material with smaller grain sizes, such as silt, will wash over the top of the dam and continue downstream. When the riverbed aquifer is full, usually within one or two large rainfall events, the river starts to flow as it does in the absence of the dam. Sand dams are carefully designed so that the natural flow of the stream is not altered, to avoid erosion downstream of the dam. The water held in the sand behind the dam spreads horizontally creating a permanent increase in the water table, allowing trees to grow naturally and transform the local ecology and allow for small-scale farming through irrigation.

Operations & maintenance

Sand dams are simple structures and have lowest O&M costs compared to other known rainwater harvesting technologies. O&M costs are low, estimated at about $1,000 per year. In addition, major maintenance outlays are assumed to occur every 5 years at a cost of $7,500. There are three key elements underlying the O&M plan, as outlined below.

- Full involvement of the community to ensure operation, management and maintenance after completion.
- The water committee will have the responsibility of supervising the operation and maintenance procedures. WMCs will be actively involved in the determination of the revenue collection systems to meet future maintenance expenses.
- Proper linkage between the local community, local administration and governmental sector to ensure technical and advisory assistances for the community.

To maintain the sand dams, a Dam Management Committee (DMC) will be formed. The DMC will include representatives from the locality government and members from the communities using the dam. Responsibilities will focus on providing assistance for minor repairs and for general maintenance. DMC members will receive training linked to the relevant government departments. After the DMCs have been established, they will have on technical trainings on operation, management and maintenance for the water committee.

A maintenance checklist and inspection is outlined in Table 2-7. Preventative maintenance is the key to ensuring a long life for dam. Regular monitoring of will be carried out to make sure that maintenance needs are identified early enough to take action. Monitoring should be carried out by the individual or committee responsible for management and needs to be more frequent in the first year after construction, preferably once a month. A technician will assist in the monitoring for the first year. O&M costs are low, estimated at about $1,000 per year.

Table 2-7: Sand dam maintenance checklist and inspection frequency plan

Maintenance Task	Minimum Frequency of Task	Responsibility	Results expected when maintenance is performed
Rehabilitation of drilling	Annually	Community/RWA	Water supply and storage started and normal
Change of pump spare parts	When needed	Guard and Operator/WMCs	Water yard is operational
Inspect and repair if any for water leaks	Daily-basis	Guard and operator	No leaking from water system
Inspect water outlets	Daily-basis	Guard and operator	water supply and quality is normal
Checking and controlling livestock and human separate water supply	Daily-basis	Guard and operator	organized water access and minimum water quality requirement kept
Rectification of the water yard compound fencing	Every week- months	Guard and operator /Community	Damage and pollution hazards reduced
Emergency maintenance	When needed	Community/RWA	Water yard is operational

2.4. Implementation Arrangements

The Proposed Project's implementation arrangements have been designed consistent with the lessons learned in the above successfully-implemented climate change projects. In addition, they have been designed to ensure transparent and inclusive procedures with respect to all GCF-related activities. The design of project oversight accounts for established HCENR and UNDP procedures for medium-sized and small size projects. Implementation arrangements are focused on four (4) organizational elements, namely a Project Board, Project Management team, Technical Committee, and Regional Coordinators. Each is described in the subsections that follow.

2.4.1. Project Board

High-level management duties will be focused on a Project Board. The major duties of this entity are to oversee the implementation of project and make any needed adjustments to achieve project objectives and milestones. The Board will consist of three groups of members whose functions are described in the bullets below:

- *Chair:* This role is to be played by the Secretary-General of the HCENR. The primary function within the Board is to represent project ownership and approve all sub-contractual arrangements.
- *UNDP:* This role will be played by a representative(s) from Senior management in the UNDP's country office in Sudan. The primary function within the Board is to represent the financial oversight interests of the GCF.
- *Key Ministries:* This involves 13 or more Senior representatives from the states and Federal institutions, including Ministries of Agriculture and Irrigation, Water Resources and Electricity, Animal Resources and Fisheries, Forests National Cooperation, Finance, Social welfare, Academia and Research, Civil Society and Media. The wide representation of the Board will ensure coordination and integration of the project activities within the plans of the respective institutions.

  There are several specific functions for which the Project Board will be responsible, as outlined in the bullets below.

  - *Quality assurance:* The Project Board will monitor and evaluate the progress of the project activities, and assure the quality of all processes and products.

- *Resource allocation:* The Project Board will ensure that required resources are committed and will arbitrate any internal conflicts as well as negotiate a solution to any problems with external bodies, as needed.
- *Project oversight:* The Project Board will approve the appointment and responsibilities of the Project Manager and any delegation of its Project Assurance responsibilities.
- *Coordination:* The Project Board will be responsible for ensuring coordination and that feedback take place on a regular basis to identify, and recommend any adjustments to project activities, consistent with technical feasibility and the realization of project benefits from the perspective of the Government at national level.
- *Approvals:* The Project Board will also approve the Annual work plan and Annual Report.

2.4.2. Project Management Team

Day-to-day management duties will be focused on a Project Management team, including a sound monitoring and evaluation (M&E) systems. The major duties of this entity are to manage the overall project and coordinate the implementation of all regional activities. The Project Manager, to be appointed by the Project Board, will have the authority to run the project on a day-to-day basis on behalf of the GCF within the guidelines and constraints laid down by the Project Board. The Project Manager's prime responsibility will be to ensure that the project implements the specific activities set forth in this Project Proposal, to the required standard of quality and within the specified constraints of time and cost. If management tolerances (i.e. constraints normally in terms of time and budget) are exceeded, the Project Manager will consult with the Project Board for decisions. The Project Manager with be supported by Project Assistant, M&E Officer and Finance and Admin. In addition, national and international consultants will also be used to support the project implementation where appropriate.

2.4.3. State Level Technical Committee (TC)

Implementation of activities and realization of the project expected results in each State will be supervised and managed by the State Technical Committee under the leadership of the State Coordinator. The TC will include the directors or senior representatives from relevant line ministries, namely; Agriculture and Irrigation, Water Resources and Electricity, Animal Resources and Fisheries, Social Welfare and research institutions. In addition to representatives from Academia and Civil Society. Six to ten members will form the core Technical Committee at State level, while other members will be invited as appropriate. Most importantly the TC will be formed by the State Government based on the project focus in the respective state. The TC will provide insight and perspectives regarding on-going implementation feasibility issues at state level and its members will ensure the integration of project activities in the annual and semiannual plans of their respective bodies. Moreover, TC will be responsible of preparing the annual plan and report in collaboration with the State coordinator.

2.4.4. State Coordinators

Nine (9) State Coordinators will manage the implementation of activities at the state level. These individuals will report directly to the Project Manager and will have the responsibility to run the state components of the project on a day-to-day basis on behalf of the Project Manager within the constraints laid down by him/her. Within each state, the Coordinators

will share responsibilities with the TC and work in a coordinated manner and ensure integration and consistency with the overall objectives and intended results.

3. Situation Analysis - Needs, gaps, and barriers profile

3.1. Information needs, gaps and barriers – national scale

At the national level, there are several barriers that underlie the needs, gaps, and barriers at the spatial scale of the targeted areas. These national barriers are briefly summarized in the subsections below. These are in addition to local project implementation barriers associated with the installation of water infrastructure and other activities.

3.1.1. Insufficient coverage of weather, climate and hydrological monitoring infrastructure

Sudan is a vast country with five different climate zones, which makes planning and forecasting for Sudanese agriculture and pastoralism very complex. Highly variable amounts of rainfall within limited geographic areas require extensive surveillance and monitoring coverage. Currently, there is weak drought contingency planning in place and limited data infrastructure. Monitoring is required to support the generation of reliable weather forecasts/climate predictions and timely early warnings. However, to date insufficient government budget allocations have prevented the procurement of weather stations and the purchase of high resolution satellite data. Insecurity in conflict areas such as South Darfur has also limited the amount of equipment which can be installed. Consequently, insufficient coverage has resulted in limited ability to produce reliable seasonal forecasts and early warnings. It has also decreased the incentive of microfinance institutes and insurance companies to provide financial services for rain-fed farmers and pastoralists, when yields cannot be accurately predicted and losses cannot be easily validated.

3.1.2. Challenges with cross-sectorial data sharing and institutional collaboration

There is currently no centralization of hydro-meteorological/agricultural data due to various institutions acting as information producers with limited technical means to transfer data efficiently between institutions. This is due to low institutional capacity. Most of the existing environmental data is not archived securely and awareness of information databases at different departments and institutions is limited. Extension services and farmer/pastoral trade unions currently have no access to environmental databases, which prevents cultivation/husbandry planning. Similarly without access, banks and insurance companies do not have yield and accurate risk information. Consequently, insurance companies are unable to gauge losses during extreme events in an objective manner, and financial institutions lack the means to tailor microfinance products for the rural sector. As concluded during Stakeholder conversations, all the information required to assess vulnerability and calculate risks needs to be transparent and accessible through a centralized portal for all relevant Stakeholders.

3.1.3. Challenges in providing tailored weather/climate information and agricultural advisories

Currently, rural populations do not receive weather/climate/agricultural advisory information which can assist them in building resilience to climate change. Stakeholder discussions during project development indicated that forecasts/predictions need to be translated into specific

hazards experienced by different sectors e.g. heat units for livestock or wind speeds for agriculture. This information should then be combined with known vulnerabilities to identify areas and communities at risk. Furthermore, the warnings are often too technical for end-users and are not translated into Arabic or local dialects. Extension services have the potential to play a role in simplifying and communicating early warnings and climate information for rural populations, however, at the moment they have limited capacity to do so.

Similarly, the Agricultural Research Cooperation has been developing numerous adaptation technologies which can be tailored to specific sites (e.g. rainwater harvesting equipment). In spite of the fact that the technologies undergo rigorous field testing and approval mechanisms before they are released, actual applications are limited due to a lack of financing. Moreover, there are significant limitations in the amount of food security research. Consequently, rural communities are not aware of these proven technologies, which can help them adapt to climate change. Rain-fed farmers and pastoralists are also not familiar with how some technologies are gender-specific and can enable women and youth to more effectively contribute to farming/pastoral practices.

Banks and insurance companies are also unaware of the adaptation technologies. For instance, the institutions that currently provide credit services to farmers do not link lending with appropriate dry farming technologies. As a result, MFIs are increasing the risk of default on payments and are counterproductive by not exploiting the appropriate technologies to build the resilience of rural populations to climate change.

3.1.4. Long approval and complicated compensation process for existing insurance products

Insurance services for rain-fed farmers and pastoralists are extremely limited in Sudan. There is a lack of availability of market outlets and insurance agents in rural areas to disseminate insurance awareness and services. Furthermore, there are high administrative costs to judge compensation because parcels are often scattered and not demarcated. Also, there are limited weather stations and high-resolution satellite data for monitoring and surveillance, which can be used to validate damage/losses (See Barrier 1.3.1). Consequently, insurance premiums are exorbitant for farmers and pastoralists and currently amount to 7% of the sum insured (i.e., the amount of the production loan). Furthermore, the lack of clarity and consistency in compensation criteria has deterred farmers and pastoralists to use insurance services. For instance, depending on the insurance company, regions with less than 300 mm or 450 mm rainfall are often not insurable. Also, Stakeholder consultations indicated that the window in which farmers/pastoralists are able to report damage/losses is often so limited, and the distances so long to reach Khartoum-based insurance companies that many claims are left unreported. Finally, international reinsurance support is often not possible. Often re-insurance companies refuse to insure livestock in open grazing lands and the US trade sanctions, recently re-imposed on Sudan in 2012, have deterred some major, global companies from providing reinsurance to Sudan (e.g., SwissRe).

3.1.5. No experience with Weather Index Insurance products

Sudanese insurance companies have no experience with Weather Index Insurance products at national or local levels. Although a previous attempt was made to develop a product, development could not be facilitated because reinsurance could not be guaranteed. Consequently, the adoption of creative insurance solutions is likely to be challenging for insurance companies. For instance, remotely sensed data-based indices are necessary when

weather stations are not in the proximity of farmers/pastoralists, yet understanding and adapting such indices requires significant technical knowledge. Consequently, insurance companies, both public and private require significant capacity building. Additional and continuous capacity building will also be required in order to provide insurance companies with the knowledge to adapt WII products to new crops and data.

3.1.6. Lack of customized and understandable microfinance services for rural clients

Currently, there is a lack of smallholder access to financing. The main microfinance products for banks are traditional credit products. These products are generalized to all clients and do not consider the unique needs for flexibility and adaptability for farming/pastoral clients. Also, in terms of technology, most banks rely on traditional core banking systems, which do not have the ability to access the poor in remote areas. By not customizing MF products to suit the needs of targeted rural communities, this has given an advantage to informal providers who are more flexible with their guarantee requirements and repayment processes, but also less affordable.

Stakeholder consultations in the six target States during the project development phase indicated that rural populations are not taking out loans from established MFIs due to lack of collateral and lack of knowledge/understanding on the bureaucratic procedures and regulations. They also found that the existing products were not flexible during periods when no income could be gained (e.g., the planting period).

Support for developing customized MF products is also limited in Sudan, because training programs for MFIs are infrequent and the capacity of Microfinance service providers to develop new products is weak. Furthermore, extension and Business Development Services (BDSs) require studies on how to improve value chains in order to properly develop sustainable MF products.

3.1.7. Poor long-term sustainability of observational infrastructure and technically skilled human resources

The maintenance of monitoring equipment, the human capacity to use, maintain and repair this equipment, process data and develop forecasts and advisories, all require sustainable financing mechanisms and capacity development. Costs to support operation and maintenance, as well as salaries and capacity building for technical public servants within the NHMS, are recurring annual expenditures which require planning and budgeting. At present, the NHMS often struggle to pay for the maintenance and upgrade of existing equipment due to poor long-term budget planning. Insufficient and inconsistent budgeting has led to the inability of the Sudan Meteorological Authority, SMA, to rehabilitate four radars previously in the country, and explains why approximately 40% of the hydrological equipment is currently not operational.

Moreover, there is no link with the NHMS and insurance companies to support systemic use of weather/climate data and support for continuous monitoring. Weather/climate monitoring data is required for risk management (e.g., for index product creation, pay-out validation). However, NHMS is unaware of the private demand for data, particularly how much the private insurance sector is willing to pay for tailored data services. Knowledge sharing is required between the institutions so that data on covariate risks (such as severe drought) can be fully exploited to assist with private sector demands. By generating revenue-

bearing products, the NHMS has the potential to use the funds for equipment upkeep, operation and maintenance as well as license renewals, thereby enabling monitoring sustainability.

Additionally, qualified human resources at all levels are required so that adequate technical expertise is available for equipment maintenance/operation and data analysis/modelling/forecasting. Running forecast models and analysing satellite data is a highly skilled task and requires many years of education and training. However, in Sudan, training for technicians is one of the main limiting factors to maintain equipment and continue model simulations as well as to gain experience with new technological developments.

3.2. Information needs, gaps and barriers – targeted area scale

The Proposed Project applies cutting-edge adaptation practices and appropriate technologies to build resilience to climate change risks among subsistence farmer communities throughout Sudan. The key objective is to disseminate a set of adaptation-focused measures that have been tested via a NAPA project. These measures have been validated by stakeholder consultations as effective to minimize the impact of climatic impacts on small-scale farmers and pastoralists, thereby reducing vulnerability from increasing climatic variability. These measures involve a hierarchy of activities spanning risk minimization, risk absorption, and risk avoidance strategies in water and agricultural systems. Moreover, each of the individual water and agricultural measures to be implemented in the project areas has been selected on the basis of their high cost efficiency/effectiveness on the basis of recent economic performance analysis conducted by the Ministry of Water Resources, Irrigation and Electricity.

Together, these activities will improve knowledge systems, diversify household incomes, and transfer appropriate technologies. The focus of the project is on a total of 211,773 subsistence farming households distributed among 138 villages across 9 states, the primary beneficiaries of project activities. These households correspond to 1,181,538 people, or 31% of the total population in targeted villages. A further 2,499,712 people are indirect beneficiaries.

3.2.1. Challenges with resource constraints

The main barriers confronting development and adoption of a range climate-smart practices, as described above, in the targeted localities and village communities is attributed to the absence of financial resources, lack of efficient extension services, and lack of technical know-how, farmer's awareness about existing technologies and limited or no fund available for conducting research.

In the Sudan adaptation intervention experience, the introduction and transfer of improved technology (innovations, knowledge or practice) is a process that has led to the adoption of the new technique or product by users. One of the reasons for the successful interventions in the Sudan context is the combination of dissemination, demonstration, training and other activities. In Sudan, the transfer of technology from agricultural research to farmers is carried out largely by the public agricultural extension services and to a lesser extent by the private sector and some NGOs.

In the targeted areas, extension is the responsibility of the individual states as part of their responsibility for agriculture and livestock services, by institutional mandate. Extension activities within the Department of Ministry of Agriculture and Animal resources have been

converted into a Technology Transfer and Extension Administration (TTEA) which has the task of modernizing agriculture, increasing crop yields and the quality of production, improving farmers' income, achieving sustainable use of resources and sustainable production.

The target states share a common set of information needs, gaps and/or barriers. These are related to a lack of technical support, funds and public extension services. The result is poor efficiency in delivering agricultural information and in transferring new technologies. Most of the extension staff, not to mention the farmers themselves, in the targeted areas have not received any extension training. A weakness of current extension is that they lack the capacity to deliver extension messages related to climate-resilient development. This is because the focus of current government extension services is largely unrelated to climate change risks and seeks to improve productivity without parallel emphasis on climatic factors. The proposed project brings this parallel emphasis and in the process provides important benefits that are additional to ongoing rural development and extension activities.

3.2.2. Lack of reliable and/or relevant field-based research activities

The government Agricultural Research Corporation (ARC) has research stations across the ten targeted states. These stations have prioritized developing early maturing and drought tolerant varieties, improved crop husbandry practices, water harvesting technologies, and livestock improved husbandry practices. However, research is primarily on-station and farmer participation (on-farm research) is limited. This is a significant drawback as the benefits of community engagement (e.g., awareness-raising, personal investment of time/resources) is unrealized. Additionally, linkages with other government agencies, NGOs and the private sector are weak resulting in poor dissemination of improved technologies.

Effective adaptation need reliable data, thus, more research is needed to establish climate change patterns, vulnerability, adaptive capacity, mitigation options and develop technologies that will ensure sustainable response systems and minimize impacts and risks associated with climate change. To some degree, government activities are making progress on these issues. As such, this progress represents important baseline circumstances upon which the proposed activities will build. Several knowledge and research gaps related to climate change such as risk/vulnerability assessments/mapping, improved varieties and cultural practices, water and soil conservation have been identified as of very high importance. Specifically, certain areas represent key needs, gaps and barriers where more focused research related to climate change adaptation is needed (i.e., Natural resources and ecosystems; soil and water management; Crop husbandry and management; livestock breeding; livestock and range management; forestry and gum Arabic)

3.2.3. Poor micro-financing infrastructure in rural areas

Financial and micro-finance institutions are limited in the target states due to the risks associated with a changing climate and unstable markets (IFAD). Financial service providers (i.e., banks, microfinance institutions, and insurance companies) are discouraged from lending to farmers and livestock owners (IFAD). Thus, smallholder rain-fed farmers and pastoralists have very limited access to finance and improved opportunities to improve their production. This has prevented investments in land preparation, the ability to have climate-resilient production practices (e.g., rainwater harvesting) and has kept many families (especially single female-headed households) in continuous cycles of poverty and food

insecurity. Consequently, farmers and pastoralists have had trouble entering markets, have poor access to inputs and lack critical agricultural/livestock advisory- and extension services.

3.2.4. Inadequate data on viability of drought-resistant seed varieties

One of the most important technical capacity needs across the targeted states is a better understanding of the types of seed varieties that can fare well in Sudan's changing climate. As this is one of the main focuses of international research for adaptation to climate change, it will important to transfer knowledge of specific crop varieties that can cope with heat, drought, flood and other extremes. Such information can help local extension services to help farmers adapt to the changes and sustain increase in agricultural production and productivity.

Some of the key barriers to the transfer and adoption of improved crop varieties common to all targeted states are outlined in the bullets below:

- Poor quality control over seed supply system which are entrenched government supply chain systems that do not adequately account for climate change
- Lack of informal sector (i.e., farmers) knowledge for producing/obtaining quality drought-resistant seeds. This knowledge is lacking due to information and other barriers discussed previously.
- Lack of market signals to private sector to invest in drought-tolerant seed production. This is because rural market are small, segmented, and subject to local bartering and other non-market factors,
- Limited availability of improved seeds varieties developed and successfully cultivated elsewhere. This is because there currently is no systematic governmental process for the procurement and dissemination of improved seed varieties to needy communities.
- Ineffective or unavailable extension service training programmes in the field of improved crop varieties. This is because current extension services are disproportionally low compared to the extension service demand.

Some of the key measures to overcome barriers for improved crop varieties that are relevant to all targeted areas are outlined in the bullets below.

- Generate awareness and improving farmers' access to seed developed varieties to reduce climatic risks and improving crop productivity
- Scaling up the dissemination of new varieties through facilitation seed multiplication of the improved varieties and involve financial institutions to encourage the private sector to invest in seed production.
- Development of 'sustainable varieties' that are drought-, heat- and pest-resistant coupled with encouragement/promotion of these varieties through strengthened extension services.

3.3. Conclusions

The following normative set of conclusions provides the design basis for project interventions across the targeted areas for overcoming gaps and barriers described above. Addressing each of the conclusions outlined below is essential in order to make the people who depend on

agriculture and rangelands for their livelihood more resilient to current and future climatic risks. Each is consistent with the actual needs of the targeted areas, as surveyed during the consultative workshops.

- Promote the diffusion and adoption of existing adaptation technologies that boost productivity and safeguard natural resources through increasing agricultural extension services and outreach and encourage information exchange among farmers.
- Strengthen the linkages between research institutions and extension for proper implementation of proven research outputs at the grass root levels.
- Strengthening and building adaptation capacities through expanding and integrating adaptation measures in various long term national and local agriculture development strategies.
- Financing assistance for adaptation and mitigation measures in the agriculture sector should be prioritized.
- There is an urgent need for improving the link between the adaptation needs and national policymaking. This calls for urgent institutional capacity development efforts at national and targeted state levels.
- The extension services represent the most important activity geared towards dissemination of water harvesting technologies to farmers. The extension staff, and the farmers are characterized by being poorly equipped and trained and they need to reinforce their technical skills and facilities for better functioning. The proposed project is aiming at providing support in technical capacity building in water harvesting, control and management for farmers and agricultural engineers/extension workers.
- In most targeted States weather stations are located only in the capital of the state. Thus, rain-fed farmers/pastoralists are lacking consistent, localized weather/climate forecasts/predictions and many potentially threatening hazards have not been anticipated. Rain gauges are needed to be installed in targeted states for wide coverage.

4. Project design response to the situation analysis

4.1. Overall approach to address the situation in targeted areas

The project's overall approach to address the situation in the targeted areas has been designed to emphasize certain strategic elements. It is important to note that these elements address the nature of the proposed project's response to the barriers and challenges discussed in the previous sections.

- *Build on successes of the NAPA implementation project.* The NAPA implementation project had successfully demonstrated and documented good examples and success stories in 4 different ecological zones in improving crop and livestock productivity, water management as well as building capacities of rural communities against the adverse effect of climate change. The GCF project will build on these successes and lesson learnt taking into account respective similarities of the targeted state clusters to the NAPA four ecological zones.

- *Promote country-ownership.* This was pursued through involvement and participation of a wide range of relevant government institutions, including research, Non-Governmental organizations, microfinance institutions and private sector. The design paid great attention to build the required country capacity to enable sustainability of the project's results, design and implement supportive policies and integrate successful options into national planning. Building on the successful institutional arrangement of the NAPA Implementation Project, the project will be implemented by multi-disciplinary technical committees at state level and guided by board composed of relevant institutions to provide policy and strategic support at national level.
- *Establish viable grassroots institutions.* The village development committee model, successfully implemented in other projects, should be established. Such committees engage key stakeholders such as sedentary farmers, pastoralists, IDPs, returnees, customary institutions and Government Locality(ies) into one decision making body. These committees can also assist in resolving conflict that arises from competition on use of natural resources; especially in the Darfur and Kordofan areas.
- *Support women and women-headed households.* Recurrent droughts, persistent and prolonged war in some targeted areas (Darfur) as well as migration of men to cities has resulted into a relatively large number of women-headed households in the targeted states. The GCF project should pay a special attention to this category of beneficiaries by ensuring rights of access to resources, production inputs, restocking of domestic livestock, credit and agricultural technology.
- *Ensure up-scaling and replication potential.* This involves establishing a system to promote and scale-up those project aspects and measures that are particularly successful outside the project site and into the wider community. Promotion of successful techniques and lessons learnt should be pursued through a combination of approaches involving innovation platforms (e.g., community demonstrations) and the local media. Moreover, farmers and pastoralists as well as personnel from related development projects should be engaged as strategic partners in the process.
- *Link beneficiaries with micro-financing institutions.* The project should build on recently enacted policies on microfinance that are being promoted by the highest political levels in Sudan. Specifically, the GoS has recently approved and supported 33 microfinance institutions under the endorsement and guidance of the Central Bank of Sudan. These institutions are well distributed to most of the targeted states and are meant to provide essential credit for small farmers, women and youth groups, individually or through their community based associations. The GCF project should seek to link beneficiaries to these institutions to ensure safe and easy access to microfinance funding.

4.2. Type of interventions to build resilience in targeted areas

An overview of the types of interventions to be implemented in each of the targeted areas is shown in Table 4-1.

4.3. Knowledge management and learning initiatives in targeted areas

There are three key dimensions of knowledge management and learning that are readily feasible to be addressed by the project. These are briefly described in the bullets below.

- *Community level.* The project can develop a systematic approach to introduce capacity building regarding specific kinds of farm and rangeland management methods that can increase resiliency and overall productivity in the context of Sudan's ecological zones. Certain trainings on climate resilient agronomic measures should be tailored to meet the needs of women and be specific to their livelihood demands. Community mobilization workshops, field based demonstrations, and other formats should be explored to improve skills and knowledge associated with interventions.

Table 4-1: Types of proposed climate change adaptation initiatives in targeted areas

		Darfur States			Kordofan States		Eastern States		Nile States	
No.	Description	West	East	Central	South	West	Kassala	Red Sea	North	Khartoum
1	Afforestation and nurseries for improved seed varieties	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	Awareness-raising and capacity building	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	Borehole development	✓			✓	✓	✓		✓	
4	Construction/rehabilitation of hafirs, small earth dams, and traditional water ponds	✓	✓	✓	✓	✓	✓		✓	
5	Construction/rehabilitation of micro catchments for household gardens						✓	✓	✓	
6	Improved fodder production and processing, including pasture seed broadcasting						✓	✓	✓	
7	Policy development, including integrated water resource management	✓	✓	✓	✓	✓	✓	✓	✓	✓
8	Range management, rehabilitation, shelter belts, reseeding, enclosures	✓	✓	✓	✓	✓	✓	✓	✓	
90	Rehabilitation of Gum Arabic gardens		✓	✓						
10	Specific demonstration projects for sustainable practices	✓	✓	✓	✓	✓		✓		
11	Women household gardens and alternative income generating activities	✓	✓	✓			✓	✓	✓	

- *Institutional level.* The project can target technical personnel of the key institutions such as Ministries of Agriculture, Ministry of Animal Resources, Water and Environment, Ministry of Finance, Planning and Development department and engages them in training on climate resilience practices and disaster risk management as part of the state level and sectoral planning. Specialized training on integrated water management (IWRM) approaches, water harvesting techniques and technologies, groundwater management, including artificial recharge regimes, and other related topics should be offered to government technical staff and agricultural extension agents.
- Planning/policy level. The project can facilitate the integration of successfully tested adaptation practices, especially those that specifically address women's adaptation needs into the agriculture and food security related programmes and policies, including national and state level programme and budgets for further up-scaling.

4.4. Innovativeness/effectiveness of interventions in targeted areas

There are two key findings from the technical feasibility assessment activities regarding ways to ensure the most innovative and effective form of building resilience in the targeted areas. These are described in the following bullets.

- *Work with and enhance existing production systems.* The farming systems at village level in most of the target areas are integrated and based on traditional systems of cropping, animal husbandry, forest products and off-season activities. Cropping, livestock raising, and forestry will remain the main supporting activities for sustaining local livelihoods. Project interventions are oriented to supporting these essential components and improving local access to services and climate-smart practices.
- *Involve local communities throughout the implementation process.* Involving households directly is feasible and essential to ensure successful demonstration and adoption of the proposed methods and techniques at the farm level. Activities will seek to engage communities throughout the project cycle; starting from the design of the actual on-the-ground measures, proceeding to implementation activities, and including the development and implementation of community-run monitoring and evaluation schemes to gauge the actual effectiveness of the implemented strategies.
- *Engage and empower women.* A high level of local engagement of women is feasible and is also viewed as critical to ensuring the ongoing viability of the adaptation measures that will be maintained through the duration of the project and thereafter. Women's role in this regard is critical and their engagement will be pursued in the context of women's associations. Women tend to feel much of climate change impact due to male migration which has led to increased number of woman-headed households.

