Sudan's Nationally Determined Contributions (NDC) Project

Baselines for adaptation contributions in the water sector

1. National circumstances

Sudan is characterized by water scarcity since about 94% of the country area is located in the dry and semi-dry climates. The Nile and its tributaries constitute the main water source however, characterized by high seasonality and controversy on the legal framework for cooperation and equitable utilization of its shared resources. Moreover, the country is hardly hit by the impacts of climate change including increased incidence of extreme events (floods and droughts). Desertification further contributed to deterioration of the water systems for instance clearance of the vegetative has led to accelerated water and wind erosion (El Gamri, 2020). Beside that sand encroachment to the Nile system has potentiated riverbank erosion and build-up of sand bars with dramatic impacts and the livelihoods especially in the Northern State (NCR, 2011). Sudan is characterized by low coverage of domestic water supply and sanitation that is lagging behind population growth. SoE, (2020) revealed the fact that about 58.7% of the population has access to safe drinking water (69.4% in urban areas, 51.6% in rural areas), while access to adequate sanitation averages 39.9% (63.2% urban, 23.6% rural). It's worth mentioning that 40% of the basic schools in the country have to withstand water shortages and inadequate sanitation facilities (MWRIE, 2016). The relatively high occurrence of water borne and water based diseases is attributed to poor situation in water supply and sanitation in both urban and rural areas. Sudan developed its drinking water safety strategic framework in 2017 (MWRIE and MoH, 2017, SoE, 2020). The current policies, strategies, legislation and institutional set-up needs to critically be revised to mainstream the slogans of December Revolution (Freedom, Peace and Justice) and to grasp the new opportunities due to normalization of the relations with the international community.

1.1 Water resource of the Sudan

Rainfall:

The total rainfall of the Sudan is estimated at about $440*10^6$ m^3 per annum (SoE, 2020, Adam and Abdo 2017). Rainfall (amount and distribution) plays a significant role in the environmental and the socio-economic aspects of the country particularly pastoralism and rain fed agriculture (MOIWR, 1999; Adam, 2000).

Rainfall in Sudan can be divided into three distinct zones, namely:

i. The desert zone which is located north Lat. 17° and characterized by annual rainfall of less than 75 mm.
ii. The semi desert zone which is located between Lat. 17° Lat. 15° and characterized by annual rainfall of 75 mm to 300 mm that occurs during 2-3 months.
iii. The Low Rainfall Savannah zone which is situated between Latitudes 9° and 15° characterized by annual rainfall of 300 mm – 900 mm.

Rainfall surpasses evapotranspiration only during August, September and part of October (Adam and Abdo, 2017 and SoE, 2020).

The Nile system:

The Nile is shared by eleven countries these are namely; Burundi, DR Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, South Sudan, The Sudan, and Tanzania. The watershed of the Nile Basin occupies about 67.4% of Sudan's total area (MoI, 2011). Table 1 shows water supplies from the Nile and its tributaries. The river extends about 6,695 km from its source, the Kagera Basin in Burundi and Rwanda to the Mediterranean Sea hence, considered among the longest rivers in the world. The basin covers an area of about 3 m km^2 and host a population of about 238 distributed among the eleven riparian countries anticipating benefits from the shared resources. Fig. 1 exhibits the water courses and drainage system in Sudan (UNEP/GRID).

Table 1: Supplies from the Nile and its tributaries

River	Flow (km^3/ year)	Hydrological Characteristics
Blue Nile at Deim	49.0	The lowest daily flow was 34 m^3 /sec in May 1984. It has not gone below 100 m^3/sec after 2010 when the Tana-Beles tunnel in Ethiopia became operational.
Dinder and Rahad	3.3	The flows occur between June and November.
White Nile at Malakal	31.8	The lowest daily flow is 550 m^3 /sec and the highest is 1,200 m^3 /sec.
Setit and Atbara at the borders	12.9	The river used to dry up from January to May. After 2010, the minimum flow has been around 80 m^3 /sec after the operation of Tekezi Dam in Ethiopia.
Nile (Total)	97.0	The average annual flow at Sudan borders (when the Nile and its tributaries enter Sudan) is 97 km^3. The annual evaporation and transmission loss is 13.2 per cent, and as a consequence 84.2 km^3 reaches Aswan.

Source: SoE, (2020)

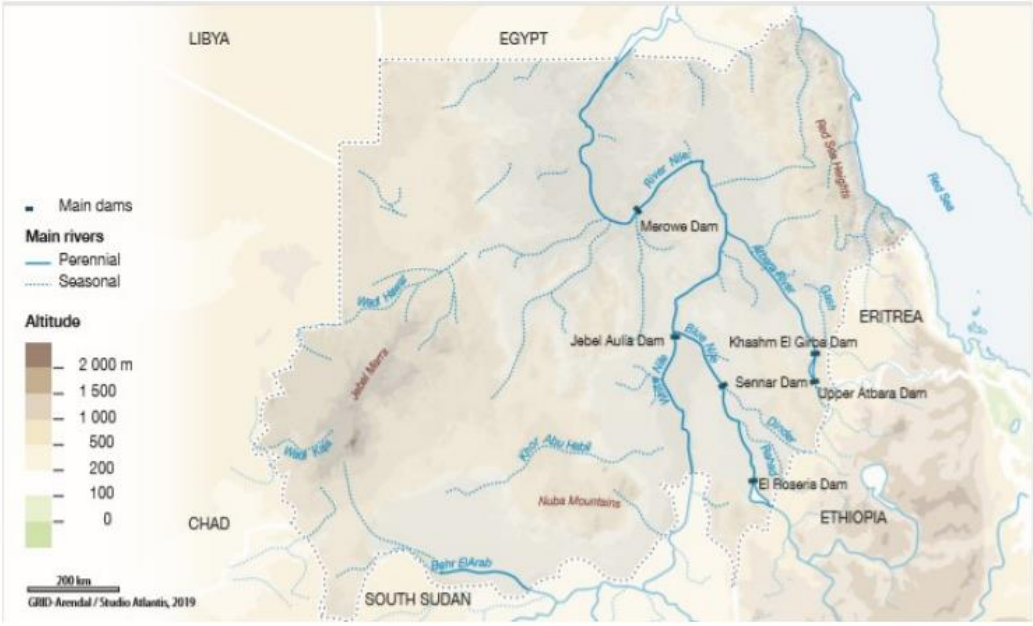

Fig. 1: Water courses and drainage systems in Sudan (UNEP/GRID)
Source: SoE, (2020)

Wadi Waters:

There are numerous seasonal streams locally known as Wadis and Khors. They flow with high irregular, but short duration flows. The collective total runoff of all the Wadis in the country is estimated at 5.5 km³/ per annum with high seasonal variability (Adam and Abdo 2017, SoE, 2020). Gash and Baraka which, originate from Eritrea are the main wadis in the country, each with a total annual average discharge fluctuating between 200 and 800 mcm. Wadi Azum and Wadi Hawar constitute the main Wadis in western Sudan, with estimated total annual discharges of 500 to 750 mcm, respectively. Over 300 small local Wadis distributed in the Red Sea region and the Savannah Belt with sporadic discharges mainly during August, lasting for few days or hours. Such discharges, partly recharge the alluvial deposits, and partly evaporate. The greatest part of small wadis are not equipped with flow monitoring devices. The situation is becoming even worse after the Decentralization Act of 1994 due to shortage of funds and lack of clear mandates of