4.5. Alternative Scenario: Building resilience against climate change impacts

The project aims to increase climate resilience among agro-pastoralists and nomadic pastoralists, particularly women, in dryland areas through an integrated approach to agricultural production, water resource management, and rangeland management. The project will help to transition targeted communities toward an alternative scenario that improves on the baseline scenario by addressing barriers through the following:

- *Introduce sustainable practices.* The project seeks to disseminate a set of sustainable technologies and practices through the distribution of drought-resistant, early maturing seeds, establishment of integrated women-led sustainable farms, rehabilitation of communal rangelands, development of multi-purpose tree nurseries, and establishment of shelterbelts to shield cultivatable plots from dust storms.
- *Install water supply and distribution infrastructure.* The project seeks to increase the availability of, and access to, water resources for humans and animals through the construction and/or rehabilitation of hafirs (i.e., underground reservoirs designed for water storage), water yards (i.e., pump, above ground storage tank, and small-scale water distribution system), and sand dams (i.e., reinforced concrete wall built across a seasonal sandy river in order to retain rainwater and recharge groundwater). Climate-related factors as well as intra-group conflicts, have had a cumulative and destructive impact on water supply infrastructure, leading to significant deterioration and low yields, with a poor environment where animals and people intermingle. Improving access to water through

improved/rehabilitated and/or construction of additional/new water sources will reduce vulnerability to increased water scarcity by mitigating water-related conflict in the project areas.

- *Enhance local governance capacity to address climate resilience.* The project seeks to strengthen local governance by building capacity among Village Councils, Village Development Committees and Popular Committees on best practices, as well as increasing capacity of extension agents from state-level Ministries of Agriculture and Forestry on sustainable technologies and practices suitable for dryland areas.

In implementing the above activities, the project builds upon the lessons learned from recent climate change adaptation projects such as: 1) LDCF-funded Climate risk finance for sustainable and climate resilient rain-fed farming and pastoral systems; 2) CIDA-funded Implementing Priority Adaptation Measures to Build Resilience of rainfed farmer/pastoral communities; and 3) GEF-funded Implementing NAPA Priority Interventions to Build Resilience in the Agriculture and Water Sectors to the Adverse Impacts of Climate Change in Sudan. The project complements these projects and applies a similarly integrated approach to crop, water, and rangeland management that incorporate recurring drought concerns and understanding linkages between agro-pastoralist and nomadic pastoralist livelihoods.

Moreover, in implementing the above activities, the project will support the integration of field activities into ongoing research activities. Research institutions in Sudan have for several decades been developing and promoting agricultural innovations aimed to deal with the changing environmental conditions. More recently the Agricultural Research Corporation (ARC) released sustainable technologies including early maturing-drought tolerant crop varieties and climate-smart husbandry practices for crops and livestock. However, few of these technologies have reached the beneficiaries due to limited outreach. One of the main challenges facing agricultural research in Sudan is to enhance the dissemination of research findings regarding sustainable technologies. The project represents an opportunity for nearby research stations in target states to participate based in part on funds allocated to capacity building as well as governmental co-financing.

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Annex A: Background details for targeted states

Nine (9) of Sudan's eighteen states are being targeted by the proposed project. These states are grouped into four regional clusters, namely Greater Kordofan cluster (2 states - South Kordofan, West Kordofan), Greater Darfur cluster (3 states - East Darfur, Central Darfur, West Darfur), Eastern States Cluster (2 states - Red Sea, Kassala), Northern States Cluster (2 states - Northern, Khartoum). Rain fed agriculture is the predominant production system in all clusters. Details of clusters and specific state vulnerabilities are described in the following sections:

Greater Kordofan cluster (2 states - South Kordofan, West Kordofan)

Greater Kordofan is situated in the mid-west of Sudan between latitudes 11°28'N and 14°07'N and between longitudes 27°42'E and 30°34'E. It covers an area of about 380,000 km², representing 24% of the total area of the country. Population of Greater Kordofan is about 5.4 million people. The livelihoods of Kordofan is largely based on small scale rain fed traditional production systems of cropping and animal husbandry. Animal husbandry is carried out on natural rangeland and crop residues. Many of sedentary farmers on the sandy soils in the north and western Kordofan incorporate production of gum Arabic (acacia Senegal) into their long-term crop production. Household gardens for vegetable production are widely practiced, especially, in South Kordofan. Sedentary rural population and nomads constitute more than 75% of the population. Kordofan consists of three states: North Kordofan, which falls into a semi-desert zone and West and South Kordofan States, a high rainfall savannah area.

A number of climate change scenarios are available for Kordofan states. Climate scenarios for 2030 and 2060 in Sudan's INC projected a decrease in average precipitation and an increase in average temperatures, with pronounced changes expected for Northern Kordofan (INC 2003). Alam et al (2012) confirmed these findings in modeling future climate change scenarios through 2080 in 5 locations in the Kordofan States, with the exception that rainfall and evapotranspiration rates may decrease in some localities. The major sectors impacted by climate change are agriculture, water and health, in both Northern and Southern Kordofan. That said, Northern Kordofan is considered more vulnerable due to a climate that is already prone to low rainfall and extreme temperatures and has been one of the focused states for climate change adaptation activities. The proposed GCF project will, therefore, target south and West Kordofan States. Details on vulnerabilities to climate change for the two states are described below:

Southern Kordofan

Southern Kordofan state is located in the heart of Sudan and is composed of two climates. The northern part of the state is a semi-dry low rainfall savannah while the south is a semi-humid high rainfall savannah. Over 85% of the state's population lives in rural areas and depends on a mix of traditional and mechanized agriculture. Fertile soil and predictable rainfall mean the state has high agricultural potential yet large swaths of arable land and forests go unused due to poor water infrastructure. The existing water infrastructure - hafirs and boreholes -remain insufficient to meet even current demands.

A recent study of two sites in Southern Kordofan - Rashad and Kadugli - recorded significantly higher baseline rainfall. While both sites averaged temeraptures of around 27 °C, Rashad

received on average 654 mm of rainfall per year from 1970-1990 while Kadugli received 598 mm per year over the same time frame (South Kordofan State NAP Committee 2013). A high climate change scenario predicted large gains in temperatures (nearly 5°C) and large losses in rainfall (53 mm and 26 mm, respectively). A low climate change scenario predicted a 2.5 °C increase in temperatures and negligible changes in rainfall.

Because of its wetter climate, Southern Kordofan state is less vulnerable to drought conditions than its northern counterpart. However, the adverse impacts of climate change may be experienced indirectly via forced migration. That is, as agricultural regions in other parts of Sudan become less productive, states further south may see an influx of climate refugees.

At present, Southern Kordofan lacks the infrastructure to accommodate rapid population growth. Having been at the center of a long running civil conflict with the south, the state is characterized by widespread poverty, lack of basic services, poor infrastructure and continued land disputes.

Climate change adaptation in Southern Kordofan should focus on developing institutional and infrastructure capacity to accommodate a potential influx of climate refugees. Despite the area's high potential for agriculture, poor infrastructure, maladaptive policies and insufficient policy implementation have caused serious land degradation. For example, poor policy implementation allowed mechanized farming to expand without leaving the shelterbelts required by the Forest Act.

Western Kordofan

Western Kordofan is located in the southwest corner of Kordofan State. The northern part of the state is classified as semi-desert; the southern part of the state is classified as high rainfall woodland savannah. The area is almost flat with sandy soils covering about 60% of the state. Transhumance dominates socioeconomic activities. Nomadic tribes dominate the population and economy of Western Kordofan. Inhabitants are mainly Baggara tribes, who are mainly cattle owners and Hamar tribes, who are mainly camel and goat breeders. Most of the population is found where water and other services are available.

Western Kordofan is confronting several climate change impacts. In the agricultural sector, higher temperature and increased rainfall variability has led to crop failure, increased pest incidence, and out-migration by farmers. For natural resources, climatic hazards have resulted in overgrazing of rangelands and the loss of forested areas. For pastoralists, lower humidity levels and higher temperatures has led to grassland degradation and animal diseases. For the water sector, there have been diminished levels of healthy drinking water due to lower rainfall. Finally, communities have experienced a higher incidence of certain climate-related epidemics.

It will be important for adaptation planning in Western Kordofan to address underlying socioeconomic factors that contribute to vulnerability to climate change, namely poverty levels among nomadic tribes and their lack of household income diversification

Greater Darfur Cluster (East, Central and West Darfur States)

Darfur cluster occupies the far west of Sudan, extending between latitudes 11°10'N and 14°30'N and between longitudes 22°5' E and 26°40' E, with a total area of 490,000 km². Traditional agriculture is the most important form of production and characterized by various

types of small-scale sedentary cultivation and pastoralism. Integration of animal and crop production is traditionally practiced. Water is the most important resource limiting agricultural productivity and human settling. The southern part of the region is characterized by the availability of a number of seasonal water courses that are comparatively water-rich, which offer possibilities for irrigated small-scale potential for fruits and vegetable production.

Darfur is comprised of five major States: North Darfur is characterized by a semi desert climate; West and Central Darfur are low rainfall savannah zones; and the remaining South and East Darfur are high rainfall savanna zones.

While rainfall has always shown high variability in the Darfur States, recent years have seen this pattern intensify. For example, in North Darfur, 20 of the 25 driest years on record have occurred since 1972, threatening agricultural and livestock production, particularly in North Darfur (North Darfur State NAP Committee 2013). Across the northern and western areas of the region, 40% of harvests currently fail on average; by 2050, it is expected that 70% of harvests are likely to fail on average. Only the high rainfall savannas of the southern area are less vulnerable to drought.

Without appropriate planning, future climate change is expected to have serious impacts on Darfur's economy and population. For example, shifting rainfall patterns and high demand are rapidly depleting groundwater levels. Monitoring systems at groundwater sites and wells show a risk of acute groundwater depletion.

Hence, adaptation planning is crucial across the Darfur States to achieve food and water security in the face of poverty and climate change. Given the diversity of ecological zones within the Darfur States, each state faces a different set of vulnerabilities and requires a tailored suite of adaptation plans, as described in the paragraphs below. While Greater Darfur is comprised of five major States, the proposed GCF Project will target East, West and Central Darfur States.

East Darfur

East Darfur falls into several climatic zones; semi-arid in the northern areas; low rainfall savannah in the central areas; and high rainfall savannah in the southern areas. Economic activity is dominated by pastoralism and agriculture, with about 90% of the population being pastoralists and farmers. Key agricultural products include gum arabic, groundnuts, Millet (known locally as Dokhn), sorghum, Hibiscus (known locally as Kerkrade) and other crops. Large numbers of cattle, camel, and sheep are found throughout the state, one of the state prominent characteristics relative to the rest of Sudan. Current trends of changing climatic conditions - notably decreasing annual rainfall and increasing variability - have taken increasingly burdensome tolls on the livelihoods of local communities.

East Darfur faces a number of impacts associated with climate change, particularly related to water. Reduced or highly variable rainfall levels have led to serious degradation of rangelands. This has resulted in a lack of regeneration or rangelands and in some cases, the disappearance of certain grasses and herbs. Nomads who rely on these resources have been forced to cope by means of several unsatisfactory options for feeding their livestock herds, namely accessing forests for lower quality tree leaves; depends on crop residues for feeding their animals; or moving across the border to South Sudan. Moreover, East Darfur has become the home for significant numbers of displaced people from other states of the region, all suffering from reduced rainfall in their places of origin. This has amplified the consequences of climatic

change for the state and further exacerbated environmental degradation and socio-economic disruptions.

It will be important for adaptation planning in Central Darfur to address underlying socioeconomic factors that contribute to vulnerability to climate change.

Central Darfur

Central Darfur falls into the low rainfall savannah zone. The region is characterized by diverse climate and soils, including volcanic soils in Jebel Marra (a mountainous area) sandy, clay and alluvial soils in the different valleys traverse the state towards the west to Chad and Central African Republic. Most economic activities are focused on agriculture and pastoralism. About 80% of the state's population is comprised of farmers and pastoralists. Communities are suffering from recurrent droughts, increasing temperature and rainfall variability, which together with high poverty rates have led to a growing misuse of resources as evidenced by overgrazing and denuding of forests.

Central Darfur faces a number of hazards associated with climate change. These include higher maximum temperatures, increased drought frequency; decline in annual rainfall; and increased rainfall variability. Communities throughout the state have experienced all of these hazards over recent decades. As in other Darfur states, the only coping strategy available to poor households is a deepening exploitation of limited land, water and animal resources. This has in turn led to reductions in soil fertility; loss of total forested area; reduced forest productivity; declining crop productivity; decreased groundwater levels and seasonal streamflow, and increased outbreaks of diseases such as malaria, typhoid and yellow fever.

It will be important for adaptation planning in Central Darfur to address underlying socioeconomic factors that contribute to vulnerability to climate change.

West Darfur

West Darfur falls into a low rainfall savannah zone, an ecosystem rich in seasonal valleys and tributaries that can sustain forests, rangelands, and agriculture. There is a large variation within the state, with areas in the south receiving nearly 500 mm of rain per year and areas in the north receiving less than half of that amount (West Darfur State NAP Committee 2013). The Paleozoic sandstones provide groundwater resources that have sustained the area during dry years.

Approximately 80% of the state's economy is based on agriculture and livestock production. Farmers produce a diverse set of cash crops that include cereal crops, oil crops (groundnuts, sesame), legumes, vegetables, and horticultural crops (mango, citruses etc.).

West Darfur has a history of chronic food insecurity. A household health survey conducted in 2006 found that it is the most food insecure region in Sudan with greater than 40% of the population unable to obtain a health daily diet. While additional modeling needs to bar carried out to predict changes in temperature, rainfall and evapotranspiration rates for West Darfur, the current expectation is that food insecurity will deepen in West Darfur in the absent of effective adaptation. The region will experience increasing temperatures, increasing rainfall variability, and higher drought frequencies. Combined, these effects will adversely impact crop yield, lead to further deterioration of rangelands, and further deplete groundwater resources.

Climatic stress is exacerbated by the absence of a rational land use policy, which has led to a host of maladaptive strategies. For example, the livestock population far exceeds the carrying capacity of many rangelands and persistent deforestation is accelerating land deterioration (West Darfur State NAP Committee 2013). At the same time, farmers who are unaware of best practices are utilizing low quality crop varieties that are not suitable for changing climatic conditions. Adaptation in West Darfur should address these trends and focus on both climate and non-climate stressors on its agricultural, water, and public sectors.

Eastern States Cluster (2 states - Red Sea, Kassala)

The Eastern Cluster lies in the Eastern North part of Sudan, extending between latitudes 15° 20'N and 18°58'N22° N and between longitudes and 34°36'E and 38° 45'E with a total area of 255, 597 km². The targeted area in this cluster are Red Sea and Kassala States. About 50% of the Red Sea State is occupied by volcanic rocks alternating with seasonal water courses. Urban population estimates are 62%. The main livelihood groups in the state are pastoralists found across the state primarily in settlement by streams and seasonal water courses (Khors). Other livelihood sources are agriculture and fisheries (in coastal area). The state has been in a long-term dry condition with more than 90% of the cereal consumed coming from other parts of Sudan. Agriculture and livestock herding are the two major livelihoods activities in Kassala state. The consistently dry conditions in the area have destabilized traditional livelihoods. Small scale irrigated horticulture production is widely practiced depending on pumping of groundwater. Rural areas still suffer shortage of adequate and a safe water which have led to environmental degradation.

Over 80% of Kassala state area is flat with clays and alluvial plains, with a few outcrops of rocks and hills. Agriculture and livestock herding are the two major livelihoods activities in the state. More than 80% of the population engaged in crop production, while 20% practice pastoralism in the of northern part of the state. The consistently dry conditions in the area have destabilized traditional livelihoods.

Small scale irrigated horticulture production is widely practiced depending on pumping of groundwater. Rural area still suffer shortage of adequate and a safe water which lead to environmental degradation. The Eastern States consists of three states in three separate ecological zones. In the North, the Red Sea state falls into the desert zone; the centrally located Kassala state is in the semi desert zone; and Al Gedarif state is a low-rainfall savannah ecological zone. Similar to other areas in Sudan, these states are experiencing increased rainfall variability, decreased average rainfall, and increased temperatures. However, given the region's ecological variety these changes are projected to be unevenly distributed across the three states. Of these states, Kassala is considered the highly vulnerable due to high rainfall variability and increasing temperatures while the Red Sea state is considered to be highly vulnerable due to sea level rise and the adverse of impacts of sea surface temperature changes on marine biodiversity. The Proposed GCF project will target the Red Sea and Kassala States.

Kassala State

Kassala state extends across a semi desert zone as well as a low rainfall savannah zone in the south. Its population of 1.7 million is growing at an average 2.5% per year, with most inhabitants living in Kassala town and other semi-urban centers. The economy is dominated

by agricultural activities. As a result, water and agriculture, and to a lesser extent health, were identified as the primary sectors of concern during the vulnerability assessment.

Given its location in the semi-arid north, Kassala is extremely vulnerable to climate change. Over the past decade temperatures have increased and rainfall has decreased. In particular, the range in annual rainfall has dropped to between 67 and 425 mm/year over the past decade, well below baseline rainfall conditions (Kassala State NAP Committee 2013).

High rainfall in certain parts of the state means Kassala is coping with frequent seasonal flooding from the Gash and Atbara rivers in the western part of the state. Historically, floods have occurred every 6-7 years over the 1970-200 period. In recent decades, flooding frequency has increased to about every 4-5 years. Moreover, in semi-desert zones, drought frequency has also been increasing, with two major droughts occurring in 2008 and 2011. In the future, this intensifying cycle of floods and drought is projected to continue and intensify, with Kassala's already vulnerable rural population - 85% of which are living below the poverty line and relying on subsistence agriculture - most at risk.

Red Sea State

The Red Sea state is distinguished from other states in the Eastern region as the only state with a coastline. The state covers about 219 thousand square kilometers state and has the highest poverty rate in Sudan. The Red Sea state has a750-kilometer coastline characterized by numerous islands, the majority of which have no fresh water or vegetation. The State's climate is characterized by high rainfall variability, low rainfall, and extreme temperatures. The marine environment is characterized by high salinity and high evaporation rates. Box 4-11 provides some essential climatic and vulnerability information for Red Sea state.

For inland areas, the hilly topography at the Basement Complex formation of base rock makes surface run-off the only reliable source of fresh water in the Red Sea state. The Basement Complex's combination of rocks, compact soils, steep slope, and pattern of rainfall and poor vegetation cover, all contribute to high rates of run-off in the region that is difficult to predict or control. On the whole, the region relies on dams, water treatment, hafirs and wells from both ground and surface water for their water supplies. Over the last decade, the water table has reduced an average of 5 to 10 meters, with declining well productivity (Red Sea State NAP Committee 2013).

For coastal areas, the Red Sea supports varied and diverse coastal and marine habitats, including coral reefs, mangroves, and seagrass beds. A large number of bird and fish species are supported by these ecosystems, many of which are not found anywhere else in the world. These resources also provide food and income for the communities living along the Red Sea coast. The most significant implications of climate change affecting these coastal zones are the increase in sea surface temperature and sea level rise. Rising sea levels threaten to inundate wetlands and other low-lying lands, erode beaches, intensify flooding, and increase the salinity of coastal lagoons and groundwater.

An overarching concern across inland and coastal areas is water scarcity. Since the drought in the 1980s, the state has been in a constant condition of food insecurity and has relied on external assistance, particularly in rural areas. The lack of ready access to water threatens the state's main livelihoods, which are agriculture and livestock raising. About 102 thousand square kilometers are classified as natural grazing area, supporting about 1.8 million heads of livestock (Red Sea State NAP Committee 2013). At present, there is a gap between production

and demand in key crop groups. At the same time, overgrazing is rapidly deteriorating rangeland, in particular placing the Beja agro-pastoralist group in jeopardy.

Northern States Cluster (2 states - Northern, Khartoum)

The Nile States consist of Khartoum and the Northern state. Both states are characterized by an arid climate with low rainfall, extreme temperatures, sparse vegetation, and increasingly erratic weather patterns. The region covers an area of nearly 471 thousand square kilometers and has a population of about 7.2 million people.

The Northern and Khartoum states extend between latitudes 15°30'N and 19°30'N and between longitudes 27°36'E and 34°30'E with a total area of 493,030 Square Kilometres. The most important feature is the rive Nile which passes through the region from south to north. Most of the population is engaged in intensive agricultural production along both banks of the Nile and its vicinity where the water table is high enabling for reliance on shallow surface well. Various methods of irrigation are used, including river diversion to flood large areas; small riverbank pumps; large pump stations serving schemes; residual moisture along the riverbanks and on the islands following the summer floods (gerif); pumped groundwater in the high-terrace areas; residual moisture following the flooding of wadis (demira); and recently, centre-pivot sprinkler systems in a few locations. In Khartoum State horticultural and forage production is dominant. Nomadic tribes herd their animals along the wadis (seasonal streams). With exceptional riverain ecosystem most of the area lies within the desert and semi desert climate. The proposed project will target the three states in this cluster.

Northern State

Located in the heart of the desert zone, the Northern state is characterized by low rainfall, extreme temperatures, and sparse vegetation. The local economy depends upon both irrigated and rainfed agriculture. Box 4-13 provides some essential climatic and vulnerability information for the Northern state.

Rising temperatures, decreasing rainfall, fluctuations in the River Nile, and increased wind speeds have combined to result in a mix of drought and flooding with adverse effects on crop yields, rangelands, animal production, and river bank erosion (Northern State NAP Committee 2013). Shifting climates have also hastened the arrival of new plant diseases, such as the date palm disease in the Elgab area, and new skin diseases, such as Jarab, which are not historically common in the state. While irrigated agriculture is vulnerable at all localities, hotpots for rainfed agriculture include forests and rangelands in Marawi and Adabah localities.

Khartoum State

Khartoum, the capital of Sudan, is located in the tropical zone around the River Nile. During the rainy season, from July to September, Khartoum receives between 110 and 200 mm of rainfall on average, with the remainder of the year being fairly dry. Dust storms are regular occurrences and river fluctuations threaten riverbank erosion and flooding (Khartoum State NAP Committee 2013). Box 4-14 provides some essential climatic and vulnerability information for Khartoum state.

Rapid urban growth combined with rising temperatures, rainfall variability, and river fluctuations have placed serious pressure on Khartoum's resources. Although studies are

needed to assess existing and future climate change, if Khartoum follows the country-wide trend of an increasingly dry climate, then this will threaten crop yields, rangelands, and natural forests in the area.

Annex B: Summary of state-level stakeholder consultations

Screening activities to establish targeted states

Prior to the launch of stakeholder consultations, desk-based research was conducted to synthesize the range of lessons learned that have emerged on the basis of the nine (9) previous adaptation projects implemented in Sudan. On the basis of this review three essential criteria were developed that formed the basis for conducting follow-up field missions and field-level consultations with stakeholders. The first criterion was the degree of uptake of adaptation activities to the wider community beyond direct beneficiaries of project activities. This reflected the potential for replicability, post-project. The second criterion was the level of vulnerability to climatic impacts. This reflected the potential for focusing on those regions that were in need of urgent adaptation responses. The third criterion was ongoing and or planned government programme in rural development activities focused on agricultural, water resources, and pastoralism. This reflected the potential for future adaptation projects to leverage existing national investments and provide incremental benefits focused on building resilience to climate change. As a result of the screening process, a number of regions were identified as potential candidates for project interventions, as described in the next section.

Workshops and field missions for field level consultations with stakeholders and state authorities in the targeted states

Four workshops and field missions for field level consultations with stakeholders and state authorities in the targeted states were organized by UNDP and HCENR during the period 10 July to 20 august, 2016 as follows:

- West and South Kordofan(EL-Fula/ West Kordofan)
- Kassala and Red Sea(Port Sudan/ Red Sea)
- Northern(Dongola Northern State)
- West, Central and East Darfur(Khartoum)

The main objectives of the workshops were:

- Complete the consultations with government institutions in the targeted states regarding the project: building resilience in the face of climate change within traditional rain fed agricultural and pastoral systems in Sudan; and
- Agree on the climate change adaptation measures and interventions in sectors of water and agriculture (crops, livestock and forestry)
- Agree with the stakeholders on the localities and villages where the activities of the project will be implemented, based on NAP and vulnerability assessment.

The workshops brought together key officials from agriculture, livestock and water sectors, farmers associations, extensionists, forests corporation, range and pasture administration and scientists affiliated to different research institutions, universities, HCENR and various government institutions and individuals dealing with the issues of climate change(attached a list of participants). Participants represented both genders.

This workshop, therefore, has provided a good opportunity for participants from different organizations, institutions and agencies to share experiences and knowledge related to climate change adaptations and activities. Facilitators of the workshop were the three national consultants.

During the workshop sessions the following focuses were made.

- Highlights of the proposed projects
- Climate change impact, adaptation options and activities
- climate change adaptation measures and interventions in sectors of water and agriculture (crops, livestock) and natural resources
- localities and villages where the activities of the project will be implemented
- The role of the line ministries in project implementation

Information prepared by states and discussed for finalization of the GEF project document included:

1)	Selected localities, villages, administrative setting and maps if available, to be targeted by the project. Selection criteria is also important.
2)	No. of people and households targeted/village/locality and their socioeconomic profile and indicators including also: main economic activities and other off farm activities, description of farming system (crops and livestock):- • Cropping systems (field crops)-rain-fed: • Horticulture (vegetable production (if existing): • Livestock production system and feed resources: • Range land (availability and constraints): • Irrigated agriculture (if existing) crops farming systems and water sources:
3)	Water resources: surface water sources potential (rivers /seasonal streams, water harvesting, dams – storage, and aquifer recharge); groundwater sources potential (shallow and deep wells), accessibility and description of potential sites for interventions.
4)	Current uses of water resources in agriculture (field and horticultural crops and livestock)
5)	Drought alleviation and climate mitigation technological packages used.
6)	Cultivated areas by crops and livestock numbers by species. These information normally available at the state level.
7)	How has climate change affected the region and people's life? What are the trends in rainfall and drought frequency? What is the level of infrastructure available, including main markets and access to local/regional ones?
8)	Potential climate adaptation options in livestock, agriculture and water sector.
9)	Proposed climate change adaptation measures(activities), best practices and their respective sources (indigenous/introduced) • Cropping systems (field crops)- -rain-fed: proposed interventions (activities) • Horticulture (vegetable production: proposed interventions (activities) • Livestock production system and feed sources): proposed interventions (activities) • Range land (availability and constraints): proposed interventions (activities) • Irrigated agriculture: proposed interventions (activities)
10)	Focal ministries for the project intervention i.e. Electricity, Irrigation and Water Resources, Agriculture and Forestry, Animal Wealth, Fisheries and Range land and National Economy, Finance and Planning or others
11)	State technical committee suggested membership
12)	Related state polices and plans developed/implemented in the last 5 years (supportive or otherwise)

Workshops attendants at different states

		
		

Sites, targeted households, activities and opportunities as stated by stakeholders at the states workshops are presented in the tables below. Some changes were made at the final workshop.

Sites and Activities – West Kordofan State

Locality	Village clusters	Population Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water	
Al Nohoud	1. Alrawiana 2. Omragaditi 3. Alsibahat 4. Alzilata 5. Abusairor 6. Abushiror 7. Awladgibril 8. Abusabiba 9. Tolob 10. Alshamamia	10x100x6= 6000 HH	• Improved seed varieties NPK, Intercropping, IPM, animal draw implements and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Gum Arabic belt restocking and rehabilitation	• Range rehabilitation and management and construction range enclosures (WH) • Livestock health and nutrition (supplementary feeding and vet services) • Non wood forest products	Construction of water plastic lined water ponds, cisterns, rehabilitation/improvement of hafirs, boreholes, roof water harvesting	Promotion and development of Gum Arabic (ADB) Saving and credit groups, Saving Bank, Animal and agricultural community societies
Wad Banda	15	10x100x6= 9000	• Improved seed varieties NPK, Intercropping, IPM, animal draw implements, agroforestry using productive trees (godaim, hashab, cider) and other climate-smart practices • Supplementary irrigation), drip irrigation and water saving techniques • Gum Arabic belt restocking and rehabilitation	• Shelter belts for environmental protection • Community forestry • Livestock health and nutrition (supplementary feeding and vet services)	Construction of boreholes for domestic use and supplementary irrigation	Animal and agricultural community societies
Al Odaya	15	15x100x6= 9000 HH	• Improved seed varieties NPK, Intercropping, IPM, animal draw implements and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Horticulture gardens (shallow wells, hand dug wells, solar pumps, irrigation systems)	• Range rehabilitation and management (reintroduction of high nutritive spp.) and construction range enclosures (WH) • Livestock health and nutrition (supplementary feeding and vet services) • Non wood forest products	• shallow wells, hand dug wells, solar pumps • Cisterns, rehabilitation/improvement of hafirs and natural depressions	Nile Bank, Animal and agricultural community societies

Locality	Village clusters	Population Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water	
Babanosa	1. Wasata 2. Aldilaima 3. Omosh 4. Algantor 5. Gajalhila 6. Alghiwirat 7. Alkiliabat 8. Aburafai 9. Shagelhaik 10. Giwagita	10x100x6= 6000	• Improved seed varieties NPK, Intercropping, IPM, animal drawn implements and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Home nurseries and fruit trees	• Range rehabilitation and management (reintroduction of high nutritive spp.) and construction range enclosures (WH) • Livestock health and nutrition (supplementary feeding and vet services) • Non wood forest products	• Rehabilitation of boreholes (pastoralists) • Construction of improved hafirs and natural depressions	Alneelain Bank, Animal and agricultural community societies Saving and credit groups Need for micro-finance window
Al Salam	1. Kobara 2. Alnomriki 3. Jagimni 4. Wasata 5. Gobash 6. Aldaba Eltawila 7. Adoma 8. Garb 9. Shag Elgana 10. Targato	10x100x6= 6000 HH	• Improved seed varieties NPK, Intercropping, IPM, animal draw implements and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Horticulture gardens (shallow wells, hand dug wells, solar pumps, irrigation systems)	• Range rehabilitation and management (reintroduction of high nutritive spp.) and construction range enclosures (WH) • Livestock health and nutrition (supplementary feeding and vet services)	• Shallow wells, boreholes, • Rehabilitation/improvement of hafirs • Rehabilitation of Kigaira Dam	Agric. Bank, Animal Resource Bank, Microfinance West Kordofan Institution Animal and agricultural community societies
Aldibab	15	15x100x6= 9000 HH		• Grazing management (extension and conflict resolution, fire management file lines, cutting and balling) • Livestock health and nutrition (supplementary feeding and vet services) • Gum production (collection and marketing)	• Boreholes construction • Rehabilitation and construction of hafirs and natural depressions	Need for Microfinance window
6	75	45,000				

Sites and Activities -South Kordofan state

Locality	Village clusters	Population Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water	
Al Goz	20	20x100x6= 12,000 HH	• Improved seed varieties NPK, Intercropping, IPM, animal draw implements and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Agroforestry • Supplementary irrigation from seasonal streams	• Range rehabilitation and management • Livestock health and nutrition (supplementary feeding and vet services)	• Construction of hand pumps with solar energy, submersible pump and water tank. • rehabilitation/improvement of hafirs	Saving and credit groups Swaaid rural finance institutions), ABS Animal and agricultural community societies Development call organization (NGO)
Al Abasia	10	10x100x6= 6000	• Improved seed varieties NPK, Intercropping, IPM, animal draw implements, agroforestry using productive trees (godaim, hashab, cider) and other climate-smart practices • Water harvesting techniques, conservation agriculture • Supplementary irrigation • Terrace cultivation • Seed propagation(added value)	• Community forestry • Livestock health and nutrition (supplementary feeding and vet services)	• Rehabilitation of hafirs and deepening of natural ponds • Hand pumps	ABS Braa (rural microfinance) Saving and credit groups Animal and agricultural community societies
Al Dalang	15	15x100x6= 9000 HH	• Improved seed varieties NPK, Intercropping, IPM, animal draw implements and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Horticulture gardens (shallow wells, hand dug wells, solar pumps, irrigation systems) • Terrace cultivation	• Range rehabilitation and management • Livestock health and nutrition (supplementary feeding and vet services)	• shallow wells, hand dug wells, solar pumps • rehabilitation/improvement of hafirs and natural depressions	ABS, Saving Bank , Swaaid, NGOs Animal and agricultural community societies Faculty of Agriculture

Locality	Village clusters	Population Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water	
Al Tadamon	5	5x100x6= 3000	• Improved seed varieties NPK, Intercropping, IPM, animal drawn implements and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Home garden with supplementary irrigation and roof • Supplementary irrigation with pumps • Certified Seed production)	• Range rehabilitation and management (reintroduction of high nutritive spp.) and construction range enclosures (WH) • Livestock health and nutrition (supplementary feeding and vet services) • Non wood forest products	• Construction of improved hafirs and natural depressions	Seed development project Animal and agricultural community societies Saving and credit groups Need for micro-finance window
Al shargy	15	15x100x6= 9000 HH	• Improved seed varieties NPK, Intercropping, IPM, animal draw implements and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Ca • Terracing cultivation	Livestock health and nutrition (supplementary feeding and vet services) • Fire line	Hand pumps • Rehabilitation/improvement of hafirs	Microfinance Animal and community societies
Rashad	5	5x100x6= 3000 HH	• Terrace cultivation • Improved seed varieties NPK, Intercropping, IPM, climate-smart practices • Water harvesting (chiseling, contour bunds) • Home garden with supplementary irrigation	• Grazing management (extension and conflict resolution, fire management file lines, cutting and balling) • Livestock health and nutrition (supplementary feeding and vet services) • Gum production (collection and marketing)		braa Microfinance ABS
6	70	42,000				

Sites and Activities - Red Sea state:

Locality	Village clusters	Population Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water	
Agig	5 village clusters (Agig, Adobana, Agitar, Aiterba, Garora, Andal)	16,000 Direct: 7,000 Indirect: 9,000	• A forestation: Replacement of Meskeet trees by Acacia spp. Sider, Sayal, Adleeb, Soadia • Mangrove forest rehabilitation • Apiculture development (bee hives and accessories) value chain, marketing etc.	• Supplementary feeding, new improved breeds, vet services • Alternative HH energy sources (LPG & solar)	WH-based improvement of agriculture activities (sustainable practices) - Assessment of wad diversion infrastructure	Saving and credit groups Home gardens in Sinkat locality Microfinance institutions: Red Sea microfinance institution
			• Fisheries: capacity building of fishermen (training, equipment, improved nets, fish farms, women small scale products, new fishing technologies), market development and improved storage facilities • Improvement and development of Sea cucumber • Rehabilitation of key habitat (coral reef, mangrove, sea grass, salt march) • Sea shells development (community off season activities)	•	-	
			• Range land improvement (reseeding, WH, range enclosures)	•		
Dordaib/ Haya	village clusters: 1-Haya: Gadamaye, Adarhi ShoraAmrab ShoraHawin Hankalawaib Hamisait Amasa Sarobit Asot	30,000 HH Direct 20,000 indirect	• Range land improvement (reseeding, WH, range enclosures) • Forestry: plantation of Dom trees value chain, women handcrafts	• Women small scale improvement of dietary products, • Restocking, supplementary, feeding, vet services • Poultry production \ • Alternative HH energy sources (LPG & solar)	WH for agriculture and drinking: Check dams, diversion structures terraces, hafirs, Improvement of shallow wells, - Cistern	

Locality	Village clusters	Population Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water	
	Halag Sanganai Tolak Derodeb: LashobHadalit Lashob Algarada Absalam Brritak Gadamaye Agotaye Derbab Deodeb					
Guneb Olib	12 village clusters: Rabaeyet+Arbabeyeb Godeedit Balonaye Agwambt-sarar Dadat Amor Sarara Mahale- Meserar Togaylawo Hayet-wassat	15,000 HH Direct 20,000 Indirect	• Agriculture practices animal husbandry • horticulture • fisheries	•	Improvement of spate irrigation in wadis Check dams for recharge of groundwater, shallow wells, - River bank protection (gabion)	
			• Improvement of horticultural production • Nurseries for forestry and hotrt. Crops, home gardens • A forestation (Arak tree) • Fisheries: capacity building of fishermen (training, equipment, improved nets, fish farms, women small scale products, new fishing technologies), market development and improved storage facilities	• Green fodder spate irrigated (clitoria, gerawiaetc) • Animal fattening/milk production supplementary feeding, poultry, restocking of resistant goat breeds (darai) • Alternative HH energy sources (LPG & solar)		Saving and credit groups Home gardens in Sinkat locality Microfinance institutions: Red Sea microfinance institution

Locality	Village clusters	Population Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water	
			• Rehabilitation of key habitat (coral reef, mangrove, sea grass, salt march) • Sea shells development (community off season activities)			

Sites and Activities – Kassala states

Locality	Village clusters	Population Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water	
Nahr Atbara (West bank of Atbara River)	5 Reraha Dimiat Simidaha Ejuneed Sidera	17,818	• Terrace cultivation • Crop and varieties diversification (sorghum, early maturing spp such cow beans and CC smart packages) • Improved seeds bank(s)	• Fodder production in crop rotation (clitoria) • Range land improvement (reseeding and seeds collection) • Supplementary feeding(rumianants • Shelterbelts (small scale farm, villages) • Tree nurseries (central and community) • Alternative HH energy sources (LPG & solar)	• Supplementary irrigation (farm ponds), WH • Small scale irrigation schemes (pumps)	Women Saving and credit groups, revolving funds Microfinance institutions
Rural Aroma (outside Gash Delta)	Garateet Tugrar Togoub Am Raho East Adergawi	30,120	• Irrigated vegetables and fruits gardens • Integrated farm for women • Improve marketing capacities	• Range improvement • Fodder production in river bank (clitoria, Abu sabeen, Gerawia, Barseem, etc) • Supplementary feeding(rumianants • Shelterbelts (small scale farm, villages) • Community nurseries • Alternative HH energy sources (LPG & solar)	• Hafir rehabilitation • Small scale irrigation schemes on river banks • Shallow wells installation and rehabilitation (solar system package)	
Kassala	6 Kassala Sabeel Alshokria Aljamam Wad sharefaie Tajouj	30,000	• Horticulture • Integrated farm for women groups • Marketing • Value chain (dehydration and processing of vegetables and fruits) • Apiculture	• Afforestation (shelterbelts, agroforestry and tunjia) • Supplementary feeding • Fodder production (clitoria, Abu sabeen, Gerawia, Barseem, etc) • Alternative HH energy sources (LPG & solar)	• Modern irrigation systems(water saving) • Drilling and installation of shallow wells (women groups) • River bank erosion training in horticulture areas (Gabion, shelterbelts)	
Talkouk	5 Talkouk Tawiat	17708	• Crop varieties diversification (sorghum, early maturing spp	• Improve water shed management (forestry and range)	• Sand storage dams • Check dams • Spate and flood irrigation	

Locality	Village clusters	Population Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water	
	Tahjar Temikeet Tahadi		such cow beans and CC smart packages) • Apiculture • Vegetables	• Animal restocking(ruminants and poultry for women) • Meskeet management in collaboration with partners, possibly WFP) • Supplementary feeding • Community tree nurseries • Alternative HH energy sources (LPG & solar)	• Shallow wells • Water yards	
		95,646				

Sites and Activities – Northern State:

Locality	Village clusters	Population/ Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water	
Dongola	6 AlKhwai Labab Shaeg Jertoad Aloagal Gaabellagia Algouba	1729	• Land development and rehabilitation: • (Land leveling, • Shelterbelts, • Salt leaching., soil amendments) • Modern irrigation systems • Sustainable practices • Heat resistant crop varieties • Community organization to access and manage microfinance • Research component focused on new technologies	• Sub-surface water utilization for range land development (Algouba) • Vet services, including mobile vet services • Improved animal breeds • Supplementary feeding • Shelterbelts	• Drilling of wells, accessories and solar pumps • Modern irrigation systems	Northern Company for Microfinance Farmers and pastoralists committees Agricultural Development Fund Farmer window schools (saving and lending groups
AlGaold	5 Molwad Om Krabeej Howd Lati Alzaraib Nawa	1140 (This locality provides support to nomads and it has high potential for large scale production	• Land development and rehabilitation: • (Land leveling, • Shelterbelts, • Salt leaching., soil amendments) • Modern irrigation systems • Sustainable practices • Heat resistant crop varieties • Community organization to access and manage microfinance • Research component focused on new technologies	• Sub-surface water utilization for range land development (Algouba) • Vet services, including mobile vet services • Improved animal breeds • Supplementary feeding • Solid Shelterbelts (8 Km Molwad, om karabeej, Elzaraib, Nawa) • Tree nursery	• Drilling of wells, accessories and solar pumps • Modern irrigation systems	
Al Daba	3 Argi Alafad Selib Tanganrati	2600	• Land development and rehabilitation: • (Land leveling, • Shelterbelts, • Salt leaching., soil amendments) • Modern irrigation systems • Sustainable practices • Heat resistant crop varieties • Community organization to access and manage microfinance	• Vet services • Supplementary feeding • Rangeland improvement in Wadi Elmalik (WH, seed broadcasting) • Rehabilitation of tree nurseries	• Drilling of wells for nomads (Wadi Elmalik)	

Locality	Village clusters	Population/ Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water	
			• Vegetable and fodder production in wadi Elmalik			
Marawi	6 Mora Kori Kannar Algorair Osli Om Jawaseer	4600	• Ground water-based small irrigation schemes (solar pumps, irrigation wells, modern systems, shelterbelts and crop diversification and intensification) • Training for fishermen	• Shelterbelts and tree nurseries (sayal, salam, arak sarih and tomam) • Wadi reseeding for range improvement • Vet services • Supplementary feeding	• Rehabilitation of irrigation wells, solar systems • Modern irrigation system • Check dams along the Wadi for recharging ground water and flood irrigation(Om Jawaseer)	
		10,069				

Sites and Activities - Khartoum State:

Locality	Village clusters	Population Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water	
Rural Umdorman	Abuhleaf,Mondra,Fatasha Elgadima, Fatasha Elzaoia, Fatasha A.	1,115	• Improved sorghum crop varieties (early maturing CC smart packages) • Home garden with supplementary irrigation • Fodder production	• Supplementary feeding(small ruminants) • Range improvement • Community nurseries • Poultry , fish farms and Apiculture, green belt protection	• Access to belt boreholes	Microfinance institutions Khartoum Green Belt Project Close to various services and markers
Rural Sharg ElNil	Algaba abuzaid,Elhour,Elhoela,ELakoda	1,232	• Home garden with supplementary irrigation	• Supplementary feeding(small ruminants) • Range improvement • Community nurseries • Poultry , fish farms and Apiculture, green belt protection	• Access to belt boreholes • Rehabilitation of borehole(Abuzaid)	Access to belt boreholes
Total		2,347				

Sites and Activities - Central Darfur State:

Locality	Village clusters	Population/ Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water Safe drinking water, Irrigation)	
Zalingi	Abtta,Androw,Calgo, Fasi, Dankouj, Shawa Tamar Bolgameel	400,123 (Locality Total)	• Improved seed varieties NPK, Intercropping, IPM, and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Horticulture gardens (shallow wells, hand dug wells, solar pumps, irrigation systems) • Supplementary irrigation), drip irrigation and water saving techniques	• Livestock health and nutrition (supplementary feeding and vet services) • Range rehabilitation and management • Non wood forest products	• rehabilitation/improvement of hafirs, boreholes, for drinking water supply, Water ponds • Cisterns (Hodhs): • Water yards: • Shallow hand dug wells and boreholes: • Sand Storage Dams	• Central Darfur Microfinance Institution, • Professional Producer Associations. • WFP (FFA, FF Education, Early recovery, Environment rehabilitation, Firewood) • Research stations • Integrated solution for Agric. Sector Programme • NGOs (local National, International) CRS, Norwegian Church Aid, Danish Refugees Council , RC and local CBOs and N. NGOs) • Professional groups (Livelihood and food security, Environment, Livestock) • Gebal Mara Rural Development project • University of Zalengi,SPDP,SECS
Azoom	Rongatas,Momo, Omshalaya, Mara Finfiny	321,240	• Improved seed varieties NPK, Intercropping, IPM, and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Horticulture gardens (shallow wells, hand dug wells, solar pumps, irrigation systems) • Supplementary irrigation), drip irrigation and water saving techniques	• Livestock health and nutrition (supplementary feeding and vet services) • Range rehabilitation and management • Non wood forest products •	• rehabilitation/improvement of hafirs, boreholes, for drinking water supply, Water ponds • Cisterns (Hodhs): • Water yards: • Shallow hand dug wells and boreholes: • Sand Storage Dams	

Sites and Activities- East Darfur State:

Locality	Village clusters	Population/ Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water Safe drinking water, Irrigation)	
ELdain	Glabi (cluster) 1 Higliga Om labania	22,100/110,500 27,429 HH per locality 137,144	• Improved seed varieties NPK, Intercropping, IPM, animal draw implements and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Gum Arabic belt restocking and rehabilitation	• Range rehabilitation and management and construction range enclosures (WH) • Livestock health and nutrition (supplementary feeding and vet services) • Non wood forest products	• Construction of water plastic lined water ponds, cisterns, rehabilitation/improvement of hafirs, boreholes, roof water harvesting	• East Darfur Microfinance Institution, • Professional Producer Associations. • WFP (FFA, FF Education, Early recovery, Environment rehabilitation, Firewood) • Care Switzerland,Research stations • Integrated solution for Agric. Sector Programme • NGOs (local National, International) UMCOR,ZIOA • RC and CORE (Commission for refugees) • UNHCR • Professional groups on Livelihood and food security • SPDP,SECS ,Integrated management of natural resource for livelihood support (EC) • Basic Needs for sedentary and pastoral communities,UNAMID • Youth Initiatives
Firdous	Abo sinadirra Hibaeil	16,400/ 82,000 282,247	• Improved seed varieties NPK, Intercropping, IPM, animal draw implements and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Gum Arabic belt restocking and rehabilitation	• Range rehabilitation and management and construction range enclosures (WH) • Livestock health and nutrition (supplementary feeding and vet services) • Non wood forest products	• Construction of water plastic lined water ponds, cisterns, Rehabilitation of hafirs and deepening of natural ponds • boreholes, roof water harvesting	
Asalia	Abusaida Om Elgoura Gazala Jawazat Kilaikil	9,200/ 46,000 241,452	• Improved seed varieties NPK, Intercropping, IPM, animal draw implements and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Gum Arabic belt restocking and rehabilitation	• Range rehabilitation and management and construction range enclosures (WH) • Livestock health and nutrition (supplementary feeding and vet services) • Non wood forest products	• Construction of water plastic lined water ponds, cisterns, rehabilitation/improvement of hafirs, boreholes, roof water harvesting	
		47,700/238,500 560,843 (total pop direct and indirect)				

Sites and Activities - West Darfur State:

Locality	Village clusters	Population/ Number of HH	Activities			Opportunities Other Projects, financial and microfinance institutions.
			Agriculture	Livestock and natural resource management	Water Safe drinking water, Irrigation)	
Genana	Aishbara Korti Gargar Atia	1629/ 10934	• Improved seed varieties NPK, Intercropping, IPM, and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Horticulture gardens (shallow wells, hand dug wells, solar pumps, irrigation systems) • Supplementary irrigation), drip irrigation and water saving techniques	• Livestock health and nutrition (supplementary feeding and vet services) • Range rehabilitation and management • Non wood forest products	• rehabilitation/improvement of hafirs, boreholes, for drinking water supply, Water ponds • Cisterns (Hodhs): • Water yards: • Shallow hand dug wells and boreholes: • Sand Storage Dams	• West Darfur Microfinance Institution, • Professional Producer Associations. • WFP (FFA, FF Education, Early recovery, Environment rehabilitation, Firewood) • Research stations • Integrated solution for Agric. Sector Programme • NGOs (local National, International) CRS, Concern, World Relief, RC • Professional groups (Livelihood and food security, Environment, Livestock)
Krenik	Habila kanari (Zawia, Dewait, Azerni)	1200/ 8400	• Improved seed varieties NPK, Intercropping, IPM, and other climate-smart practices • Water harvesting (chiseling, contour bunds) • Horticulture gardens (shallow wells, hand dug wells, solar pumps, irrigation systems) • Supplementary irrigation), drip irrigation and water saving techniques	• Livestock health and nutrition (supplementary feeding and vet services) • Range rehabilitation and management • Non wood forest products	• rehabilitation/improvement of hafirs, boreholes, for drinking water supply, Water ponds • Cisterns (Hodhs): • Water yards: • Shallow hand dug wells and boreholes: • Sand Storage Dams	
		2,829/ 19,334				

Workshops attendants are listed below:

Ministry of Agriculture, Natural Resources and Forestry -West Kordofan State, Elfula

West Kordofan and South Kordofan States Workshop

No.	Name	Address	E-mail	Tel.
1.	Fadlallah Elmana Salih	National Coordinator of the resources of western Sudan		0915612587
2.	Huda Ahmed Huda	Water Management		0911319441
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Ministry of Agriculture, Natural Resources and Forestry -West Kordofan State, Elfula

West Kordofan and South Kordofan States Workshop

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Ministry of Environment and Tourism and Wildlife - Red Sea state, Port Sudan

Red Sea and Kassala states Workshop

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Ministry of Environment and Tourism and Wildlife - Red Sea state, Port Sudan

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Ministry of Agriculture, Natural Resources and Forestry -Northern State,Dongola

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Higher Council for Environment and Natural Resources

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Annex C: National institutions involved in agricultural and water management activities

Institutions / actors	Mandate
Ministry of Water Resources and Electricity	• Planning and policy formulation • Administration and management of efficient water resources development and use at federal level • Develop federal state level coordination and networks for data collection, project formulation, planning and follow up activities • Capacity building of staff at federal and state levels
National Council for Water Resources (NCWR)	• Policy formulation and coordination of water resources supplies among water demanding sectors and stakeholders
General Directorate for Nile water and Dams	• Record annual surface water resources flows and trends in Sudan • Store water Nile in dams • Monitor consumption of Nile water in Sudan.
General Directorate of Ground Water and Wadis	• Survey water harvesting potential areas • Assess water harvesting carrying capacity and duration of Wadies and Khors • Survey ground water resources potential areas • Assess ground water carrying capacity and duration
General Directorate for Policies, Planning and Projects	• Planning and policy formulation and studies for water resources and AWM and electricity generation • Monitoring and follow up of water resources and AWM and energy related activities
Dams Implementation Unit (DIU)	• Carry out technical, administrative and financial management responsibilities of construction of dams • Resettle newly constructed dams displaced people and residents.
The Hydraulics Research Centre (HRC)	Conduct research on • developing new water resources • efficient management of water resources • managing of agricultural irrigation systems • hydropower supplies to agriculture and manufacturing industry • river transport • river training • river banks protection, • flood protection and control • water supplies
Ministry of Agriculture and Irrigation	• Planning and policy formulation for irrigated agricultural development • Formulate plans and policies for food security and poverty alleviation of farmers in the agricultural irrigated sector
Water Management & Irrigation Institute, Gezira University	• Conduct studies and research on water use and management for food security, poverty alleviation and maintaining of friendly environment
Agricultural Research Corporation	• Conduct basic and applied agricultural research to develop appropriate technologies of water related crops and practices • Technology transfer of research results to stakeholders for adoption

Institutions / actors	Mandate
Ministry of Livestock Resources, Fisheries and Pastures	• Formulate plans and policies to develop, conserve and protect national livestock resources • Administer veterinary delivery services that sustain livestock health and productivity • Manage livestock value chain movements from production to markets to consumers to achieve food self-sufficiency and export gains
Livestock Resources Corporation (LRC)	• Support livestock and animal production development research and studies • Support small community animal production programs and projects • Enhancement of livestock role in poverty alleviation and food security • Promote use of scientific research and studies to benefit from vast natural resources and biodiversity for sustainable economic development and investment and conservation of the environment • Provide training and capacity building opportunities for livestock researchers to use advanced technologies • Supply modern livestock labs and • tools in veterinary and animal production related activities • Address current and emerging veterinary and animal production problems and constraints facing livestock owners and producers
Animal Production Research Centre	• Support research on animal diseases, animal breeding, animal husbandry and economic feeding rations
Fishery Research Centre	• Support fisheries disease control and fish conservation, and development of fish cultivation technologies
Forests National Corporation	• Planning and policy formulation of development, conservation and protection of forest resources • Supervise and monitor forests use and management • Promote processing and marketing of forest timber and non-timber products, • Encourage partnership with private sector (wood industry and forest plantation)
Sudan Metrological Authority	• Provide quality meteorological information and statistics • Extend early warning information services at locality, state and federal levels to support crop production decision making by stakeholders • Furnish early warning awareness about droughts and floods risks for preparatory actions against natural disasters • Support information for protecting of forests and pastures against deterioration
Higher Council for Environment and Natural resources (HCENR)	• The HCENR is the technical arm of the Ministry of Environment, Natural Resources, and Physical Development; has extensive operating experience in Sudan on climate change issues; and is the government coordinating body concerned with integration of environment into national development. • HCENR is the focal point of many multilateral environmental agreements and works in close collaboration with all government institutions at both the federal and State level. • HCENR was the focal point for the development of the Sudan's National Adaptation Plan (NAP). • HCENR has a mandate as lead national agency in meeting the challenge of climate change in the near-and long-term. A Mandate that spans both coordination and institutional implementation activities. HCENR lead the formulation of medium- to long-term actions that not only mitigate the impacts of climate change related disasters such as drought, flash flooding, vector-borne disease outbreaks, but also reduce the vulnerability of communities most exposed to natural phenomena. • The HCENR has effectively coordinated all first climate change-related activities in Sudan, starting from Sudan's First National Communication in 2003 to the National Adaptation Plan completed in 2014. It is also playing an important oversight role for numerous other climate change-related initiatives including the LDCF and CiDA funded climate change adaptation project, the Biodiversity Conservation Project, the Climate Risk Finance Project, the preparation of the 3rd National Communication and the Biennial Updated Report Preparation. • The Higher Council for Environment and Natural Resources (HCENR) is the sponsor or activity coordination unit in country) for the Proposed GCF Project.

Institutions / actors	Mandate
	• At the state institutional level, the HCENR has established adaptation-focused planning institutions in each of Sudan's 18 states. In each of the states, a focal point and inter-agency technical team of experts from related government, research, academia and civil society organization, have been established. The capacity of these units has been strengthened through targeted training sessions.
Farmers Trade Union, Community based Organization(CBOs) and Native administration	• Farmers in the area have the intensions to develop civil society associations and organizations at grass-root level either for advocacy, basic services provision or as focal points in dealing with other stakeholders, government officials and NGOs. According to experience ,female farmers has at least one woman member to represent women groups within the CBOs • Farmer's union and nomad's unions (higher level organizations) stemmed out to represent the grass roots of nomads and farmers' population. • Native administration system is still somehow effective and can be used for new development opportunities especially for natural resources management and conservation, conflict resolution mediators, awareness and supervision of development programs. • Producers' Professions Organizations (Act of 2011) whose main objective is to assemble the potentials and capabilities of producers for raising the efficiency of agricultural production and livestock from a traditional subsistence economy to an international competing economy. • Producers' Professions organizations have the following specific main objectives: • Implementation of policies and general plans for development of agricultural and livestock production and management of special support provided. • Provide necessary services to members in matters related to agricultural and animal production. • Maintaining the rights of producers and to enable them managing their productive affairs efficiently.
Development Projects(e.g. IFAD Seed Development Project)	• Multilateral and bilateral Donors are recognized as essential development partners in the execution of policies and strategies • Organizations such as VDC s and CBOs existing or established through International projects activities, make use of project's institutional building efforts. The projects achievements were done through applying the Participatory development approaches which used the community as a focal part or point for development. Animation, mobilization and training were the main methods used for community organizing, skills developing and empowerment. • The VDC is always targeted by capacity building program aiming at upgrading their management and planning capacities
Other relevant NGO's, and departments Specialized in Natural Resource Management	• Other Government Institutions working in climate adaptation fields include: Range and pasture Administration, Combating Drought and Desertification Unit, Sudanese Environment Conservation Society, Environmentalists Society and many others
UN Agencies	• Support implementation of MEAs
Women Associations and women groups	• Women groups in Rural areas of targeted states have dull responsibilities of contributing to the economic resources (food security livelihoods) of the family and same time bearing to domestic labor (water fetching, fuel wood collection etc..) • High and increasing percentage of women headed households due to men migration to local gold mining
Financial Institutions	• Macro and Micro Financial institutions including specialized banks such as Agricultural Bank, Animal Wealth Bank, Farmers Bank. 12% of the resources of commercial banks supposed to be channeled as micro finance to small scale producers and invertors, through financial institutions cleared by the Central bank of Sudan.
Private Sector (Seed Industry)	• More than 10 specialized seed private companies working in marketing improved seeds through direct production or contract farming. These companies are mainly serving the irrigated sector with limited presence in the traditional rain-fed sector. Lack or insufficient supply of quality and climate change adaptive verities is considered as one of the constraints. • Private sectors is also heavily involved in inputs supply such as veterinary drugs, agrochemicals and agricultural machineries and tools. • Provision of clean energy sources such as solar, wind and fuelwood alternative energy sources for domestic use

Annex D: Completed and on-going research projects in Sudan addressing climate change adaptation

Project	Overall goal	Funding Agency
Eco-Farm Project (2007-2011	Introduction of crop and livestock climate-smart technologies	DCG
Climate Change Adaptive Production Technologies for crops and livestock Project	development of Climate Smart Crop and livestock Technologies to Enhancing Productivity in Rain-fed Areas.	DCG
Managing Risk, Reducing Vulnerability and Enhancing Productivity under a Changing Climate (2007-2011)	develop innovative strategies for mitigation of, recovery from, and resilience to climate-induced crises affecting smallholder farmers in the Horn of Africa	CCAA-IDRC-DFID
Climafrica Project: Climate change predictions in Sub-Saharan Africa: impacts and adaptations (2010-2014):	Assess climate impacts in key sectors of SSA livelihood and economy, especially water resources and agriculture	EC-FP7 - FAO
Enhancing climate change adaptation in agriculture and water resources in the greater horn of Africa (2011-2014).	strengthening (NAPAs) through economic analysis of adaptation investments that is informed by credible and scientific assessment of climate change impacts.	AARC-IDRC
Enhancing the Adaptive Capacity of Smallholders through Response Farming (2013)	Improved response option based on seasonal climate forecasts to cope with impacts of climate variability	ASARECA
Climate Change and Adaptive Production Technology Package for Crop and Livestock Production in Kordofan Region (2012-2014)	Introduction of package of climate change adaptive technologies to overcome the negative impacts of climate change	DCG
Improving the livelihoods of rural communities in the Nile valley and sub-Saharan Africa region: “Sustainable Crop and Livestock Management” (2012-2013)	Enhance food security, livelihoods and adaptive capacity of resource poor farmers to cope with climate variability and change in the dry areas of the world.	IFAD - ICARDA
inable Agricultural Water Productivity Enhancement for Improved food security and Nutrition in ECA	Increase agricultural water productivity to improve food and nutrition security as well as livelihoods in the ECA target countries.	ASRECA& ARC

Annex E: Distribution of infrastructure interventions

Sub-activity #	Type of activity	Units	Quantity	Name
1.1.4	Drought-resistant seeds	Hectares	7,500	Conduct community-based drought tolerant and early mature seed procurement
1.2.1	women's farms	Items	75	Establish integrated women sustainable agriculture farms (i.e. see priming; fertilizer micro dosing; intercropping etc)
1.2.2	women's gardens	Hectares	5,000	Establish sustainable women-centered home gardens
1.2.3	wadi cultivation	Hectares	2,500	Conduct sustainable wadi (growing crops in seasonal river or stream where some tribes cultivate crops for a short time)/depression cultivation in at least 5 specific zones
1.2.5	Farmer schools	Persons	500	Set up climate adaptation oriented Farmers' Field Schools
1.3.2	Rangelands	Hectares	2,000	Establish communal rangeland reserves for drought resistant ranged seed production
1.3.3	Rangelands	Hectares	2,500	Rangeland rehabilitation by using various types of soil conservation and water harvesting techniques
1.4.1	Nurseries	Items	500,000	Develop and implement programme for multi-purpose tree nurseries to be run by women groups
1.4.2	Shelterbelts	Items	15	Established shelterbelts with drip irrigation system
1.4.3	Afforestation	Hectares	2,500	Established climate adaptive community based afforestation
2.1.1	rehabilitated water yards	Items	30	Rehabilitation work for old water yards
2.1.2	new water yards	Items	50	Carry out drilling of new water yards and installed solar system for water pumping
2.2.1	Sand storage dams	Items	30	Establish construction of sand storage dams in drought prone area
2.2.2	Pumps	Items	50	Install small pumping units around sand storage dam for sustainable agriculture
2.3.1	Hafirs	Items	75	Carry out rehabilitation of existing hafirs and all other new construction work

State		Locality		Location		Village		Distribution of interventions													
								1.1.4	1.2.1	1.2.2	1.2.3	1.2.5	1.3.2	1.3.3	1.4.1	1.4.2	1.4.3	2.1.1	2.1.2	2.2.1	2.2.2	2.3.1
#	Name	#	Name	Longitude	Latitude	#	Name	Drought-resistant seeds	women's gardens	women's gardens	wadi cultivation	Farmer schools	Rangelands	Rangelands	Nurseries	Shelterbelts	Afforestation	rehabilitated water yards	new water yards	Sand storage dams	Pumps	Hafirs
1	West Darfur State	1	Genana	22° 32′ E to 22° 5′ E	22° 32′ E to 22° 5′ E	1	Aish bara	56	1	36	18	4	15	19	3,750	1	20	0	0	1	1	1
						2	Kotri	56	1	36	18	4	15	19	3,750	1	20	1	0	0	1	1
						3	Gargar	56	1	36	18	4	15	19	3,750	0	20	0	0	0	0	1
						4	Atia	56	1	36	18	4	15	19	3,750	0	20	0	0	0	0	1
							Locality subtotal	225	3	146	72	16	60	76	15,000	1	80	1	0	1	1	4
		2	Krenik	22° 32′ E to 23° 16′ E	13° 38′ N to 13° 10′ N	5	Habila kanari	56	1	36	18	4	15	19	3,750	1	19	0	1	1	1	2
							State subtotal	281	4	182	90	20	75	95	18,750	2	99	1	1	2	2	6
2	Central Darfur State	3	Zalingi	23° 30′ E to 23° 45′E	12° 30′ N to 13° 30′N	6	Abtta	56	1	36	18	4	15	19	3,750	1	18	1	0	0	0	1
						7	Androw	56	1	36	18	4	15	19	3,750	1	18	1	0	1	0	1
						8	Calgo	56	1	36	18	4	15	19	3,750	0	18	1	0	1	1	1
						9	Fasi	56	1	36	18	4	15	19	3,750	0	18	0	0	0	1	1
						10	Kotairi	56	1	36	18	4	15	19	3,750	0	18	0	1	0	0	1
						11	Dankouj	56	1	36	18	4	15	19	3,750	0	18	0	0	1	0	1
						12	Shawa	56	1	36	18	4	15	19	3,750	0	18	0	1	0	0	1
						13	Tamor Bolgameel	56	1	36	18	4	15	19	3,750	0	18	0	0	1	0	1
							Locality subtotal	450	6	291	144	32	120	152	30,000	1	144	2	2	4	1	8
		4	Azoom	23° E to 22°30′ E	12° 30′ N to 14° 30′ N	14	Rangatas	56	1	36	18	4	15	19	3,750	1	18	1	0	1	1	1
						15	Momo	56	1	36	18	4	15	19	3,750	1	18	1	0	0	1	1
						16	Umshalaya	56	1	36	18	4	15	19	3,750	0	18	0	1	1	0	1
						17	Finfiny	56	1	36	18	4	15	18	3,750	0	18	0	1	0	0	0
							Locality subtotal	225	3	146	72	16	60	75	15,000	1	72	1	2	2	1	3
							State subtotal	675	9	437	216	48	180	227	45,000	2	216	3	4	6	3	11
3	East Darfur State	5	ELdain	26° 15′ E to 26° 40′ E	11° 46′ N to 12° 18′ N	18	Glabi (cluster) 1	56	1	36	18	4	15	18	3,750	1	18	1	0	0	1	1
						19	Higliga	56	1	36	18	4	15	18	3,750	1	18	0	1	0	1	0
						20	Um labania	56	1	36	18	4	15	18	3,750	0	18	0	1	0	0	1
							Locality subtotal	169	2	109	54	12	45	54	11,250	1	54	1	2	0	1	2
		6	Firdous	25° 46′ E to 26° 8′ E	11° 10′ N to 11° 45′ N	21	Abo sinadirra	56	1	36	18	4	15	18	3,750	1	18	1	0	0	1	1
						22	Hibaeil	56	0	36	18	4	15	18	3,750	0	18	0	1	0	0	1
							Locality subtotal	113	1	73	36	8	30	36	7,500	1	36	1	1	0	1	2
		7	Asalia	26° 15′ E to 27° 15′E	11° 30′ E to 11° 30′ E	23	Abusaida	56	1	36	18	4	15	18	3,750	1	18	1	0	0	1	1
						24	Um goura	56	1	36	18	4	15	18	3,750	1	18	1	0	0	1	1
						25	Gazala jawazat	56	1	36	18	4	15	18	3,750	0	18	0	1	0	0	1
						26	Kilaikil	56	0	36	18	4	15	18	3,750	0	18	0	1	0	0	2
							Locality subtotal	225	2	146	72	16	60	72	15,000	1	72	1	2	0	1	5
							State subtotal	506	5	328	162	36	135	162	33,750	3	162	2	5	0	3	9
4	West Kordofan State	8	Al Nohoud	27° 42′ E to 29° 01′ E	10° 50′ N to 12° 30′ N	36	Alrawiana	56	1	36	18	4	15	18	3,750	1	18	1	0	0	1	0
						37	Omragaditi	56	1	36	18	4	15	18	3,750	1	18	1	0	0	1	1
						38	Alsibahat	56	1	36	18	4	15	18	3,750	0	18	0	1	0	1	1
						39	Alzilata	56	1	36	18	4	15	18	3,750	0	18	0	0	0	1	0
						40	Abusairor	56	1	36	18	4	15	18	3,750	0	18	0	1	0	1	1
						41	Abushiror	56	1	36	18	4	15	18	3,750	0	18	0	1	0	0	0
						42	Awladgibril	56	1	36	18	4	15	18	3,750	0	18	0	0	0	0	0
						43	Abusabiba	56	0	36	18	4	15	18	3,750	0	18	0	1	0	0	1
						44	Alshamamia	56	0	36	18	4	15	18	3,750	0	18	0	0	0	0	1
							Locality subtotal	506	5	328	162	36	135	162	33,750	1	162	1	4	0	3	5
		9	Asalam	27° 56′ E to 28° 52′ E	12° 20′ N to 14° 07′ N	27	Kabara	56	1	36	18	4	15	18	3,750	1	18	1	0	1	1	1
						28	Momok	56	1	36	18	4	15	18	3,750	1	18	1	0	0	1	0
						29	Gagamit	56	1	36	18	4	15	18	3,750	0	18	0	1	1	1	1
						30	Wasata	56	1	36	18	4	15	18	3,750	0	18	0	1	0	1	1
						31	Gabash	56	1	36	18	4	15	18	3,750	0	18	1	0	1	1	0
						32	Eldaba Eltawila	56	1	36	18	4	15	18	3,750	0	18	0	1	0	0	1
						33	Adona Garab	56	1	36	18	4	15	18	3,750	0	18	0	0	1	0	0
						34	Shag Elgana	56	0	36	18	4	15	18	3,750	0	18	0	1	0	0	0
						35	Tirgato	56	0	36	18	4	15	18	3,750	0	18	0	0	0	0	1
							Locality subtotal	506	5	328	162	36	135	162	33,750	1	162	2	4	4	3	5
						45	Dabkar	56	1	36	18	4	15	18	3,750	1	18	1	0	0	1	0

State		Locality		Location		Village		Distribution of interventions													
								1.1.4	1.2.1	1.2.2	1.2.3	1.2.5	1.3.2	1.3.3	1.4.1	1.4.2	1.4.3	2.1.1	2.1.2	2.2.1	2.2.2	2.3.1
#	Name	#	Name	Longitude	Latitude	#	Name	Drought-resistant seeds	women's gardens	women's gardens	wadi cultivation	Farmer schools	Rangelands	Rangelands	Nurseries	Shelterbelts	Afforestation	rehabilitated water yards	new water yards	Sand storage dams	Pumps	Hafirs
		10	Alsunut	28° 42′ E to 29° 35′ E	11° 28′ N to 12° 27′ N	46	Almahfora	56	1	36	18	4	15	18	3,750	0	18	1	0	1	1	1
						47	Gora Doas	56	1	36	18	4	15	18	3,750	0	18	1	0	0	1	0
						48	Om resom	56	1	36	18	4	15	18	3,750	0	18	1	0	1	1	0
						49	Albija	56	1	36	18	4	15	18	3,750	0	18	1	0	0	1	1
						50	Warnang	56	1	36	18	4	15	18	3,750	0	18	1	0	0	1	0
						51	Om karkaj	56	1	36	18	4	15	18	3,750	0	18	0	1	1	0	0
						52	Om shiwaka	56	1	36	18	4	15	18	3,750	0	18	0	0	0	0	0
						53	Darsalam	56	0	36	18	4	15	18	3,750	0	18	0	1	1	0	0
						54	Aldagag	56	0	36	18	4	15	18	3,750	0	18	0	0	0	0	1
							Locality subtotal	563	6	364	180	40	150	180	37,500	1	180	4	2	4	4	3
							State subtotal	1,575	17	1,020	504	112	420	504	105,000	3	504	7	10	8	11	13
5	South Kordofan State	11	El Goz	29° 29′ E to 30° 34′ E	12° 06′ N to 12° 45′ N	55	Abudaka	56	1	36	18	4	15	18	3,750	1	18	0	0	1	1	1
						56	Elshag	56	1	36	18	4	15	18	3,750	0	18	1	0	1	1	0
						57	hasan	56	1	36	18	4	15	18	3,750	0	18	1	0	0	1	0
						58	Umsida	56	1	36	18	4	15	18	3,750	0	18	0	0	0	1	0
						59	Aredibo	56	1	36	18	4	15	18	3,750	0	18	0	0	0	1	1
						60	umGanatir	56	1	36	18	4	15	18	3,750	0	18	0	1	0	1	1
						61	Mnago	56	1	36	18	4	15	18	3,750	0	18	0	0	1	1	0
						62	Hiltmhmd Nur	56	1	36	18	4	15	18	3,750	0	18	0	1	0	1	1
						63	Threbeja	56	1	36	18	4	15	18	3,750	0	18	1	0	1	0	1
						64	Ajour	56	1	36	18	4	15	18	3,750	0	18	0	1	0	0	0
						65	Nabag	56	0	36	18	4	15	18	3,750	0	18	0	1	0	0	1
						66	Hamar galaba	56	0	36	18	4	15	18	3,750	0	18	0	1	0	0	0
							Locality subtotal	675	8	437	216	48	180	216	45,000	1	216	2	5	4	5	6
		12	Dilling	29° 12′ E to 29° 58′ E	11° 39′ N to 12° 11′ N	67	Barka	56	1	36	18	4	15	18	3,750	1	18	1	0	0	1	1
						68	Tokma	56	1	36	18	4	15	18	3,750	0	18	1	0	1	1	0
						69	Umishush	53	1	36	18	4	14	18	3,500	0	18	1	0	0	1	1
						70	Eltamet	53	1	36	18	4	14	18	3,500	0	18	1	0	0	1	0
						71	Dagag	53	1	36	18	4	14	18	3,500	0	18	1	0	0	1	1
						72	Eltibetia	53	1	36	18	4	14	18	3,500	0	18	0	0	1	1	0
						73	Elhimedia	53	1	36	18	4	14	18	3,500	0	18	0	1	0	1	1
						74	Nurelhuda	53	1	36	18	4	14	18	3,500	0	18	0	1	0	1	0
						75	Elnila	53	1	36	18	4	14	18	3,500	0	18	0	1	0	0	1
						76	Eldain	53	1	36	18	4	14	18	3,500	0	18	0	0	0	0	0
						77	Umalwan	53	0	36	18	4	14	18	3,500	0	18	0	1	1	0	1
						78	Farshia	53	0	36	18	4	14	18	3,500	0	18	0	1	1	0	0
							Locality subtotal	638	8	437	216	48	170	216	42,500	1	216	3	5	4	5	6
							State subtotal	1,313	15	874	432	96	350	432	87,500	1	432	5	10	8	11	12
6	Kassala State	13	Kassala	36° 11′ E to 36° 48′ E	15° 20′N to 16° N	79	Kassala	53	1	36	18	4	14	18	3,500	1	18	1	0	0	1	0
						80	Wad sharefaie	53	1	36	18	4	14	18	3,500	0	18	1	0	0	1	0
						81	Alshokria	53	1	36	18	4	14	18	3,500	0	18	1	0	0	0	0
						82	Aljamam	53	1	36	18	4	14	18	3,500	0	18	0	1	0	0	0
						83	Tajoj	53	0	36	18	4	14	18	3,500	0	18	0	1	0	0	0
						84	Sabeel	53	0	36	18	4	14	18	3,500	0	18	0	0	1	0	1
							Locality subtotal	315	3	219	108	24	84	108	21,000	1	108	2	2	1	1	1
		14	Telkuk	37° E to 36° 18′ E	15° 37′N to 16° 40′N	85	Talkouk	53	1	36	18	4	14	18	3,500	1	18	1	0	1	1	1
						86	Tahadi	53	1	36	18	4	14	18	3,500	0	18	1	0	0	1	0
						87	Tawiat	53	1	36	18	3	14	18	3,500	0	18	0	1	0	0	1
						88	Tahjar	53	0	36	18	3	14	18	3,500	0	18	0	1	0	0	1
						89	Temikeet	53	0	36	18	3	14	18	3,500	0	18	0	0	1	0	1
							Locality subtotal	263	2	182	90	17	70	90	17,500	1	90	1	2	2	1	4
		15	Rural Nhr Atbra	34° 36′ E to 35° 35′ E	15° 40′N to 16° 40′N	90	Mazar 24	53	1	36	18	3	14	18	3,500	1	18	0	0	0	1	1
						91	Azaza	53	1	36	18	3	14	18	3,500	0	18	0	0	0	1	0
						92	Simidaha	53	1	36	18	3	14	18	3,500	0	18	0	0	0	0	1
						93	Juneed	53	0	36	18	3	14	18	3,500	0	18	0	1	0	0	1
						94	Village10	53	0	36	18	3	14	18	3,500	0	18	0	1	0	0	0
							Locality subtotal	263	2	182	90	15	70	90	17,500	1	90	0	2	0	1	3
							State subtotal	840	8	583	288	56	224	288	56,000	2	288	3	6	3	4	8

State		Locality		Location		Village		Distribution of interventions													
								1.1.4	1.2.1	1.2.2	1.2.3	1.2.5	1.3.2	1.3.3	1.4.1	1.4.2	1.4.3	2.1.1	2.1.2	2.2.1	2.2.2	2.3.1
#	Name	#	Name	Longitude	Latitude	#	Name	Drought-resistant seeds	women's gardens	women's gardens	wadi cultivation	Farmer schools	Rangelands	Rangelands	Nurseries	Shelterbelts	Afforestation	rehabilitated water yards	new water yards	Sand storage dams	Pumps	Hafirs
7	Red Sea State	16	Agig	37° 45′ E to 38° 45′ E	17° 22′ to 18° 32′ N	95	Agig	53	1	36	18	3	14	18	3,500	1	18	1	0	1	1	1
						96	Adobana	53	1	36	18	3	14	18	3,500	0	18	1	0	0	1	1
						97	Agitar	53	1	36	18	3	14	18	3,500	0	18	0	1	0	0	0
						98	Aiterba	53	1	36	18	3	14	18	3,500	0	18	0	0	0	0	0
						99	Garora	53	0	36	18	3	14	18	3,500	0	18	0	1	0	0	1
						100	Andal	53	0	36	18	3	14	18	3,500	0	18	1	0	0	0	0
							Locality subtotal	315	3	219	108	18	84	108	21,000	1	108	2	2	1	1	3
		17	Dordaib/Haya	35° 0′ E to 36° 45′ E	17° to 18° 3′ N	101	Adarhi	53	1	36	50	3	14	18	3,500	1	25	0	0	0	1	1
						102	Shora Amrab	53	1	36	18	3	14	18	3,500	0	18	1	0	0	1	1
						103	Shora Hawin	53	0	36	18	3	14	18	3,500	0	18	1	0	1	0	0
							Locality subtotal	158	2	107	86	9	42	54	10,500	1	61	1	0	1	1	2
		18	Guneb Olib	35° E to 37°15′ E	18° 58′ to 20° 40′ N	104	Rabaeyet	53	1	36	18	3	14	18	3,500	1	18	1	0	0	1	1
						105	Arbabeyeb	53	1	36	18	3	14	18	3,500	0	18	0	1	0	1	1
						106	Godeedit	53	1	36	18	3	14	18	3,500	0	18	0	0	0	1	0
						107	Balonaye	53	1	36	18	3	14	18	3,500	0	18	0	1	0	1	1
						108	Agwambt-sarar	53	1	36	18	3	14	18	3,500	0	18	0	0	0	1	0
						109	Dadat	53	1	36	18	3	14	18	3,500	0	18	0	1	1	1	1
						110	Amor Sarara	53	1	36	18	3	14	18	3,500	0	18	0	0	0	1	1
						111	Mahale-Meserar	53	1	36	18	3	14	18	3,500	0	18	0	1	0	0	0
						112	Togaylawo	53	0	36	18	3	14	18	3,500	0	18	0	0	0	0	0
						113	Hayet-wassat	53	0	36	18	3	14	18	3,500	0	18	0	0	0	0	1
							Locality subtotal	525	6	357	180	30	140	180	35,000	1	180	1	4	1	5	6
							State subtotal	998	11	683	374	57	266	342	66,500	2	349	4	6	3	7	11
		18	Dongala	27° 36′ E to 31° 15′ E	19° N to 19° 30′N	114	AlKhwai	53	1	36	18	3	14	18	3,500	1	18	1	0	0	1	0
						115	Labab	53	1	36	18	3	14	18	3,500	0	18	1	0	0	1	0
						116	Shaeg	53	1	36	18	3	14	18	3,500	0	18	1	0	0	1	0
						117	Jertoad	53	1	36	18	3	14	18	3,500	0	18	0	1	0	1	0
						118	Aloagal	53	0	36	18	3	14	18	3,500	0	18	0	0	0	1	0
						119	Gaabellagia	53	0	36	18	3	14	18	3,500	0	18	0	1	0	0	0
						120	Algouba	53	0	36	18	3	14	18	3,500	0	18	0	1	0	0	0
							Locality subtotal	368	3	250	126	21	98	126	24,500	1	126	2	3	0	3	0
8	Northern State	20	Marawi	31° E to 32° 48′ E	16° 35′N to 18° 45′N	121	Mora	53	1	36	18	3	14	18	3,500	1	18	1	0	0	1	0
						122	Kori	53	1	36	18	3	14	18	3,500	0	18	1	0	0	1	0
						123	Kannar	53	1	36	17	3	14	18	3,500	0	18	0	1	0	1	0
						124	Algorair	53	0	36	17	3	14	18	3,500	0	18	0	0	0	1	0
						125	Osli	53	0	36	17	3	14	18	3,500	0	18	0	0	0	0	0
						126	Om Jawaseer	53	0	36	17	3	14	18	3,500	0	18	0	1	0	0	1
							Locality subtotal	315	2	214	104	18	84	108	21,000	1	108	1	2	0	3	1
		21	AlDabaha	27° 36′ E to 31° E	18° 15′N to 18° 40′N	127	Argi	53	1	36	17	3	14	18	3,500	1	18	1	0	0	1	1
						128	Alafad	53	0	36	17	3	14	18	3,500	0	18	1	0	0	0	0
						129	Selib	53	0	36	17	3	14	18	3,500	0	18	0	1	0	0	0
						130	Tanganrati	53	0	36	17	3	14	18	3,500	0	18	0	0	0	0	0
							Locality subtotal	210	1	143	68	12	56	72	14,000	1	72	1	1	0	1	1
							State subtotal	893	6	607	298	51	238	306	59,500	2	306	4	6	0	7	2
9	Khartoum State	22	Rural Umdorman	31° 35′ E to 32° 30′ E	15° 45′N to 16° 35′N	131	Abuhleaf	53	1	36	17	3	14	18	3,500	1	18	1	0	0	1	0
						132	Mondra	53	0	36	17	3	14	18	3,500	0	18	1	0	0	1	0
						133	Fatasha Elgadima	53	0	36	17	3	14	18	3,500	0	18	0	1	0	0	0
						134	Fatasha Elzaoia	53	0	36	17	3	14	18	3,500	0	18	0	0	0	0	0
							Locality subtotal	210	1	143	68	12	56	72	14,000	1	72	1	1	0	1	0
		23	Rural Sharg ElNil	32° 30′ E to 34° 30′ E	15° 30′N to 15° 45′N	135	Algaba abuzaid	53	1	36	17	3	14	18	3,500	1	18	1	0	0	1	1
						136	Elhour	53	0	36	17	3	14	18	3,500	0	18	0	1	0	1	0
						137	Elhoela	53	0	36	17	3	14	18	3,500	0	18	0	0	0	0	1
						138	Elakoda	53	0	36	17	3	14	18	3,500	0	18	0	0	0	0	1
							Locality subtotal	210	1	143	68	12	56	72	14,000	1	72	1	1	0	1	3
		State subtotal						420	2	286	136	24	112	144	28,000	1	144	2	2	0	3	3
							PROJECT TOTAL	7,500	75	5,000	2,500	500	2,000	2,500	500,000	15	2,500	30	50	30	50	75

Annex F: Background on water resources

Perennial Surface Waters

The dominant river system in Sudan is the Nile. The river's two main tributaries, the Blue and White Niles, flow into Sudan from Ethiopia and Uganda respectively, and meet in Khartoum before flowing north to Egypt. In an otherwise arid terrain, the Nile plays a crucial role in the country's various ecosystems. Sudan has also over 750 km of coastline and territorial waters in the Red Sea, which include an archipelago of small islands. Peculiarly enough, there are no perennial water sources in the targeted regions for rainwater harvesting development.

One of the main natural features characterizing Sudan is the Nile system. It is the only perennial surface freshwater resource in the country. The Nile originates outside Sudan's borders and its water is shared by eleven riparian countries (see Figure F-1). Most of Sudan's share in Nile waters is used in irrigation and hydro-power generation and to a lesser extend in domestic water supply and industry.

Figure F-1: River Nile and its Tributaries in Sudan

The average annual discharge of the River Nile amounts to 84 billion m^3 at Aswan of which Egypt's share is 55.5 billion m^3 and the share of Sudan is 18.5 billion and the rest (10 billion) evaporates, as per the Nile Water Agreement 1959. The Ethiopian Highlands contribute for about 85% of the total water in the Nile. Branches of the White Nile maintain flow of Nile because the long-lasting period of flooding in the Great Lakes region. Different tributaries contribute to annual discharge of the River Nile, as summarized in the bullets below and Table F-1.

- Blue Nile Group: These tributaries include the Blue Nile, Dinder and Rahad Rivers. Annual discharge of this group amounts to about 48 billion m^3.
- White Nile Group: These tributaries include the Bahr al-Jabal, Bahr el-Ghazal, and Sobat Rivers. Annual discharge of this group is about 24 billion M^3.
- Atbara River Group: This includes the Atbara and Sitete Rivers. Annual discharge of this group is about 12 billion m^3.

Table F-1: Water Supply from The River Nile and its Tributaries

Tributary	Total Annual Average Supply (bcm)	Flow Characteristics
Blue Nile	50.7	Average daily peak discharge falls from 535 mcm/day in August to only 11 mcm/day in April
Rahad	1.09	Flow from July to November
Dinder	3.0	Flow from June to November
White Nile	27.8 (at Malakal)	Daily flow falls from 114 mcm/day in November to 54 mcm/day in April
Bahr El Gazal	14	Only 0.5 bcm reaches Malakal (swamps)
Bahr El Jebel	26 at Mongalla	Only 14.0 bcm reaches Malakal (swamps)
Sobat	13.3 reaches Malakal	Losses in Baro and Machar reach 8 bcm. Flows range from 8 mcm/day in April to 66 mcm/day in November
Atbara	12 (7 from Setit and 5 from Atbara branch)	Low regulated flows from February to June
Main Nile	84 (at Aswan)	Average daily peak flow of 690 mcm/day (August-Sept.) and a low flow of 74 mcm/day (April-May)

Seasonal valleys

Sudan has several water basins located within seasonal valleys as identified in the bullets below:

- The Red Sea heights
- Jebel Mara
- The Nuba Mountains
- Angasana Mountains
- AL- Managil Hill and
- Al Butana Hill

The estimated quantity of water provided by these valleys is about 6.5 Billion m^3 per year. Such valleys are considered important water resources to provide drinking water and water for agricultural purposes. They also contribute in annual water supply for natural recharging of the underground reservoirs of wadis such as Gash, Arbaat and Neyala.

There are many villages in the rural areas live on or near the banks of the river Nile and its tributaries. Many of these villages lack treated water. Typically, they drink raw water from the river using traditional means of water transport.

Groundwater

Major groundwater aquifers in Sudan cover about 50% of the surface area of the country Figure F-2 shows the distribution of these aquifers over Sudan. These aquifers fall under the following four categories (Salama, 1976, Salih and Khadam, 1994; Salih 1994).

- Nubian sandstone aquifers
- Um Rawaba formation

- Alluvial aquifers (Wadi-filled) and
- Basement complex

A brief summary of the aquifers and their characteristics are given below.

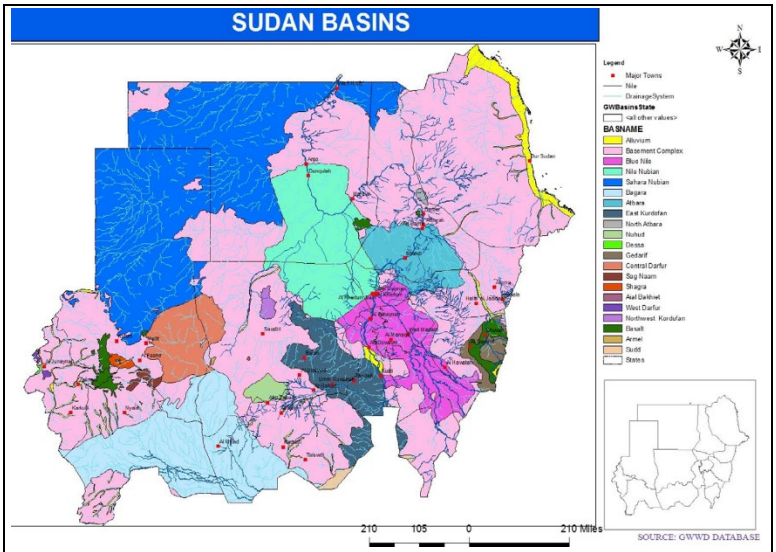


Figure F-2: River Nile and its Tributaries in Sudan (source: Integrated Groundwater Resources Management within Reverbasins Workshop; Integrated Groundwater Resources Management in Sudan; Country paper Sudan; 15th 17th Jan 2019; Nairobi Kenya

- ***Nubian Sandstone Aquifers:*** Nubian Sandstone Aquifers are the most extensive and largest aquifers in Sudan. They cover about 28% of the surface area of the country. They are preserved in nine major basins which are:
  - ✓ Sahara Basin
  - ✓ The Nile Basin
  - ✓ Atbara Basin
  - ✓ Central Darfur Basin
  - ✓ The Blue Nile Basin
  - ✓ Nuhud Basin
  - ✓ Gadarif Basin
  - ✓ Sag El Naam Basin and
  - ✓ Shagara Basin.

  The productive strata of these aquifers vary in thickness ranging from 100 to 2,000 meters. Their storage coefficient (i.e., the volume of water released from storage relative to the change in head, or water level, and surface area of the aquifer) ranges between 10^{-2} to 10^{-4} and the sustainable well yield ranges from 100 to 400 m^3 per hour (2,400 – 9,600 m^3 per day). The depth to the groundwater table varies between 5 and 100 meters.

- ***Um Rawaba Aquifers:*** Um Rawaba aquifers cover about 7% of the surface area of Sudan. They are preserved in three major basins which are:
  - ✓ Bara Basin.
  - ✓ Atshan Basin
  - ✓ Baggara Basin.

  The aquifer thickness is very large, approximately 3,000 meters. Groundwater is present under unconfined water table conditions in the recharge area and under confined water table conditions at the center of the aquifer. Sustainable well yields are much lower than that of the Nubian Sandstone aquifers, ranging from 5 to 20 m^3 per hour (120 – 480 m^3 per day).The depth to the static groundwater table varies from 10 to 150 meters below ground level.

- ***Alluvial Aquifers:*** Alluvial aquifers are relatively small but numerous, rich and of high local importance. They are preserved in several water catchment areas, the most important of which are identified in the bullets that follow.
  - ✓ Gash
  - ✓ Wadi Azoum
  - ✓ Wadi Eldain
  - ✓ Wadi Nyala
  - ✓ Khor Abuhabil
  - ✓ Arbaat
  - ✓ Wadi Dordaib
  - ✓ Other minor catchment areas

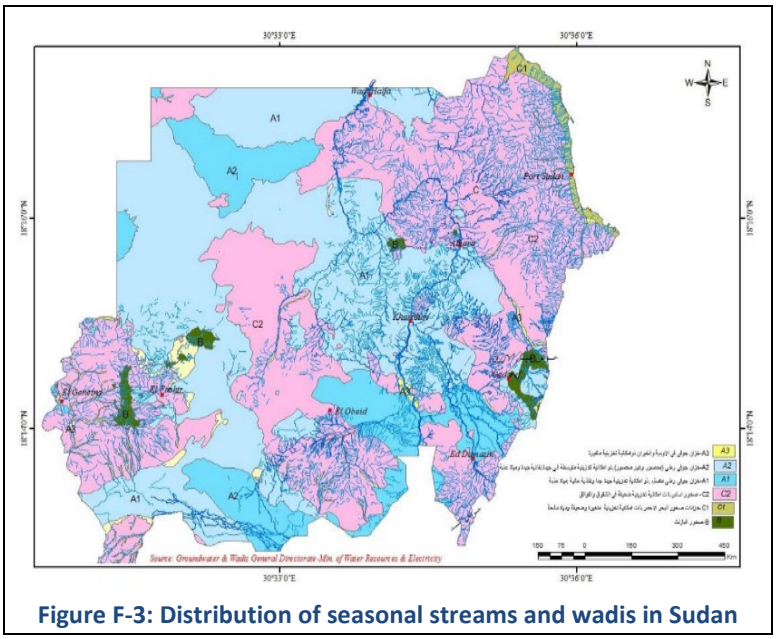


Figure F-3: Distribution of seasonal streams and wadis in Sudan

Alluvial basins are seasonal streams (known locally as *Khors*). These seasonal surface waters are widely distributed throughout Sudan (see Figure F-3). They are typically located away from perennial rivers, as well as in areas where groundwater aquifers are unavailable.

The runoff in these streams does not exceed three months per year. The runoff during this period is substantial and the aquifers are annually fully recharged through bed transmission from seasonal streams and wadis. The depth to the water table is shallow and usually varies between 2 to 15 meters. Well yields are moderate to high and range between 50 to 100 m^3 per hour (1,200 – 2,400 m^3 per day). The shallow depths enable local communities to develop their own technology for water abstraction and irrigation. Many of the alluvial basins are of promising future development centers if there are investments in water infrastructure.

- ***Basement complex:*** Ground water is very scarce in the basement complex and is not replenished. However, water can be found in alluvial basins that are formed by seasonal streams in the basement complex. The recharge rate in alluvial aquifer is similar to those of other alluvial aquifers.

A summary of the estimated storage potential, annual recharge and sustainable abstraction rate of the Nubian Sandstone, Um Rawaba, Alluvial, and Basement Complex aquifers are provided in Table F-2. As can be seen, current abstraction represents a small percentage of storage, and therefore there are large opportunities for developing groundwater resources for various purposes, specifically domestic water supply.

Renewable ground water is estimated at 5.6 billion m^3 and contributes for about 63% of the drinking water produced in the Sudan. Groundwater resources remain largely untapped

Table F-2: Estimates of groundwater storage, annual recharge and abstraction for Aquifers in Sudan (SNCIHP, 2000).

Major Aquifers	Ground water storage (Mm^3)	Annual Recharge (Mm^3)	Sustainable abstraction rate (Mm^3/year)
Nubian Sandstone Basins	503,000	1,000	700
Um Rawaba Basins	60,000	600	150
Alluvial Basins	1,000	375	160
Alluvial basins in Basement Complex	NA	0	0
Total	564,000	1,975	1,010

except in regions where aquifers are replenished by surface water from the Nile and some large seasonal streams such as Gash river and Khor Baraka in eastern Sudan. Groundwater is mainly developed for domestic water supply in large urban centers close to the Nile.

In rural areas, groundwater is the main source for drinking water for both humans and livestock. Artesian wells as well as shallow wells are dug in the regions where groundwater aquifers are available. In boreholes, diesel or electric pumps are typically used to pump water from deep aquifers. For shallow aquifers, hand pumps are used to extract water for drinking. In most cases the water from these aquifers is pumped into elevated tanks for storage and distribution to the different villages, and is adequate for drinking.

Water supply and demand

Table F-3 depicts the water supply situation as of 2017, except for Khartoum state. Average per capita water consumption across all rural areas is 24 liters per day (l/p/d). Another considerable consumer of water is the livestock. Assumptions used in the water balance analysis are summarized below:

- *Human water consumption:* The aggregate daily water consumption rate was assumed to be 50 m^3 per day, the same rate for each project locality;
- *Livestock water consumption:* The aggregate daily water consumption rate was assumed to be 50 m^3 per day for water used for livestock (i.e., camels, sheep, goats), the same rate for each project locality;
- Women gardens water consumption: The average daily water consumption rate was assumed to be 0.7 m^3 per hectare per day, the same rate for each project locality; and
- *Agricultural water consumption:* The aggregate daily water consumption rate was assumed to be 1,700 m^3 per day for water used for cultivation purposes other

Table F-3: Water Supply situation, 2017 (Source: MWRIE comprehensive report 2017)

		Average Per capita water consumption (l/c/d)		
	State	Urban	Rural	Overall
Within project scope	West Darfur	25	9	17
	Central Darfur	27	9	18
	East Darfur	37	20	28.5
	West Kordofan	46	26	35
	South Kordofan	40	25	32.5
	Kassala	65	21	43
	Red Sea	50	8	29
	Northern	66	52	59
Outside project scope	White Nile	46	25	35.5
	Blue Nile	65	19	37.5
	Sennar	71	31	51
	Gadarif	50	19	34.5
	Gezira	70	72	49
	River Nile	75	61	68
	North Kordofan	52	24	38
	North Darfur	45	15	30
	South Darfur	30	17	23.5
Total/average		50	24	37

than women's gardens, the same rate for each project locality.

Water Revenues

Water tariff rates are governed by state level legislative council resolutions and are aimed to cover operation and maintenance costs of the three major types of water infrastructure.

Table F-4: Average water tariffs

Infrastructure type		Tariff				Notes
		SDG		US$		
		Per m^3	Per liter	Per m^3	Per liter	
Water yards	Humans	2.5	0.0025	0.055	0.000055	same tariff for population and livestock
	Livestock	2.5	0.0025	0.055	0.000055	
Hafirs	Humans	5.0	0.0050	0.110	0.000110	Treated Water for population
	Livestock	2.5	0.0025	0.055	0.000055	
Sand storage	Humans	5.0	0.0050	0.110	0.000110	Treated Water for population
	Livestock	2.5	0.0025	0.055	0.000055	

Average rates are shown in Table F-4. These rates apply to each target sites during the period of project activities.

Water Balance

A water balance analysis was undertaken to assess the impact of the project's water harvesting activities on the sustainable use of aquifer waters. The spreadsheet calculations underlying the results summarized below are presented in Annex 19a of the full proposal.

As an initial step, the source of water for the water yards, hafirs, and sand storage dams was established, as summarized in the bullets below.

- *Water yards:* The water source for water yards is groundwater abstraction. A total of 30 are planned for rehabilitation and an additional 50 water yards will be installed as new infrastructure as part of Activities 2.1.1 and 2.1.2, respectively. The distribution of these installations is summarized in Table F-5. The depth to the groundwater table was conservatively assumed to be 70-80 meters for each location.
- *Hafirs:* The water source for hafirs are alluvial aquifers fed by local seasonal streams. A total of 75 hafirs will be installed as new infrastructure as part of Activity 2.3.1. The distribution of these installations is summarized in Table F-6. The depth to the infiltration surface water was assumed to be 10 meters for each location.
- *Sand storage dams and associated solar pumps:* The water source for sand storage dams are alluvial aquifers fed by local seasonal streams. A total of 30 are planned for installation accompanied by 50 solar powered pumps as part of Activities 2.2.1 and 2.2.2, respectively. The distribution of these installations is summarized in Table F-6. The depth to the infiltration surface water was assumed to be 10 meters for each location.

Water use estimates were developed for each site based on water withdrawals that were within the range of sustainable water extraction rates discussed earlier. Table F-7 summarizes annual water withdrawals for all water infrastructure installations.

Table F-5: Water sources for rehabilitated and new water yard installations

#	State	#	Locality	Groundwater source		# of installations		
				Basin	Aquifer	rehabed water yards 2.1.1	new water yards 2.1.2	Total
1	West Darfur State	1	Genana	Basalt	Um Rawaba	1	0	1
		2	Krenik	Basalt	Um Rawaba	0	1	1
2	Central Darfur State	3	Zalingi	Central Darfur	Nubian	2	2	4
		4	Azoom	Central Darfur	Nubian	1	2	3
3	East Darfur State	5	ELdain	Bagara	Um Rawaba	1	2	3
		6	Firdous	Bagara	Um Rawaba	1	1	2
		7	Asalia	Bagara	Um Rawaba	0	2	2
4	West Kordofan State	8	Al Nohoud	Bagara	Um Rawaba	1	4	5
		9	Asalam	Bagara	Um Rawaba	2	4	6
		10	Alsunut	Bagara	Um Rawaba	4	2	6
5	South Kordofan State	11	El Goz	Bagara	Um Rawaba	2	5	7
		12	Dilling	Bagara	Um Rawaba	3	5	8
6	Kassala State	13	Kassala	Atbara	Nubian	2	2	4
		14	Telkuk	Atbara	Nubian	1	2	3
		15	Rural Nhr Atbra	Atbara	Nubian	0	2	2
7	Red Sea State	16	Agig	Alluvium	Alluvial	2	2	4
		17	Dordaib/Haya	Alluvium	Alluvial	1	0	1
		18	Guneb Olib	Alluvium	Alluvial	1	4	5
8	Northern State	18	Dongala	Sahara Nubian	Nubian	2	3	5
		20	Marawi	Sahara Nubian	Nubian	1	2	3
		21	AlDabaha	Sahara Nubian	Nubian	1	1	2
9	Khartoum State	22	Rural Umdorman	Sahara Nile	Nubian	1	1	2
		23	Rural Sharg ElNil	Sahara Nile	Nubian	0	1	1
PROJECT TOTAL						**30**	**50**	**80**

Table F-6: Water catchment areas for hafirs, pumps, and sand storage dams

#	State	#	Locality	Aquifer	# of installations			
					Sand storage dams 2.2.1	Pumps 2.2.2	Hafirs 2.3.1	Total
1	West Darfur State	1	Genana	Um Rawaba	1	1	4	6
		2	Krenik	Um Rawaba	1	1	2	4
2	Central Darfur State	3	Zalingi	Nubian	4	2	8	14
		4	Azoom	Nubian	2	1	3	6
3	East Darfur State	5	ELdain	Um Rawaba	0	1	2	3
		6	Firdous	Um Rawaba	0	1	2	3
		7	Asalia	Um Rawaba	0	1	5	6
4	West Kordofan State	8	Al Nohoud	Um Rawaba	0	3	5	8
		9	Asalam	Um Rawaba	4	3	5	12
		10	Alsunut	Um Rawaba	4	5	3	12
5	South Kordofan State	11	El Goz	Um Rawaba	4	5	6	15
		12	Dilling	Um Rawaba	4	6	6	16
6	Kassala State	13	Kassala	Nubian	1	1	1	3
		14	Telkuk	Nubian	2	1	4	7
		15	Rural Nhr Atbra	Nubian	0	2	3	5
7	Red Sea State	16	Agig	Alluvial	1	1	3	5
		17	Dordaib/Haya	Alluvial	1	1	2	4
		18	Guneb Olib	Alluvial	1	5	6	12
8	Northern State	18	Dongala	Nubian	0	3	0	3
		20	Marawi	Nubian	0	3	1	4
		21	AlDabaha	Nubian	0	1	1	2
9	Khartoum State	22	Rural	Nubian	0	1	0	1
		23	Rural Sharg ElNil	Nubian	0	1	3	4
PROJECT TOTAL					30	50	75	155

The current groundwater results are summarized in Table F-8 for deep and shallow wells. Existing annual non-project related groundwater usage is estimated at around 47 Mm^3/yr.

Table F-7: Annual groundwater withdrawals for all installed water infrastructure

State		Locality		Water use (Mm3/year)							
				Groundwater aquifers (~70-80 meters deep)			Alluvial aquifers (~10 meters deep)				
#	Name	#	Name	rehabed water yards 2.1.1	new water yards 2.1.2	Sub-total	Sand storage dams 2.1.1	Pumps 2.1.2	Hafirs 2.11	Sub-total	Total
1	West Darfur	1	Genana	0.04	0.00	0.04	0.66	0.68	2.63	3.97	4.00
		2	Krenik	0.00	0.04	0.04	0.66	0.68	1.31	2.65	2.69
2	Central Darfur	3	Zalingi	0.07	0.07	0.15	2.63	1.39	5.26	9.27	9.42
		4	Azoom	0.04	0.07	0.11	1.31	0.69	1.97	3.98	4.09
3	East Darfur	5	ELdain	0.04	0.07	0.11	0.00	0.68	1.31	2.00	2.11
		6	Firdous	0.04	0.04	0.07	0.00	0.68	1.31	2.00	2.07
		7	Asalia	0.00	0.07	0.07	0.00	0.68	3.29	3.97	4.04
4	West Kordofan	8	Al Nohoud	0.04	0.15	0.18	0.00	2.04	3.29	5.33	5.51
		9	Asalam	0.07	0.15	0.22	2.63	2.04	3.29	7.95	8.17
		10	Alsunut	0.15	0.07	0.22	2.63	3.40	1.97	8.00	8.22
5	South Kordofan	11	El Goz	0.07	0.18	0.26	2.63	3.39	3.94	9.96	10.21
		12	Dilling	0.11	0.18	0.29	2.63	4.06	3.94	10.63	10.93
6	Kassala	13	Kassala	0.07	0.07	0.15	0.66	0.69	0.66	2.01	2.15
		14	Telkuk	0.04	0.07	0.11	1.31	0.69	2.63	4.64	4.75
		15	Rural Nhr Atbra	0.00	0.07	0.07	0.00	1.39	1.97	3.36	3.43
7	Red Sea	16	Agig	0.07	0.07	0.15	0.66	0.68	1.97	3.31	3.46
		17	Dordaib/Haya	0.04	0.00	0.04	0.66	0.68	1.31	2.65	2.69
		18	Guneb Olib	0.04	0.15	0.18	0.66	3.41	3.94	8.01	8.19
8	Northern	18	Dongala	0.10	0.16	0.26	0.00	1.97	0.00	1.97	2.23
		20	Marawi	0.05	0.10	0.16	0.00	1.97	0.66	2.63	2.78
		21	AlDabaha	0.05	0.05	0.10	0.00	0.66	0.66	1.31	1.42
9	Khartoum	22	Rural Umdorman	0.06	0.06	0.12	0.00	0.66	0.00	0.66	0.78
		23	Rural Sharg ElNil	0.00	0.06	0.06	0.00	0.66	1.97	2.63	2.69
PROJECT TOTAL				1.18	1.97	3.15	19.71	33.90	49.28	102.88	106.0

Finally, estimated annual water withdrawals were compared to annual groundwater recharge rates. In keeping with the criterion of sustainable exploitation of groundwater resources, the criterion was applied that total annual water withdrawals must be below 70% of annual recharge levels. For all localities, this criterion was met, as summarized in Table F-9.

Table F-8: Annual groundwater withdrawals for non-project water infrastructure in the project localities

#	State	Groundwater source		Current water Use (Mm3 /year)		
		Basin	Aquifer	Deep wells	Shallow wells	Total
1	West Darfur	Bagara	Um Rawaba	0.00	0.03	0.03
		Basalt	Um Rawaba	0.03	0.00	0.03
		Basement	Basement	0.00	0.00	0.00
2	Central Darfur	Central Darfur	Nubian Sandstone	0.02	0.00	0.02
		Alluvium	Alluvial	0.00	0.02	0.02
		Basalt	Nubian Sandstone	0.02	0.00	0.02
4	West Kordfan	Bagara	Um Rawaba	5.53	0.00	5.53
		Basement	Basement	0.00	0.00	0.00
5	South Kordfan	Bagara	Um Rawaba	0.99	0.00	0.99
		Nuhud	Nubian Sandstone	0.00	0.99	0.99
		Sudd	Nubian Sandstone	0.99	0.00	0.99
		Basement	Basement	0.00	0.00	0.00
6	Kasala	Alluvium	Alluvial	0.00	1.45	1.45
		Atbara	Nubian Sandstone	1.45	0.00	1.45
		Basement	Basement	0.00	0.00	0.00
7	Red Sea	Alluvium	Alluvial	0.00	0.60	0.60
		Basement	Basement	0.00	0.00	0.00
8	Northern	Sahara Nile	Nubian Sandstone	0.00	2.76	2.76
		Sahara Nubian	Nubian Sandstone	2.76	0.00	2.76
9	Khartoum	Sahara Nile	Nubian Sandstone	9.85	0.00	9.85
		Atbara	Other alluvial	0.00	9.85	9.85
		Blue Nile	Nubian Sandstone	9.85	0.00	9.85
Total				31.66	15.69	47.35

Table F-9: Summary

Groundwater source		Groundwater Use (Mm3/yr)									Recharge rate (Mm3/year)	Abstraction rate as % of recharge rate	Current and project-related water use as share of renewable recharge supply < 70% ?
		Current use			Project use			Total use					
Basin	Aquifer	Deep wells	Shallow wells	Subtotal	Deep wells	Shallow wells	Subtotal	Deep wells	Shallow wells	Total			
Alluvium	Alluvial	0.00	2.06	2.06	0.37	13.97	14.34	0.37	16.04	16.40	375	4.4%	Yes
Atbara	Nubian Sandstone	1.45	9.85	11.30	0.33	10.00	10.33	1.78	19.85	21.63	1,915	1.1%	Yes
Bagara	Um Rawaba	6.69	0.03	6.72	1.42	49.84	51.26	8.12	49.87	57.99	600	9.7%	Yes
Basalt	Nubian Sandstone	0.05	0.00	0.05	0.07	6.62	6.69	0.12	6.62	6.73	1,915	0.4%	Yes
Basement	Basement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	NA	NA
Blue Nile	Nubian Sandstone	9.85	0.00	9.85	0.00	0.00	0.00	9.85	0.00	9.85	1,915	0.5%	Yes
Central Darfur	Nubian Sandstone	0.02	0.00	0.02	0.26	13.25	13.51	0.27	13.25	13.52	1,915	0.7%	Yes
Nuhud	Nubian Sandstone	0.00	0.99	0.99	0.00	0.00	0.00	0.00	0.99	0.99	1,915	0.1%	Yes
Sahara Nile	Nubian Sandstone	9.85	2.76	12.61	0.18	3.29	3.47	10.03	6.05	16.08	1,915	0.8%	Yes
Sahara Nubian	Nubian Sandstone	2.76	0.00	2.76	0.52	5.91	6.43	3.28	5.91	9.20	1,915	0.5%	Yes
Sudd	Nubian Sandstone	0.99	0.00	0.99	0.00	0.00	0.00	0.99	0.00	0.99	1,915	0.1%	Yes
Total		31.66	15.69	47.35	3.15	102.88	106.03	34.81	118.57	153.38	3,265	4.7%	Yes

Annex G: Carbon sequestration estimates

This annex provides an overview of the carbon sequestration benefits associated with some project activities.

A. Project activities with sequestration benefits

Activity	Description	Carbon sequestration potential
1.3.2	**Establish communal rangeland reserves for drought resistant rangeland seed production**	**YES**
1.3.3	**Rangeland rehabilitation of 2,000 hectares of degraded rangelands and an additional 2,500 hectares of strategic rangelands by using site-suitable types of soil conservation and water harvesting techniques**	**YES**
1.4.2	**Establishe shelterbelts with drip irrigation system**	**YES**
1.4.3	**Established climate adaptive community-based afforestation**	**YES**

B. Project activities with sequestration benefits

Activity	Description	Details	Reforested area (hectares)
1.3.2	**Establish communal rangeland reserves for drought resistant rangeland seed production**	**National contractor (i.e. Agriculture Research Center) in consultation with local communities and establish range seed production area**	**2,000**
1.3.3	**Rangeland rehabilitation by using various types of soil conservation and water harvesting techniques**	**National contractor will consult with local communities and establish rangeland rehabilitation by using SCWH techniques with biological and mechanical measures**	**2,500**
1.4.2	**Established shelterbelts with drip irrigation system**	**National contractor (Forest National Cooperation) to establish 15 shelterbelts (the dimension is approximately 4 hectare per shelterbelt)**	**60**
1.4.3	**Established climate adaptive community-based afforestation**	**Form 23 Forest User Group to establish community forests in 3 agroecological zone**	**2,500**

C. Assumptions

Molecular weights

Molar mass of C (g/mol)	12
Molar mass of CO2 (g/mol)	44

Carbon sequestration potential assumptions:

Parameter	Biomass	Dead organic matter	Soils
Other Land converted to Forest Land (net Gg C/hectare per year)	0.00108	0.00130	0.00000
Rangeland conversion to rehabilitated rangeland as a % of forest conversion rate	20%	20%	20%
Rangeland converted to rehabilitated rangeland (Gg C/hectare per year)	0.000216576	0.00025962	0.00000

Assumptions used in analysis

Type	Characteristics	Rotation (years)	Uptake period (years)	Carbon uptake (thousand tC per hectare per uptake period)			Carbon uptake (thousand tC per hectare per year)		
				Min	Max	Avg	Min	Max	Avg
Rangeland rehabilitation	Biological and mechanical measures (i.e. rainfall multiplier, local grasses and bushes)	N/A	30	N/A	N/A	0.01429	N/A	N/A	0.00048
Irrigated reforestation	Eucalyptus camaldulensis and Eucalyptus microtheca (principal species to be planted)	N/A	30	N/A	N/A	0.07143	N/A	N/A	0.00238
Community reforestation	Acacia Senegal with other Acacia species planted as needed. Since community forests typically display less wood production than commercial plantations, stock density is likely to reach only 50 m3/ha by the end of the rotation. After trees reach 3 years in age, cereal crops would be able to be grown, with livestock grazing permitted after a minimum of 5 years.	N/A	30	N/A	N/A	0.07143	N/A	N/A	0.00238

D. Results

Activity	Description	Type	Characteristics	Reforested area (hectares)	Uptake period (yrs)	Average carbon uptake (Gg C per uptake period)	Sequestered carbon pool (Gg C/year)	Sequestered carbon pool over 2020-2050 (Gg C)
1.3.2	Establish communal rangeland reserves for drought resistant rangeland seed production	Rangeland rehabilitation	Biological and mechanical measures (i.e. rainfall multiplier, local grasses and bushes)	2,000	30	0.014	0.952	28.572
1.3.3	Rangeland rehabilitation by using various types of soil conservation and water harvesting techniques	Rangeland rehabilitation	Biological and mechanical measures (i.e. rainfall multiplier, local grasses and bushes)	2,500	30	0.014	1.190	35.715
1.4.2	Established shelterbelts with drip irrigation system	Irrigated reforestation	Acacia Senegal and other Acacia species	60	30	0.071	0.143	4.286
1.4.3	Established climate adaptive community-based afforestation	Community reforestation	Acacia Senegal with other Acacia species planted as needed. Since community forests typically display less wood production than commercial plantations, stock density is likely to reach only 50 m3/ha by the end of the rotation. After trees reach 3 years in age, cereal crops would be able to be grown, with livestock grazing permitted after a minimum of 5 years.	2,500	30	0.071	5.952	178.574
			Total	**7,060**	**NA**	**0.035**	**8.24**	**247.15**

Annex H: Water infrastructure design drawings

This annex provides an overview of the dimensions and other design details of water yards, sand dams, and hafirs. The contents are indicated below:

Water yards (10 drawings):

- WY-1: General layout
- WY-2: Solar panels and operations room
- WY-3: Piping arrangements
- WY-4: Distribution compound – interior walls
- WY-5: Distribution compound – animal trough
- WY-6: Distribution compound – cart filling point
- WY-7: Distribution compound – guard and operator room
- WY-8: Distribution compound – doors and windows
- WY-9: Distribution compound – fence

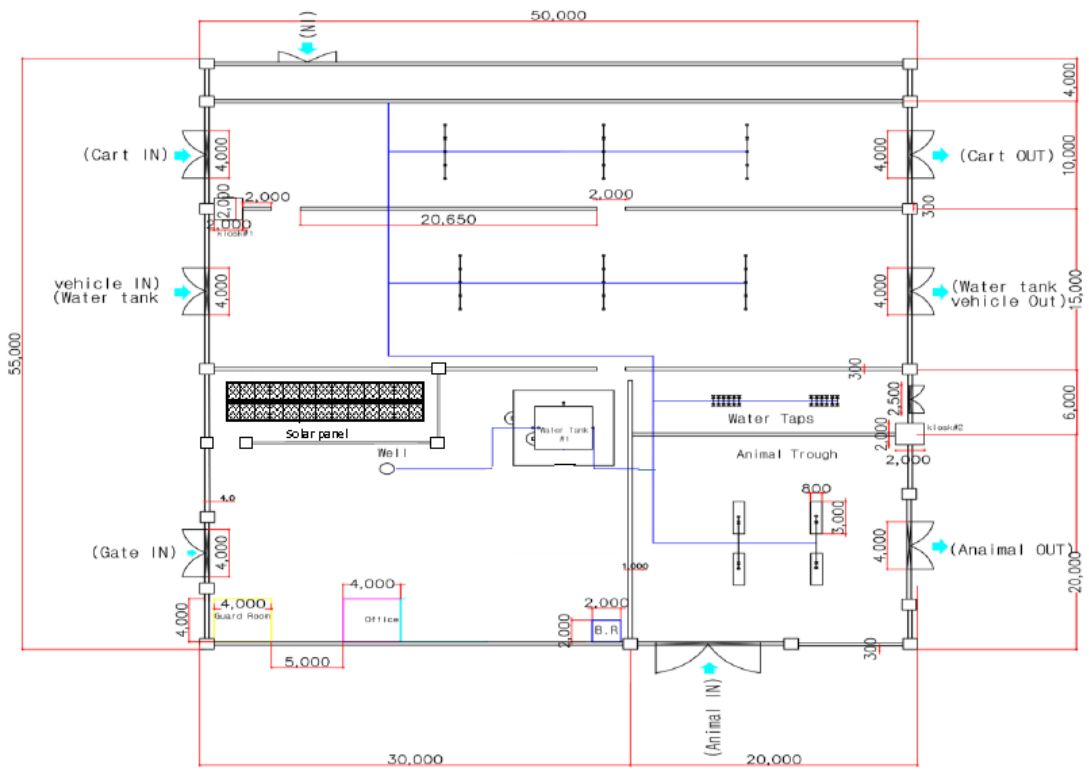
WY-10: **Sand water storage dams (6 drawings):**

- SWSD-1: General description landscape
- SWSD-2: General layout
- SWSD-3: Wall and spillway (Section A-A)
- SWSD-4: Wall and spillway (Section B-B)
- SWSD-5: Water abstraction arrangements
- SWSD-6: Protection fence details

Hafirs (12 drawings):

- H-1: General plan
- H-2: Silt trap, inlet well and control valve X-section
- H-3: Pressure well and energy dissipator well X-section
- H-4: Outlet X-section
- H-5: Fence
- H-6: Distribution compound – general layout
- H-7: Distribution compound – animal trough
- H-8: Distribution compound – cart filling point
- H-9: Distribution compound – guard and operating room
- H-10: Distribution compound – WC room
- H-11: Distribution compound – doors and windows
- H-12: Distribution compound – Fence

WY-1: General layout



Notes:

1. All dimensions are in meter.
2. Walls are made of redbrick (1.5 B).
3. Generator room could be replaced by the solar panels In case of using solar energy.
4. Double elevated tanks could be used in sites where water consumption is very high.
5. All doors are manufactured double-leaf steel doors.

Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Water yard water distribution compound - **General layout (SWC typical design)**
Project locations:	80 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

WY-2 Solar panels and operations room

Notes:

1. The borehole depth and water production dictates the number of the solar panel plates required to power the submersible pump.

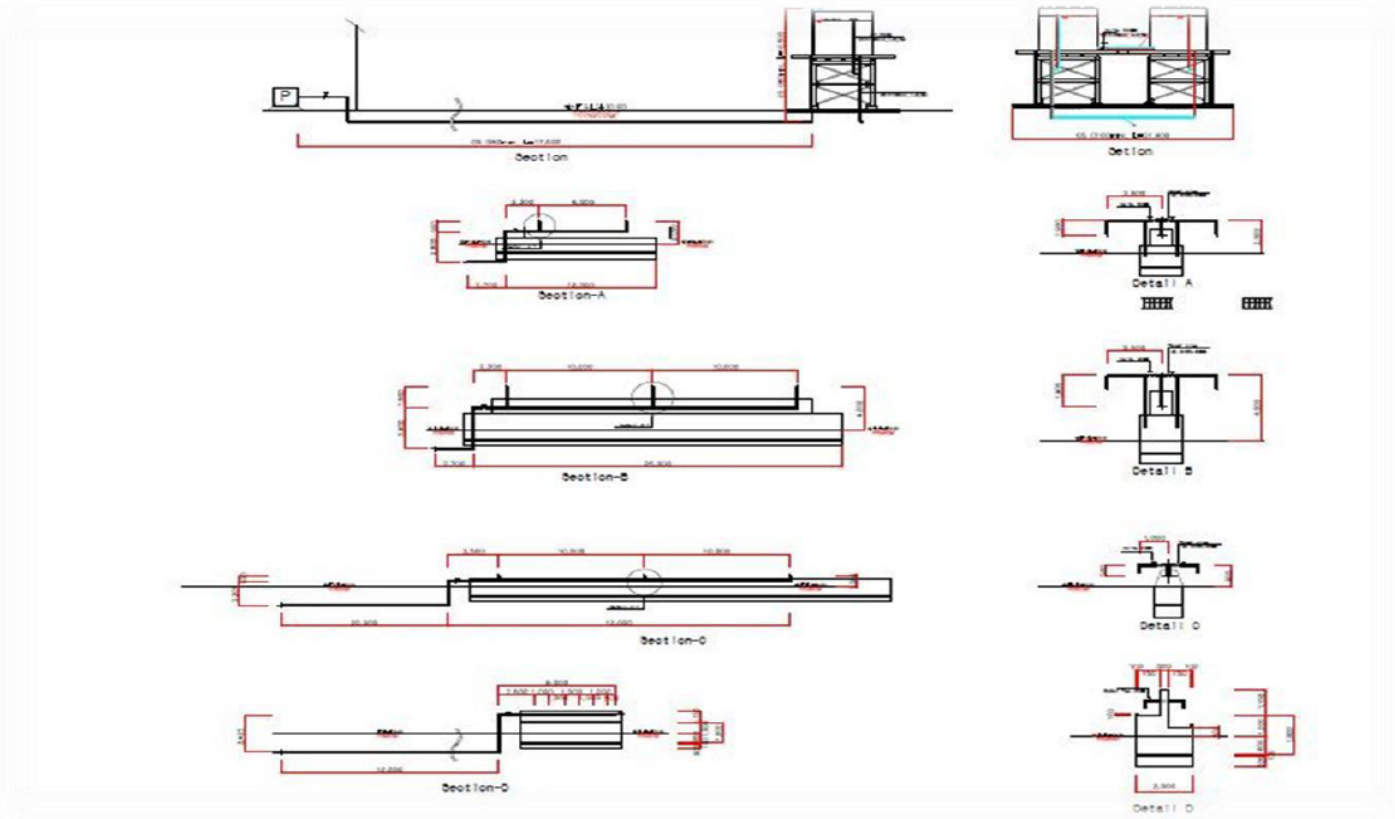
Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Water yard water distribution compound – **Solar panel and the operation room**
Project locations:	80 project sites in 9 States in Sudan

Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Consultant:
Ali Hamid Yousif

WY-3: Piping arrangements



Notes:

1. All dimension in millimeter.

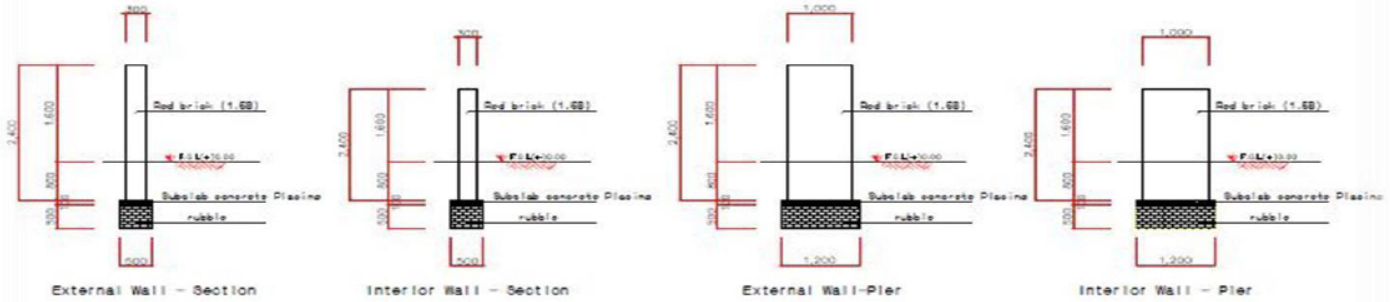
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Water yard water distribution compound – Piping arrangements
Project locations:	80 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

WY-4: Distribution compound – interior walls



Notes:

1. All dimensions in millimeters.
2. Walls are redbrick or hollow cement blocks (minimum 3N/mm) in cement mortar (1:6 cement / sand ratio).

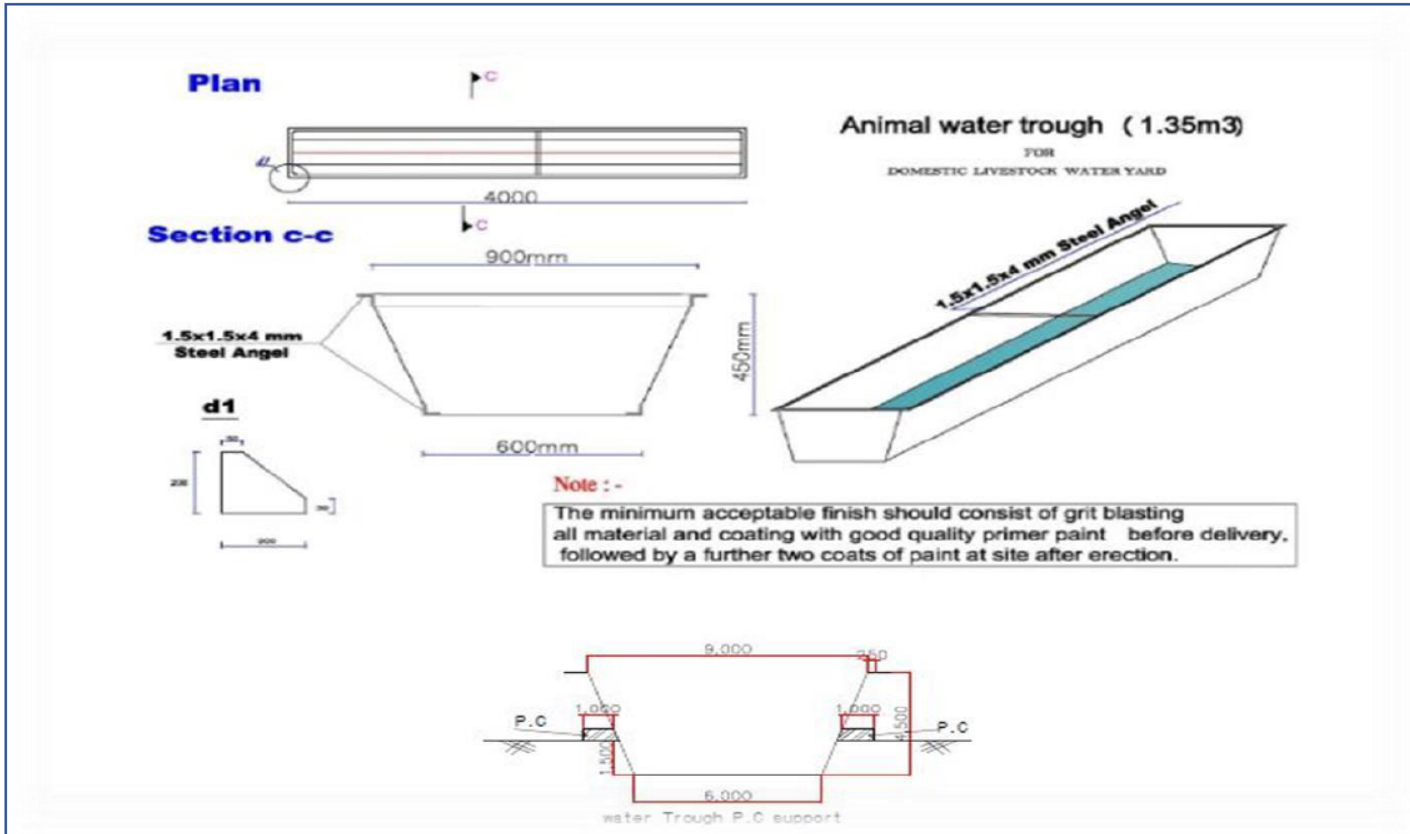
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Water yard water distribution compound – Interior walls detailed section
Project locations:	80 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

WY-5: Distribution compound – animal trough



Notes:

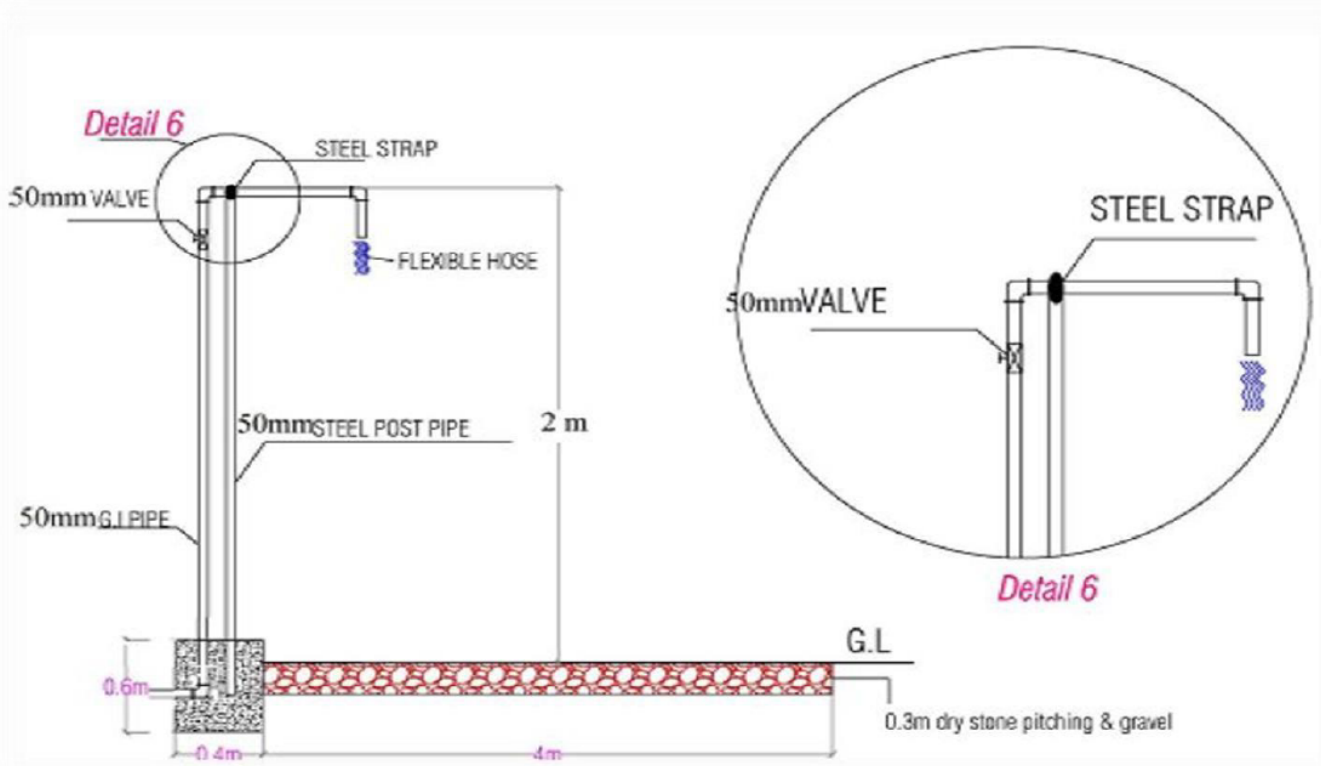
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Water yard water distribution compound – Animal water trough
Project locations:	80 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

WY-6: Distribution compound – cart filling point



Notes:

1. Mix ratio of plain concrete is 1:3:6.

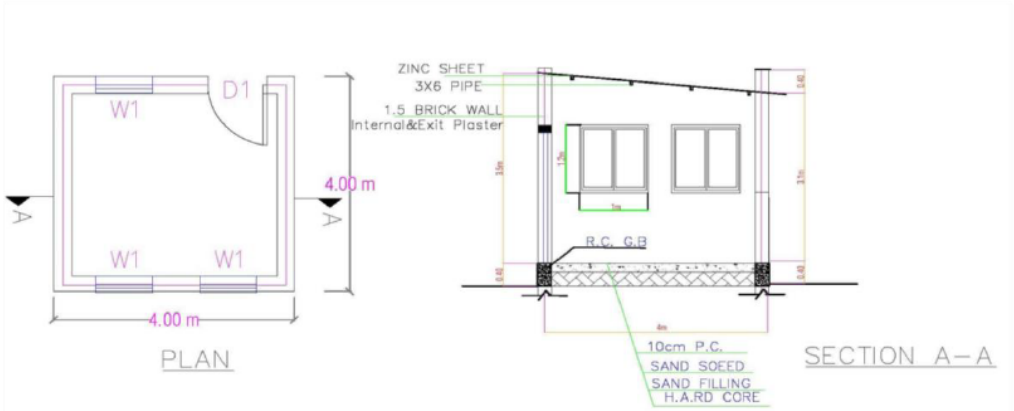
Client:
United Nations Development Program (UNDP) - Sudan

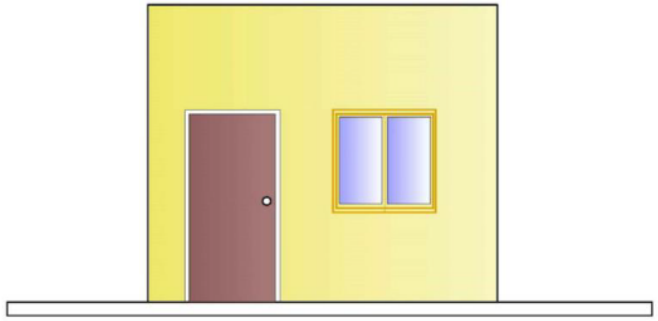
Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Water yard water distribution compound – Cart filling point
Project locations:	80 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

WY-7: Distribution compound – guard and operator room





Front Elevation

Notes:

1. All dimensions are in meter.
2. Walls are made of redbrick (1.5 B).
3. Mix ratio of plain concrete is 1:3:6.
4. Mix ratio of reinforced concrete is 1:2:4.
5. Steel shall satisfy the requirement as per grade 40 (40.000 psi).
6. Guide post spacing along the Irish bridge 2 meters c/c.
7. Clear cover from main reinforcement of bottom slab should be 50mm.
8. Clear cover from main reinforcement of top slab should be 40mm.

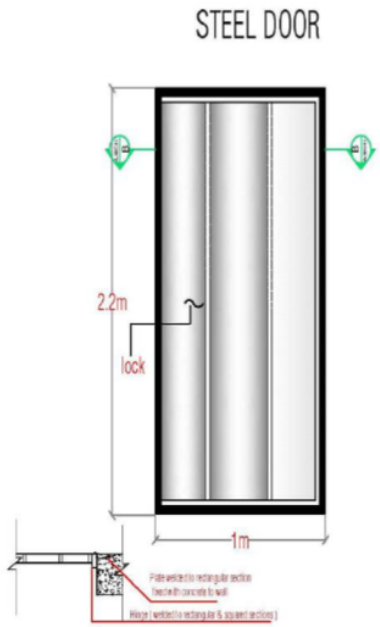
Client:
United Nations Development Program (UNDP) - Sudan

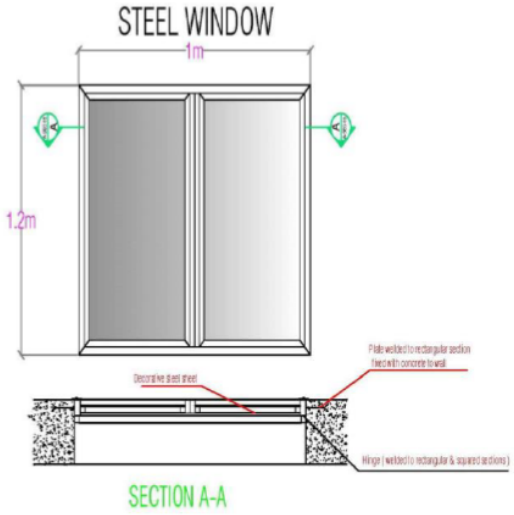
Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Water yard water distribution compound - Guard and Operation Room
Project locations:	80 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

WY-8: Distribution compound – doors and windows





Notes:

-Provide ,manufacture,assemble and fix metal steel doors and windows.
- Main frame rec steel pipe (4*8).
-left frame rec steal pipe (4*8)filled with(2*4)steel pipe complete with paint covered by steel sheets from inside.
-6mm plane glass from fon light
brass hinges
-horizontal mortise lock (turkey) with int and exit handles her doors
-sample of steel be approved by consultant engineer
- All windows are hinged double leaf from rectangular & square sections completed with decorative steel sheet, & lock colored as required.
- All doors are hinged double/ single leaf from rectangular & square sections completed with 2mm decorated front sheet, plain back sheet & lock colored as required.

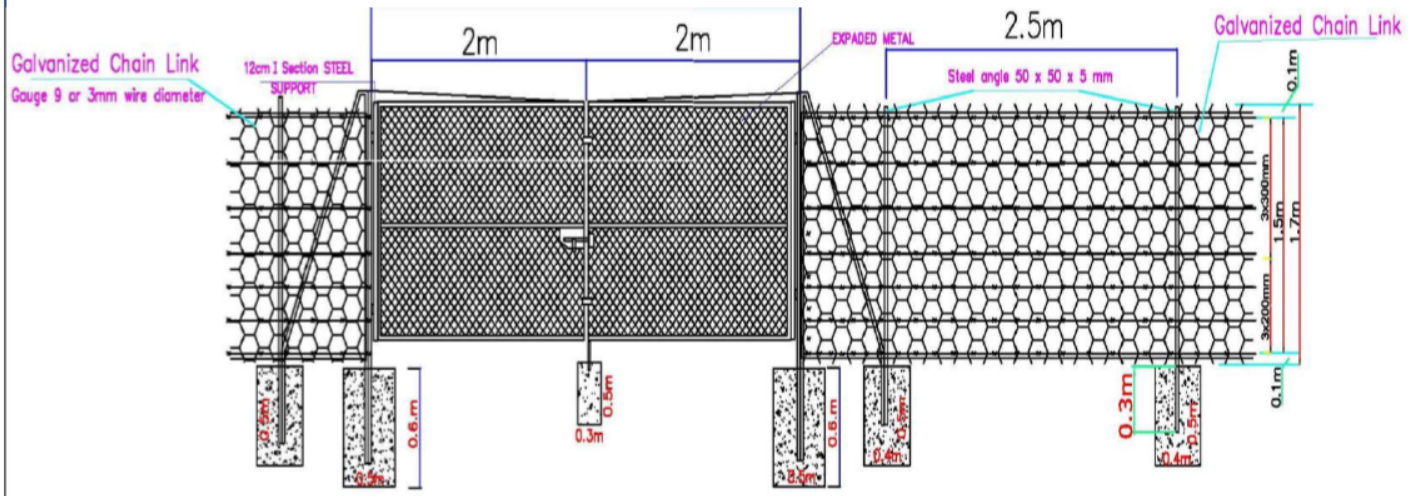
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Water yard water distribution compound - Doors and Windows General Details
Project locations:	80 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

WY-9: Distribution compound – fence



Notes:
1. Dimensions as stated

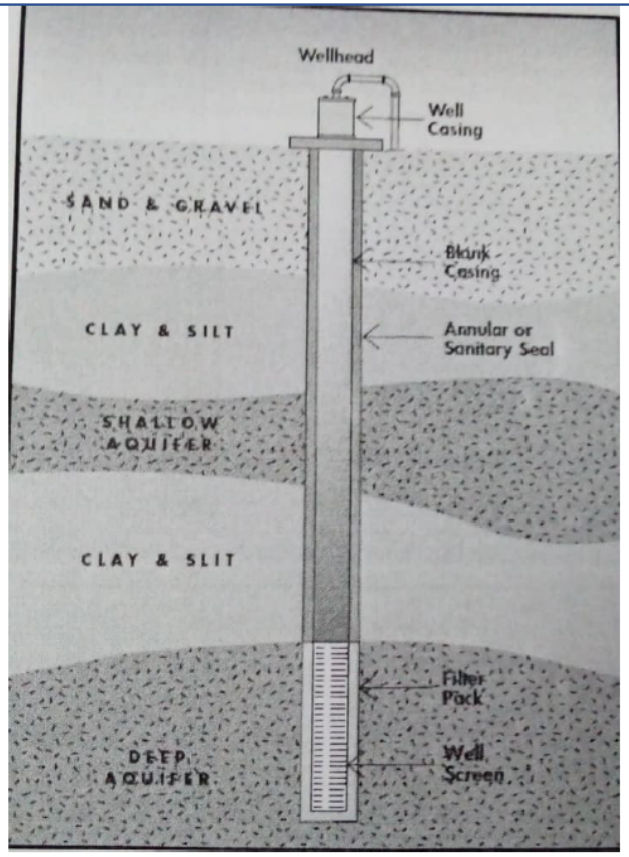
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Water yard water distribution compound – Fence details
Project locations:	75 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

WY-10: Borehole



Notes:
1. Not to scale sketch

Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Borehole illustrative section
Project locations:	30 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

SWSD-1: General description landscape

Notes:

1. A sand dam is a reinforced concrete wall built 1–5 meters high across a seasonal sand river.
2. the stream must be reasonably narrow with well defined and stable river banks and the bedrock or impermeable subsoil within a few meters of the stream bed.
3. Sand dams fill with sand over 1 – 3 seasons (maturity period).
4. 25 to 40% of the volume of the sand held is actually water.
5. A mature sand dam can store millions of liters of water–refilling after each rainfall providing a year round supply of clean water to over 1,000 people.

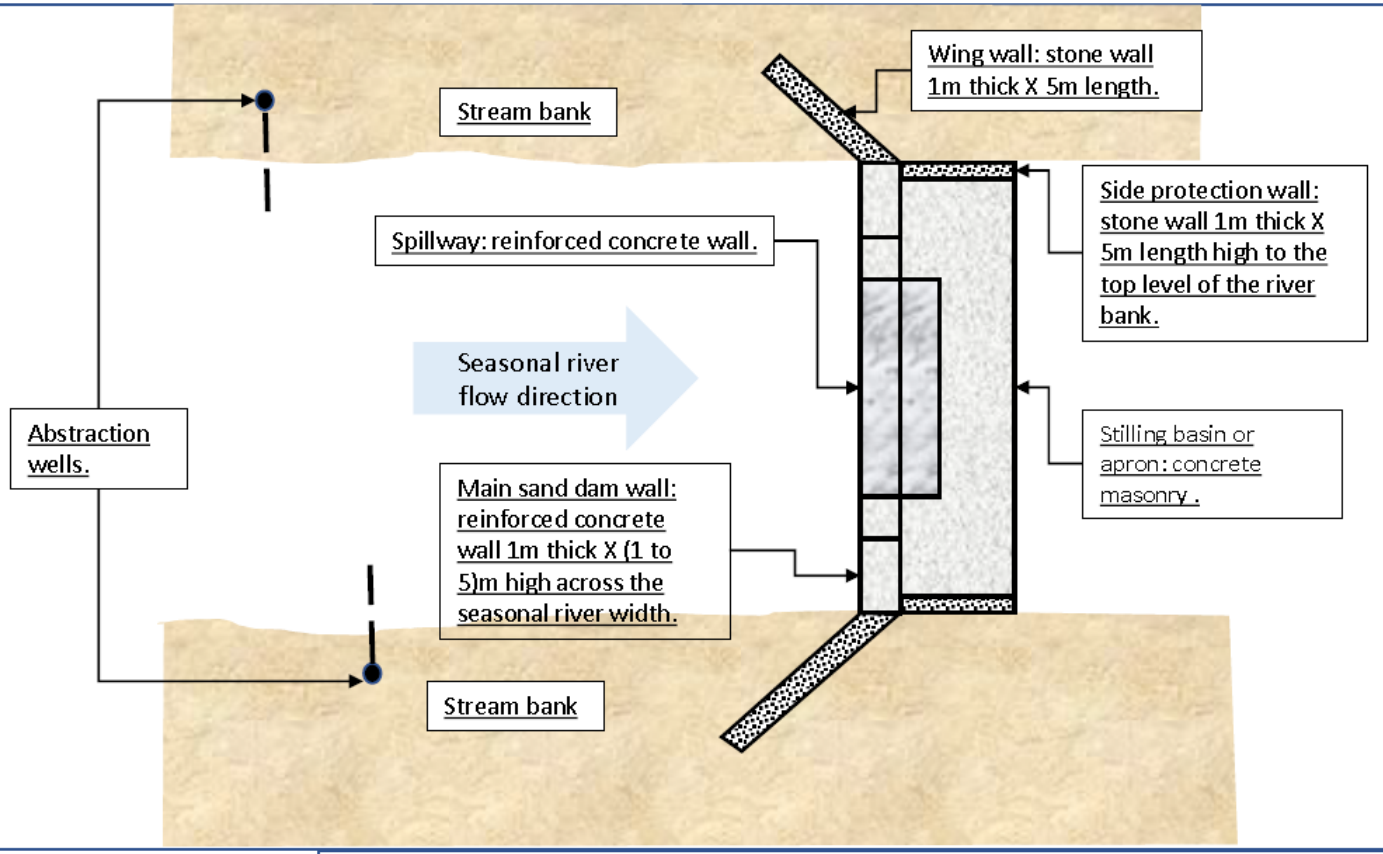
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Sand dam- **General description landscape**
Project locations:	30 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

SWSD-2: General layout



Notes:

1. All dimensions are in meter.
2. Walls are made of stones (1m thickness).
3. Mix ratio of plain concrete is 1:3:6.
4. Mix ratio of reinforced concrete is 1:2:4.
5. Steel shall satisfy the requirement as per grade 40 (40.000 psi).

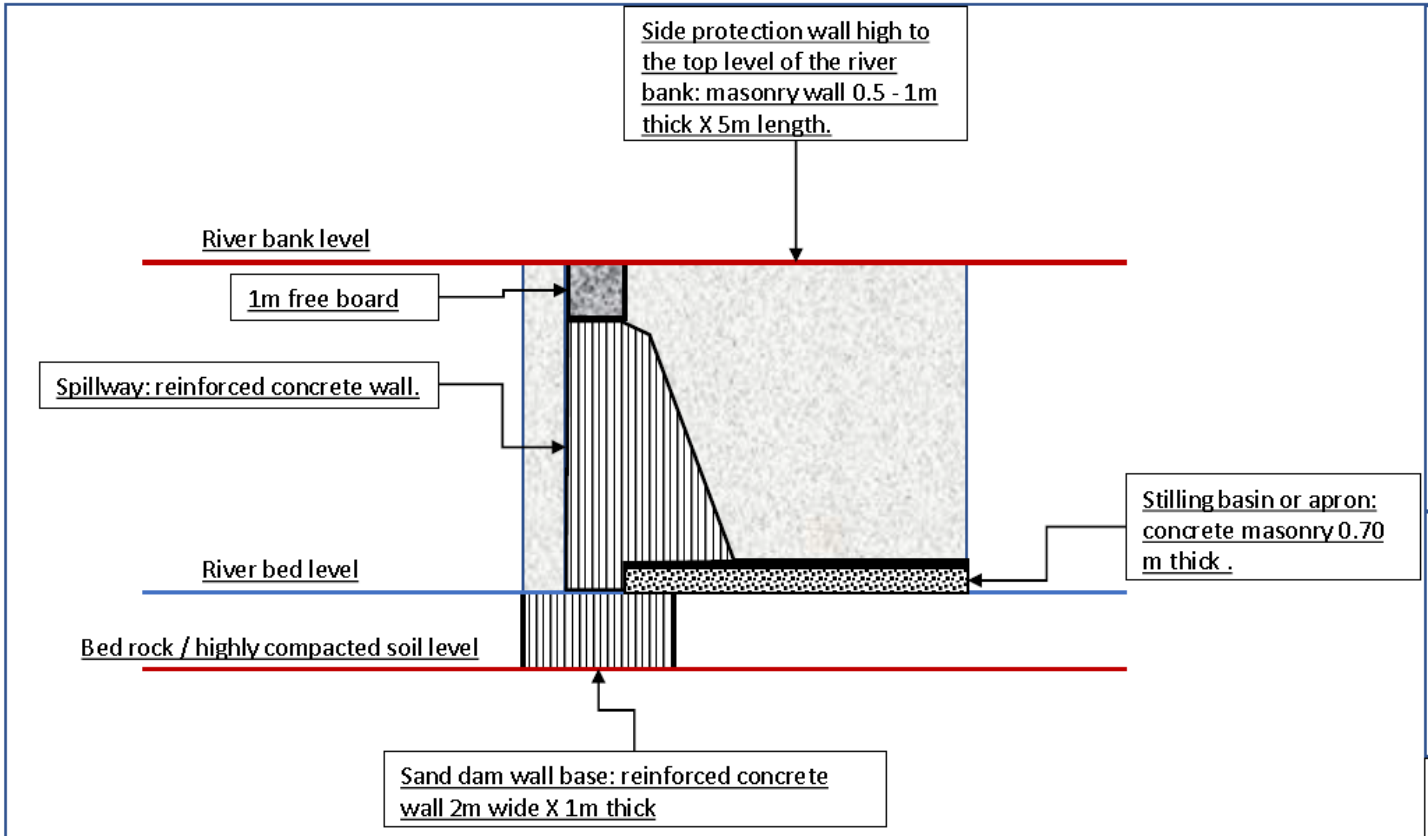
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	**Sand dam - General layout plan**
Project locations:	30 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

SWSD-3: Wall and spillway (Section A-A)



Notes:

1. All dimensions are in meter.
2. Walls are made of stones (1m thickness).
3. Mix ratio of plain concrete is 1:3:6.
4. Mix ratio of reinforced concrete is 1:2:4.
5. Steel shall satisfy the requirement as per grade 40 (40.000 psi).

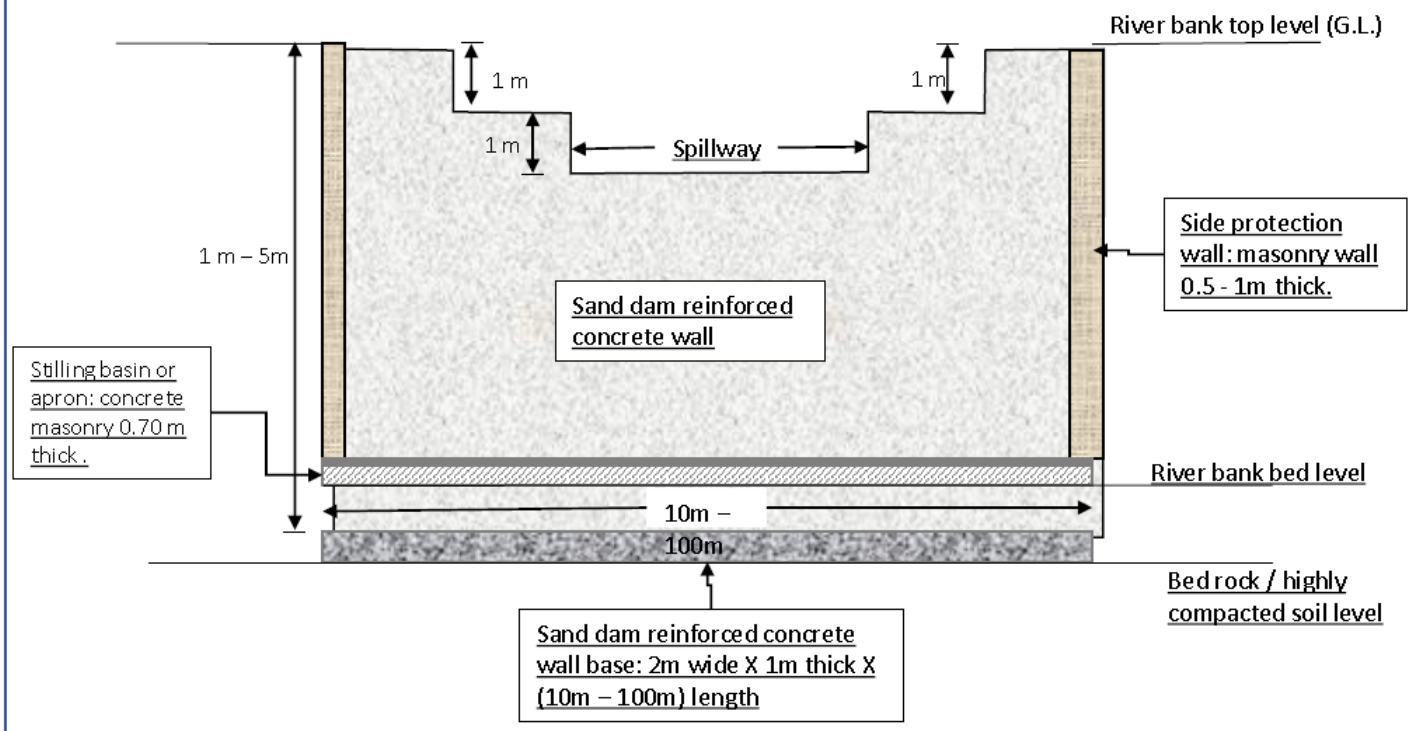
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	**Sand dam- Sand dam wall and spillway X-section A-A**
Project locations:	30 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

SWSD-4: Wall and spillway (Section B-B)



Notes:
1. .

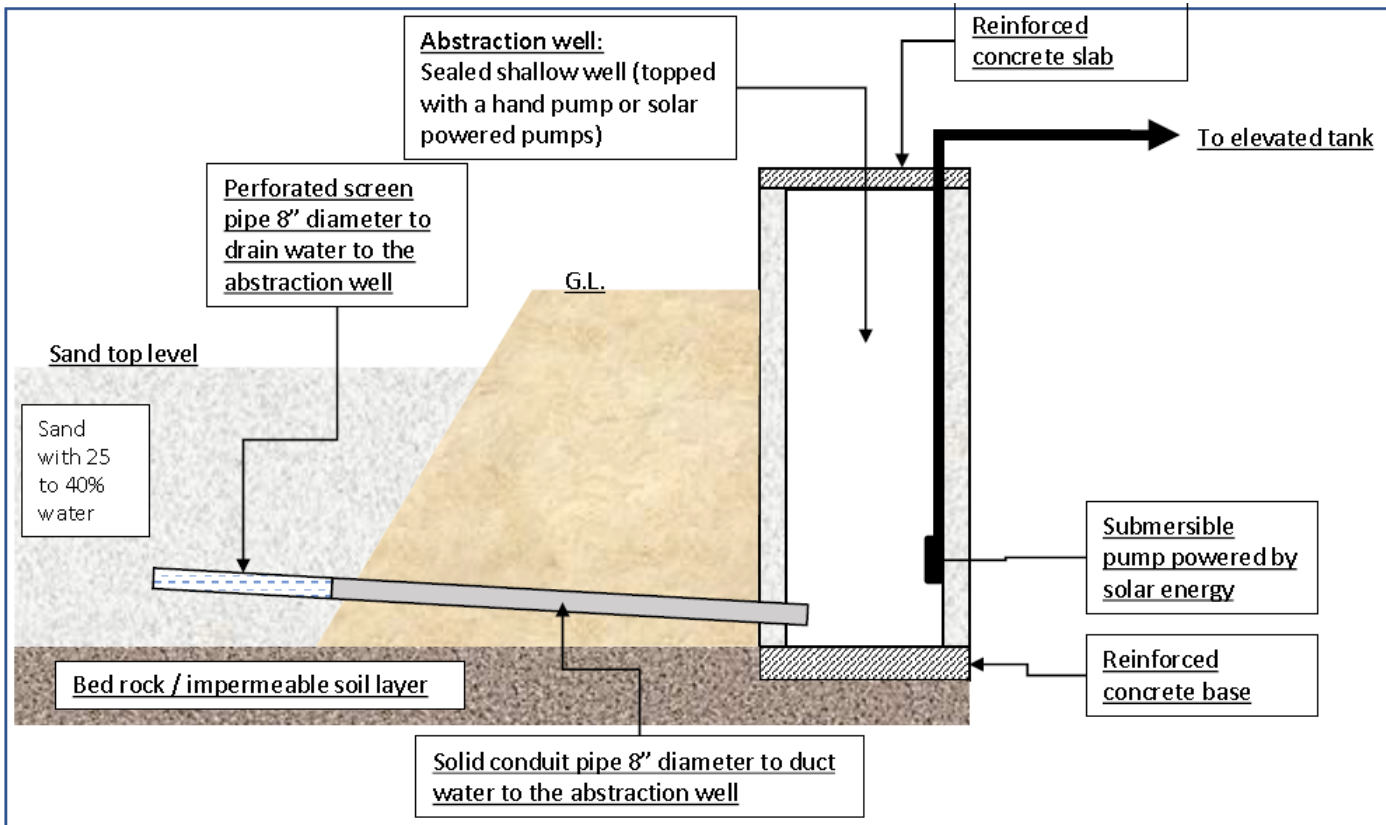
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	**Sand dam- Sand dam wall and spillway X-section B-B**
Project locations:	30 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

SWSD-5: Water abstraction arrangements



Notes:

There are two simple ways:

1. Scooping a hole in the sand. The water will naturally emerge to the surface. Scope holes used for domestic water should be protected from contamination by livestock (by fencing)
2. A slotted pipe buried in the sand that either passes through the dam wall or is connected to a simple hand pump situated on the river bank.

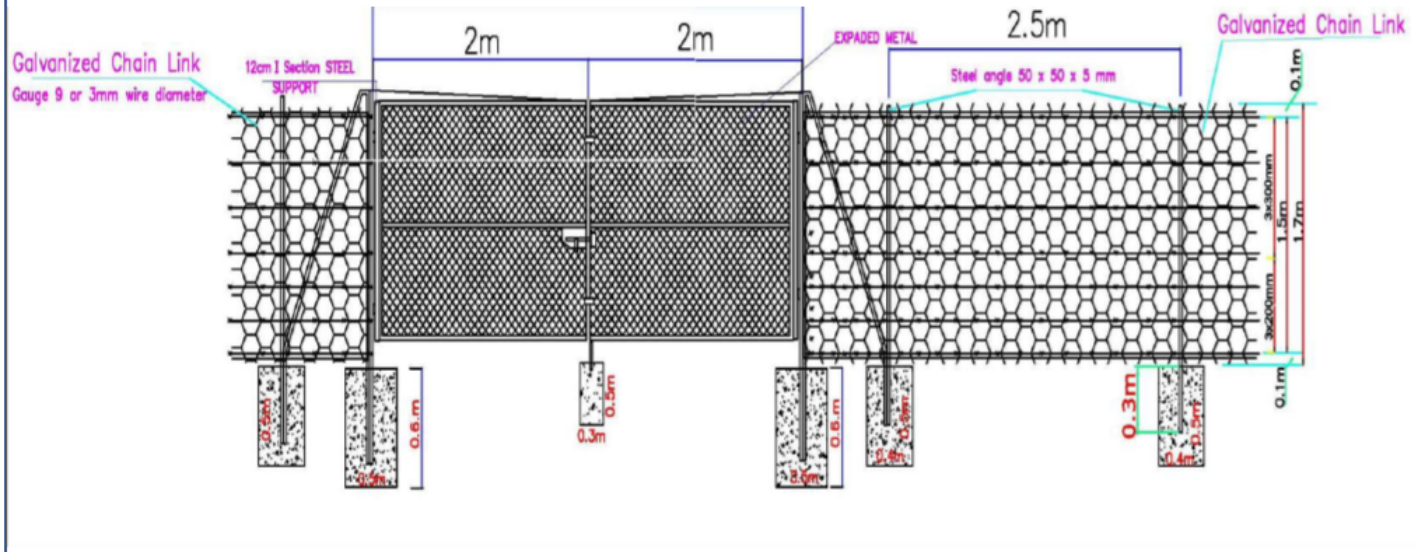
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Sand dam- **Water Abstraction arrangements**
Project locations:	30 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

SWSD-6: Protection fence details



Notes:

1. Dimensions as stated
2. The fencing is used to protect the area of water abstraction wells, water distribution compound and women groups vegetable gardens etc.

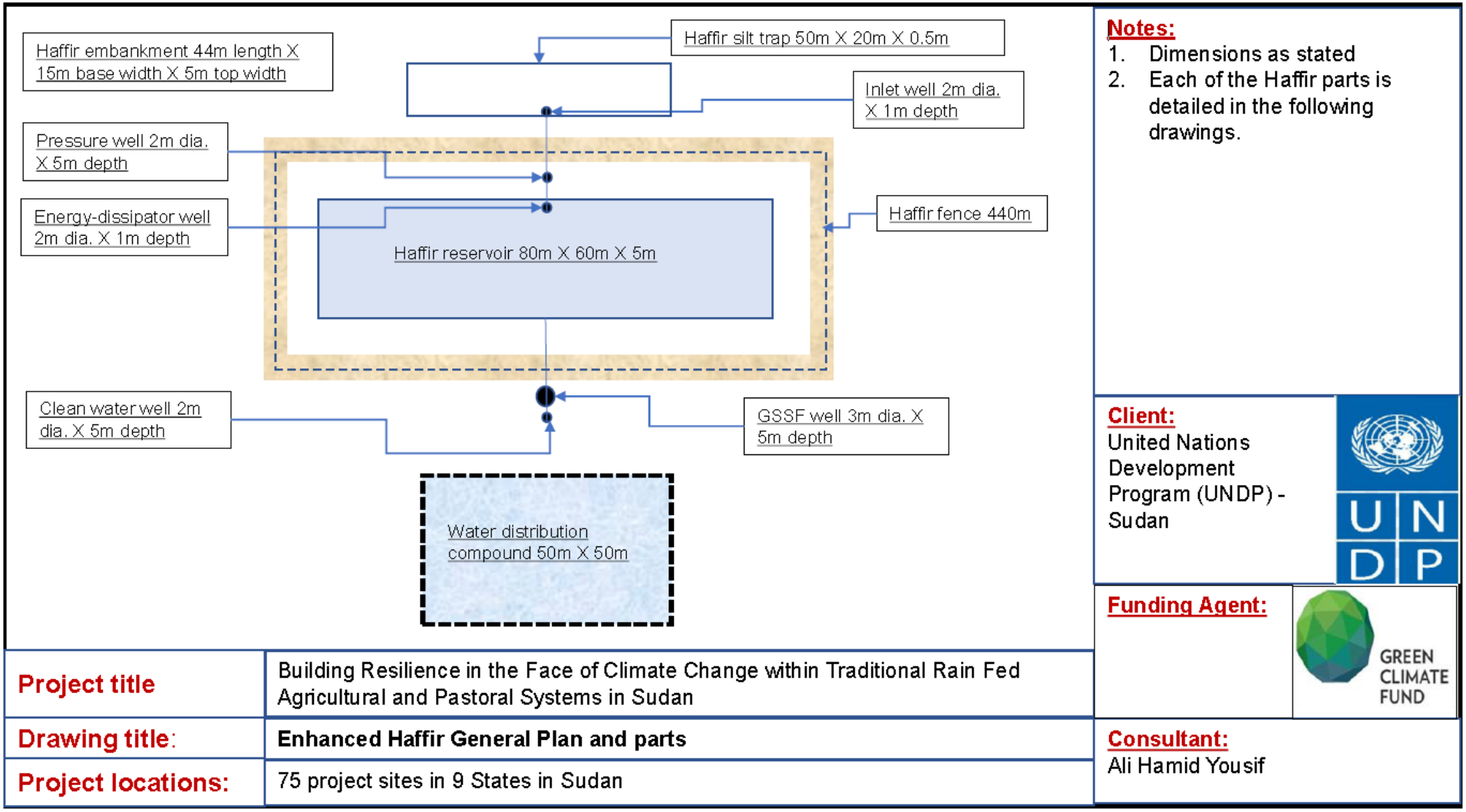
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

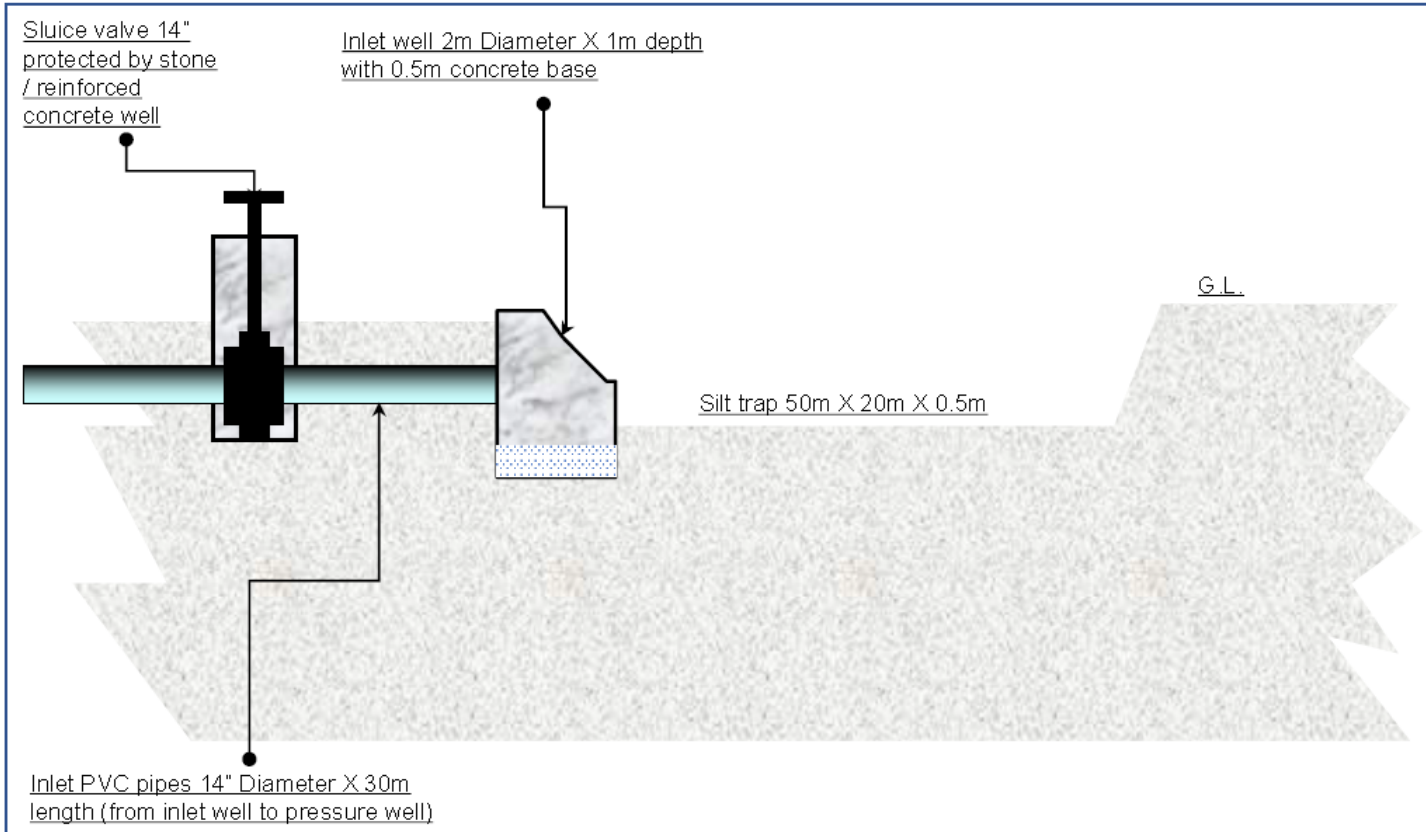
Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	**Sand dam – Protection fence details**
Project locations:	30 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

H-1: General plan



H-2: Silt trap, inlet well and control valve X-section



Notes:

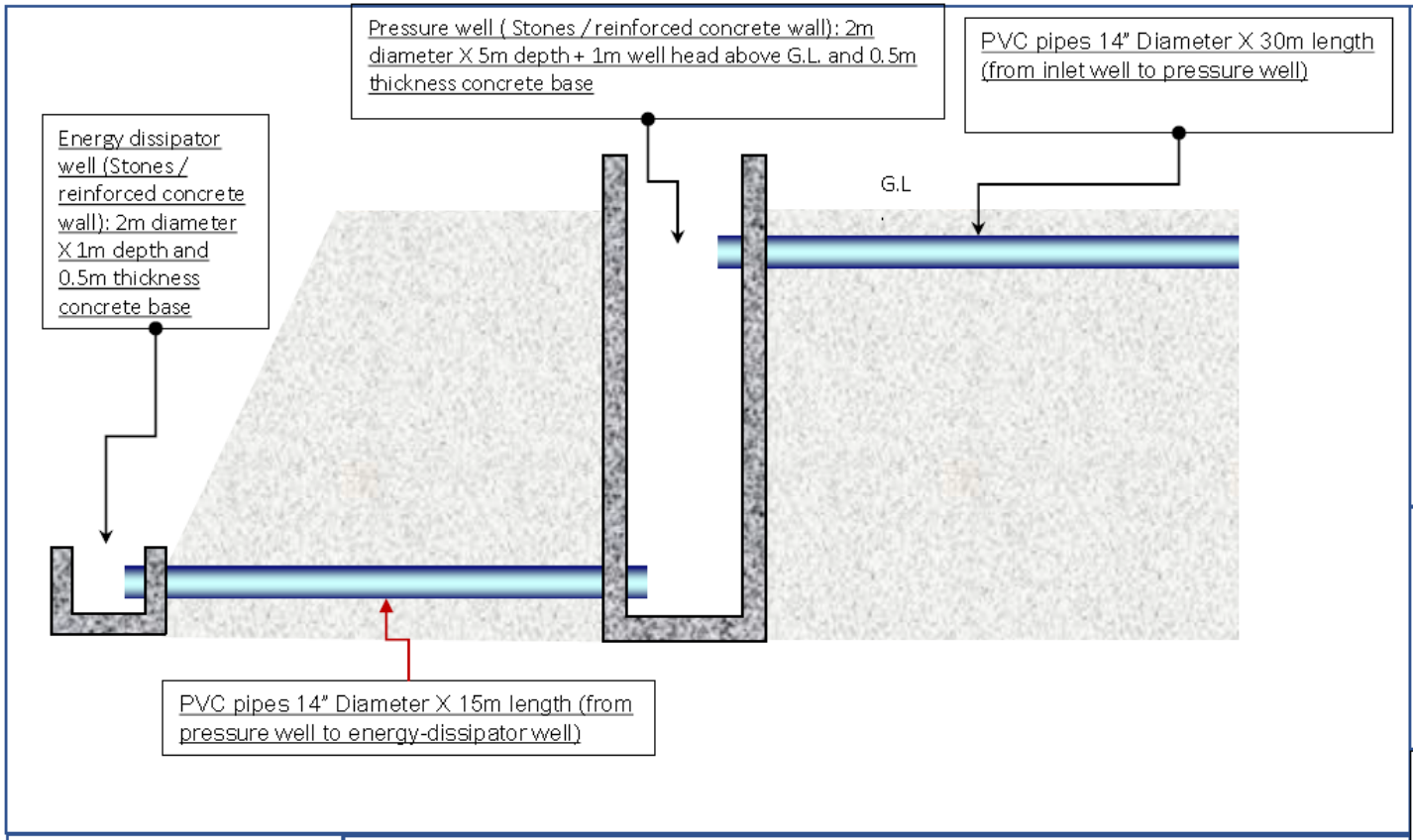
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Enhanced Haffir silt trap, inlet well and control valve X-section
Project locations:	75 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

H-3: Pressure well and energy dissipator well X-section



Notes:

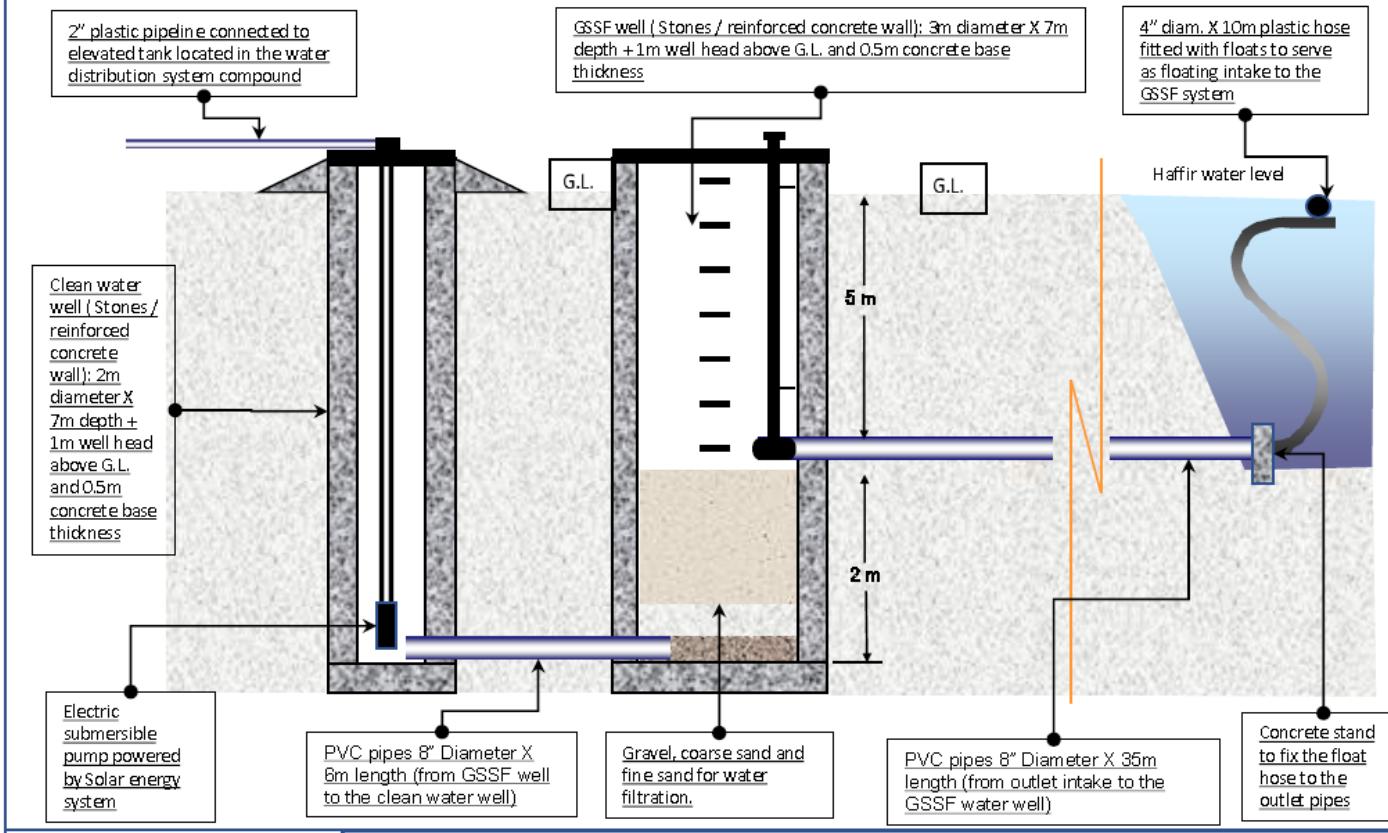
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Enhanced Haffir pressure well and energy dissipator well X-section
Project locations:	75 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

H-4: Outlet X-section



Notes:

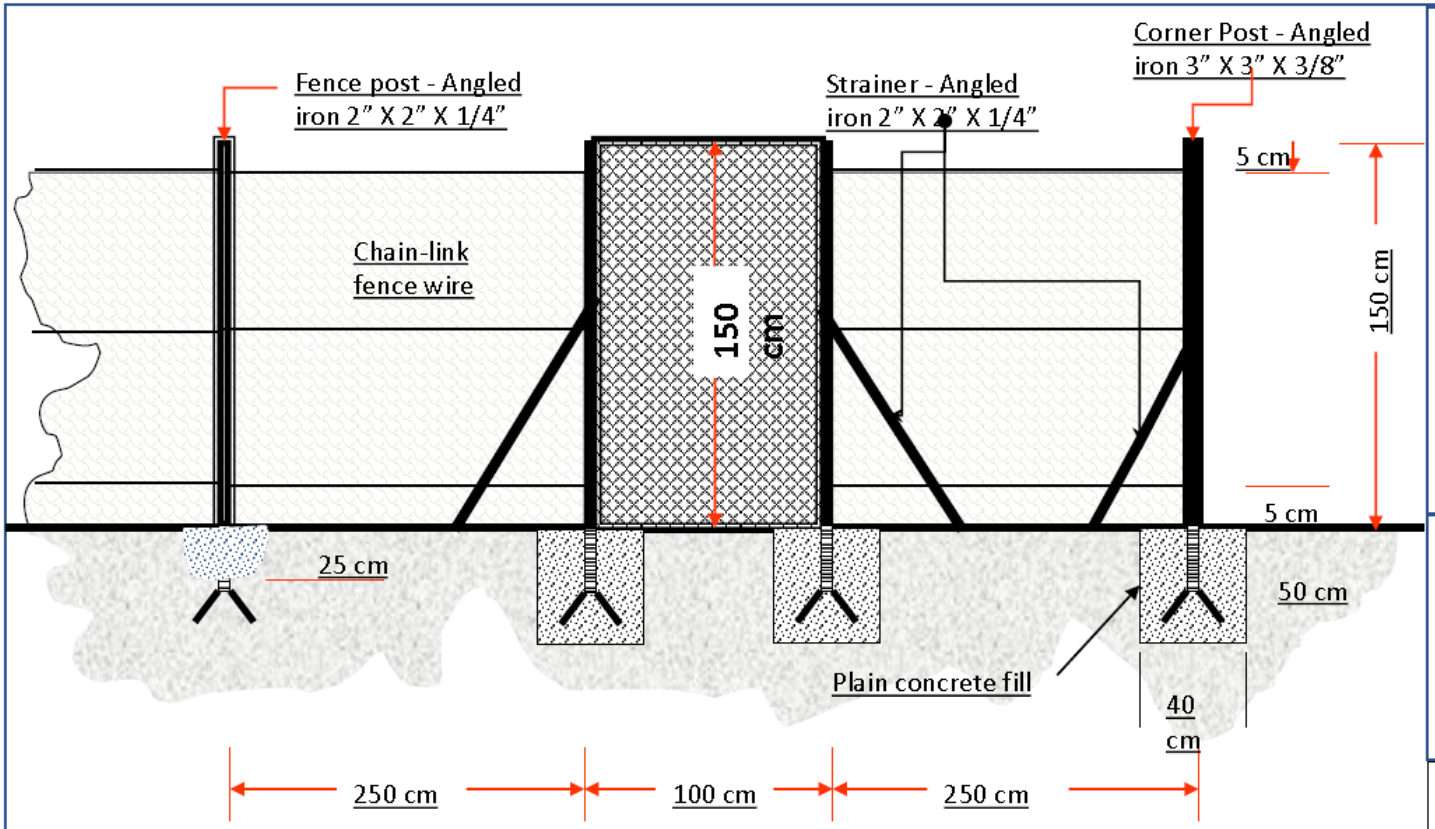
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Enhanced Haffir outlet section part (GSSF well and clean water well) X-section
Project locations:	75 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

H-5: Fence



Notes:

1. All dimensions as stated.

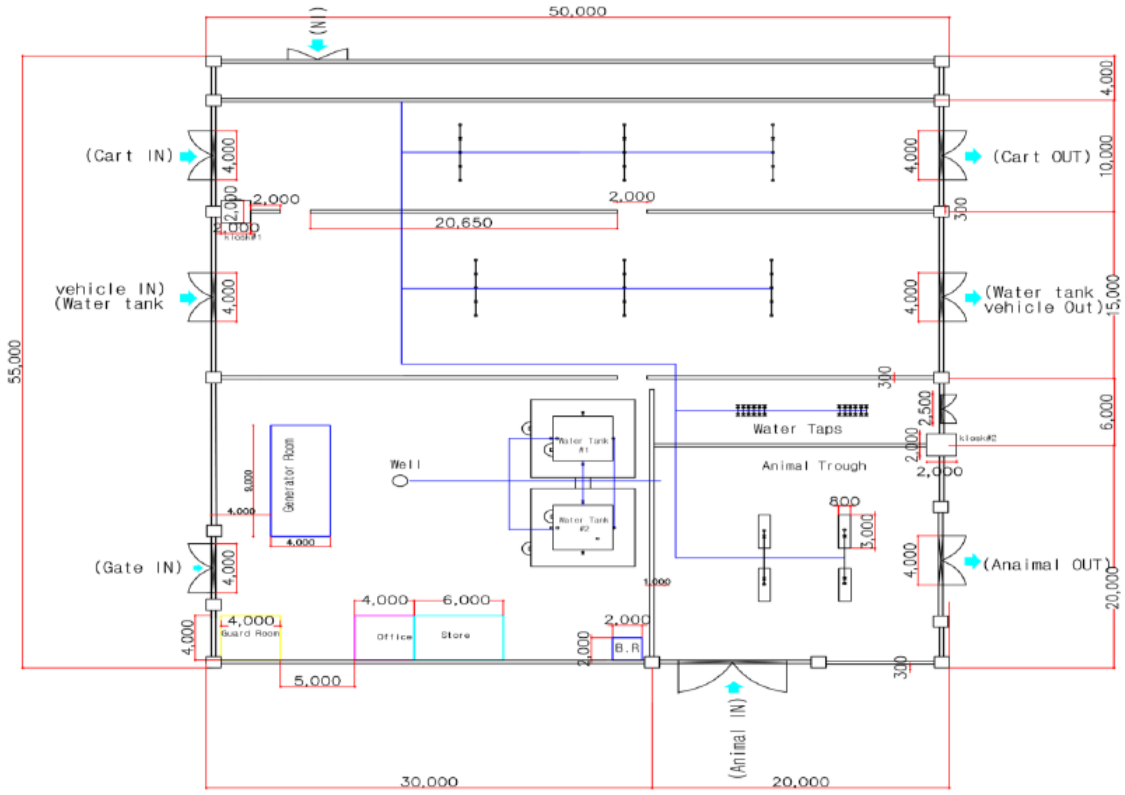
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Enhanced Haffir Fence
Project locations:	75 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

H-6: Distribution compound – general layout



Notes:

1. All dimensions are in meter.
2. Walls are made of redbrick (1.5 B).
3. Generator room could be replaced by the solar panels In case of using solar energy.
4. Double elevated tanks could be used in sites where water consumption is very high.
5. All doors are manufactured double-leaf steel doors.

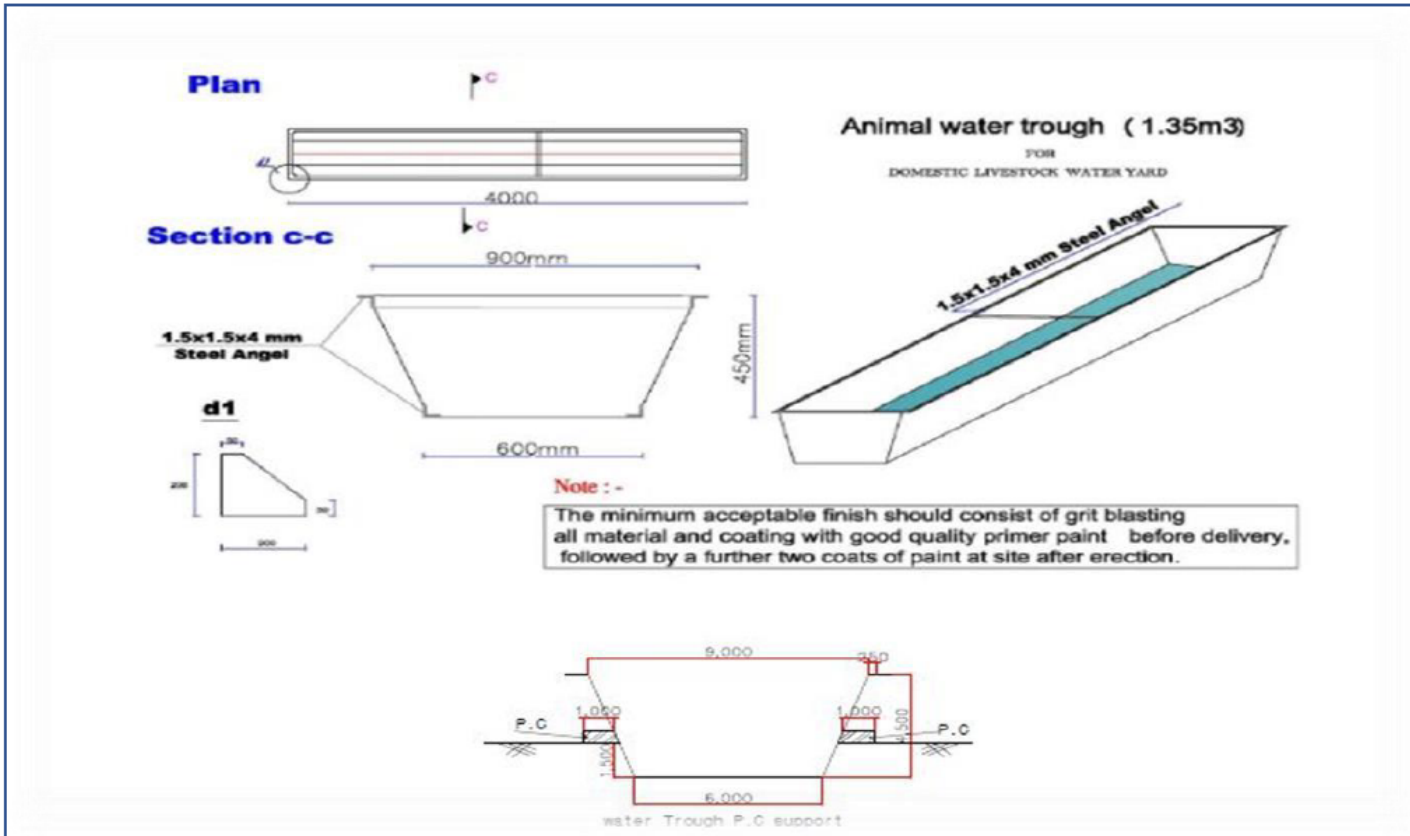
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Enhanced Haffir water distribution compound - General layout
Project locations:	75 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

H-7: Distribution compound – animal trough



Notes:

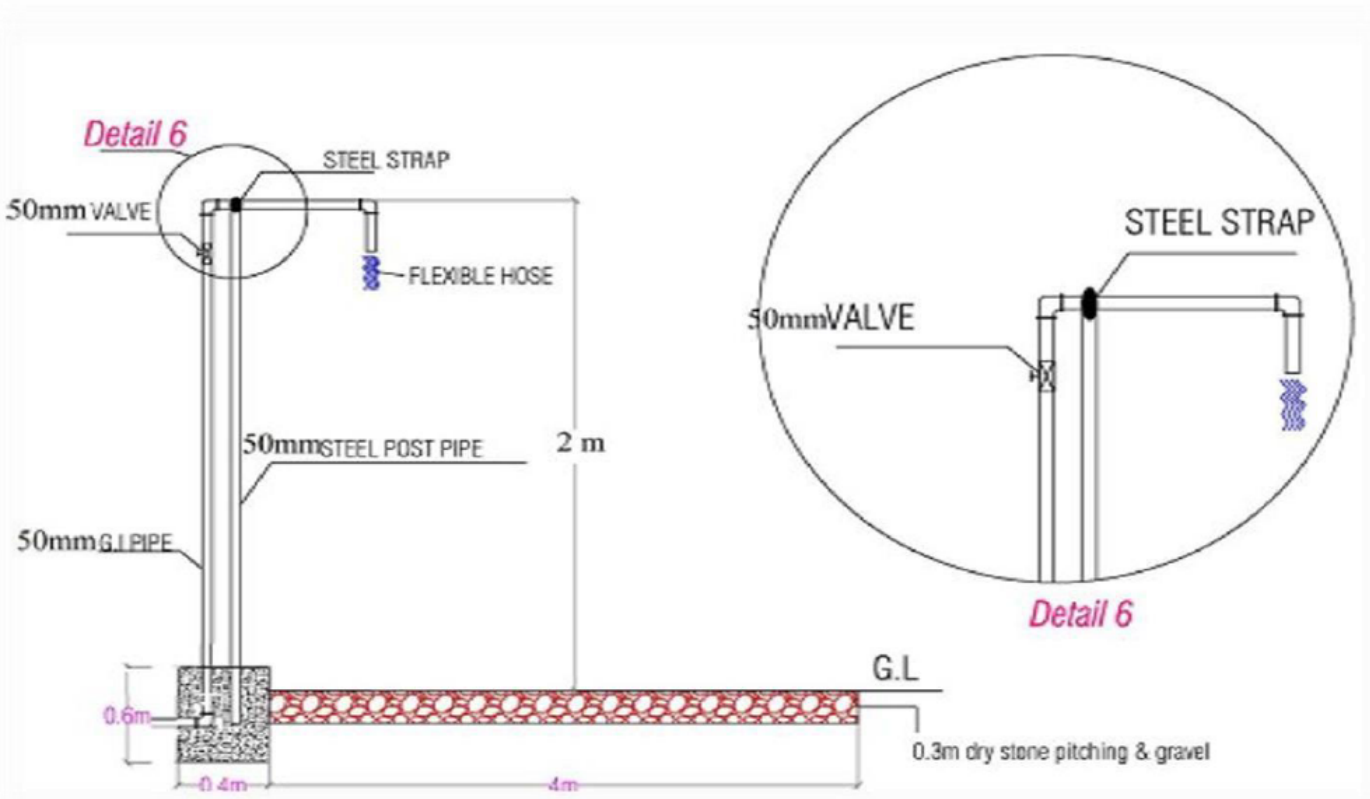
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Enhanced Haffir water distribution compound – Animal water trough
Project locations:	75 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

H-8: Distribution compound – cart filling point



Notes:

1. Mix ratio of plain concrete is 1:3:6.

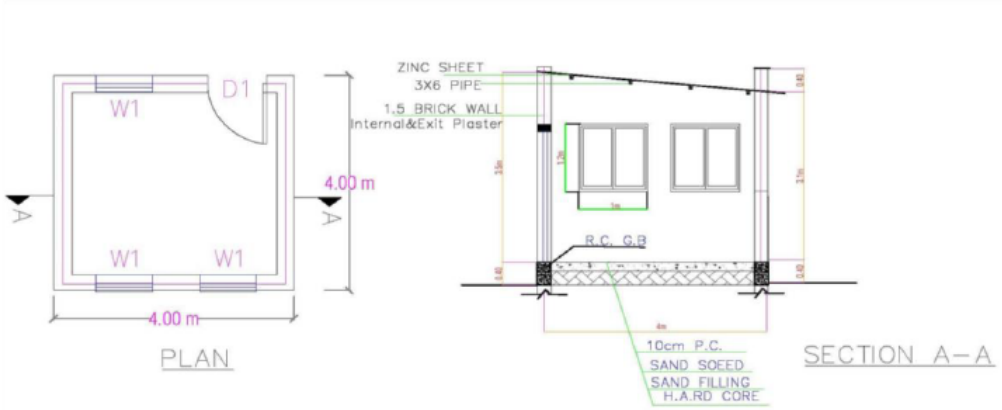
Client:
United Nations Development Program (UNDP) - Sudan

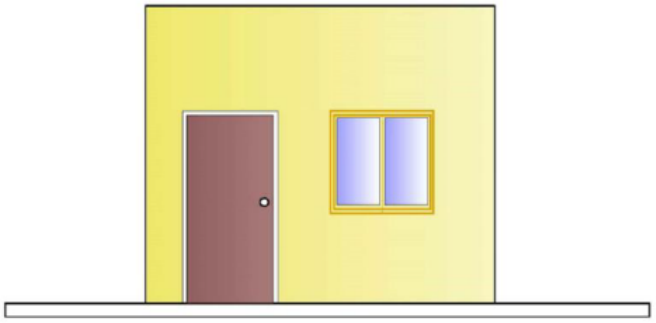
Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Enhanced Haffir water distribution compound – Cart filling point
Project locations:	75 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

H-9: Distribution compound – guard and operating room





Front Elevation

Notes:

1. All dimensions are in meter.
2. Walls are made of redbrick (1.5 B).
3. Mix ratio of plain concrete is 1:3:6.
4. Mix ratio of reinforced concrete is 1:2:4.
5. Steel shall satisfy the requirement as per grade 40 (40.000 psi).
6. Guide post spacing along the Irish bridge 2 meters c/c.
7. Clear cover from main reinforcement of bottom slab should be 50mm.
8. Clear cover from main reinforcement of top slab should be 40mm.

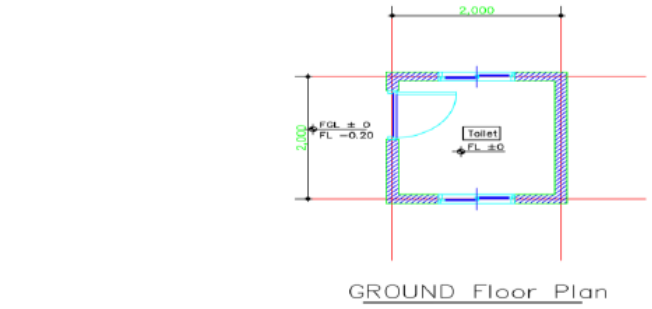
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

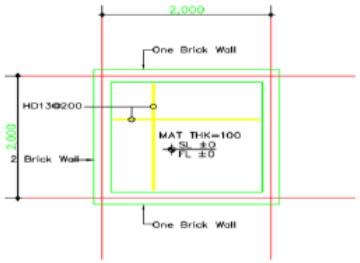
Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Enhanced Haffir water distribution compound - Guard and Operation Room
Project locations:	75 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

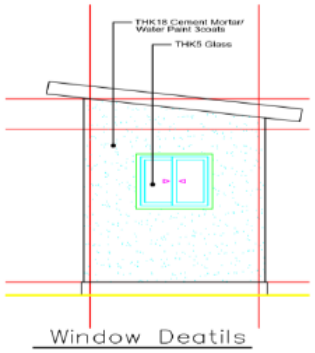
H-10: Distribution compound – WC room



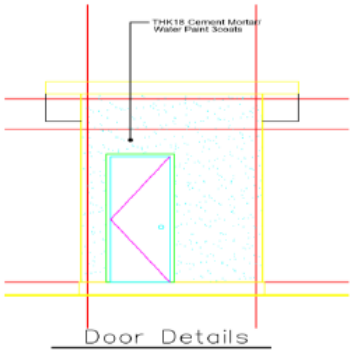
GROUND Floor Plan



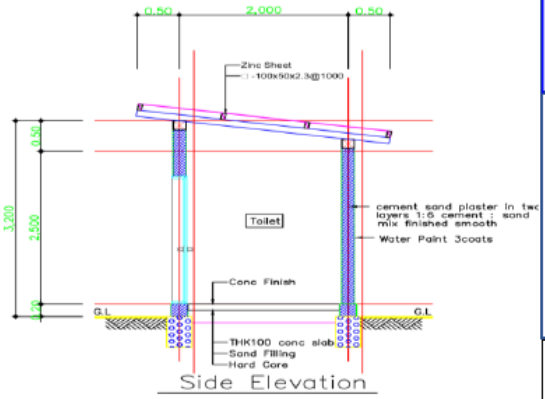
GROUND Floor Structural Plan



Window Deatils



Door Details



Side Elevation

Notes:

1. All Dimension in Millimeter
2. Walls are made of Red Bricks(1.0 B) or hollow block (min 3N/mm) wall
3. Toilet to provided with Arabic water closet and water connections
4. Drawing to be read withB.o.Q and Technical specifications
5. The Contractor should carry out detailed design for the foundation .
6. The Contractor should get the approval of the Engineer prior to Construction
7. Steel doors,manufactured door

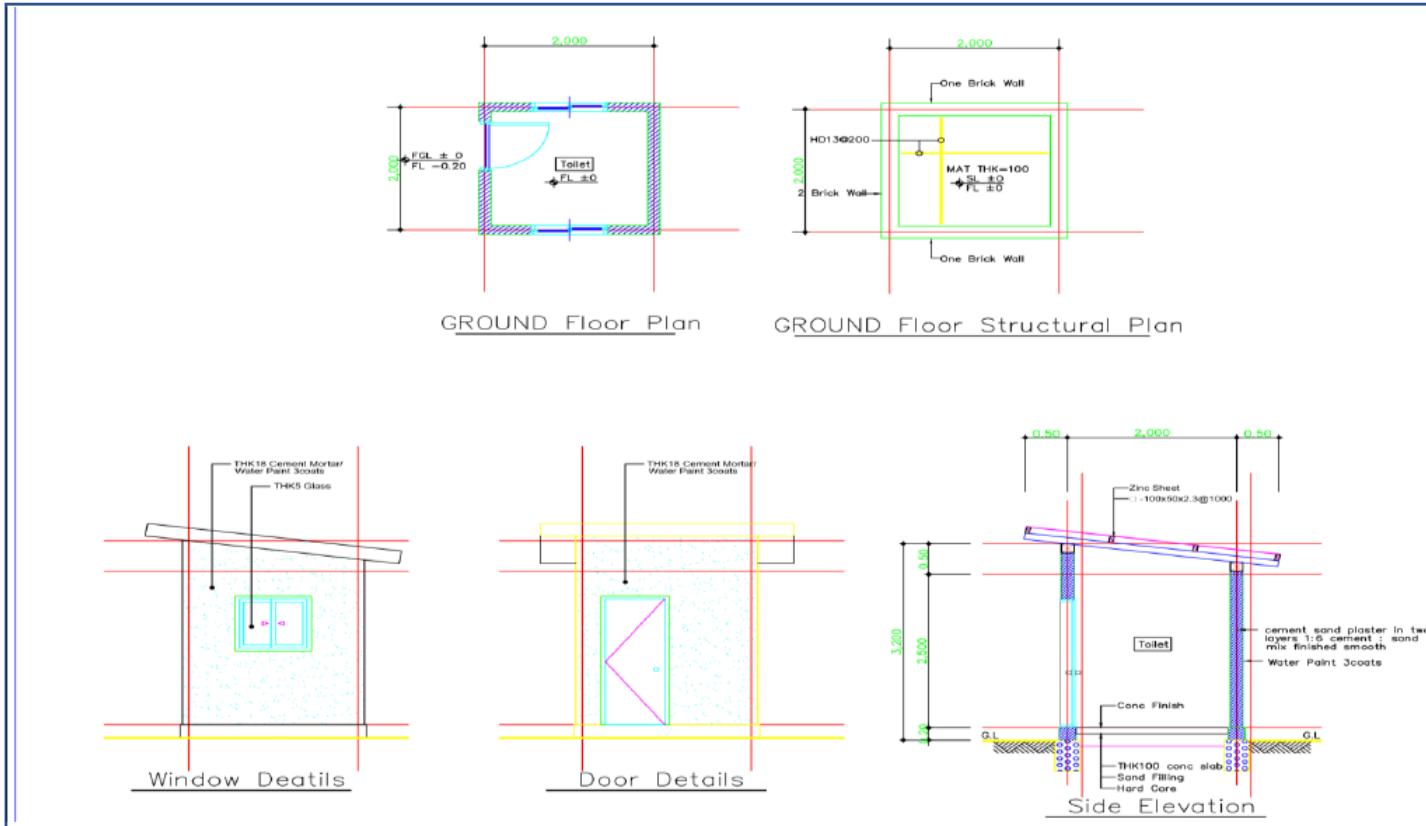
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Enhanced Haffir water distribution compound – WC room
Project locations:	75 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

H-11: Distribution compound – doors and windows



Notes:

1. All Dimension in Millimeter
2. Walls are made of Red Bricks(1.0 B) or hollow block (min 3N/mm) wall
3. Toilet to provided with Arabic water closet and water connections
4. Drawing to be read withB.o.Q and Technical specifications
5. The Contractor should carry out detailed design for the foundation .
6. The Contractor should get the approval of the Engineer prior to Construction
7. Steel doors,manufactured door

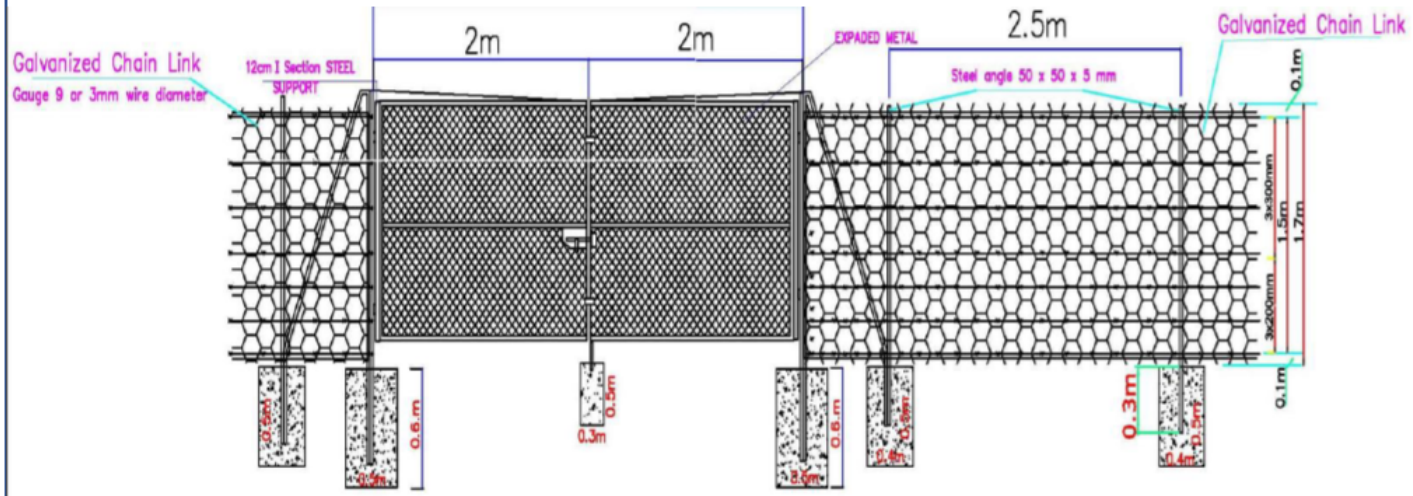
Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Enhanced Haffir water distribution compound – WC room
Project locations:	75 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif

H-12: Distribution compound – Fence



Notes:
1. Dimensions as stated

Client:
United Nations Development Program (UNDP) - Sudan

Funding Agent:
GREEN CLIMATE FUND

Project title	Building Resilience in the Face of Climate Change within Traditional Rain Fed Agricultural and Pastoral Systems in Sudan
Drawing title:	Enhanced Haffir water distribution compound – Fence details
Project locations:	75 project sites in 9 States in Sudan

Consultant:
Ali Hamid Yousif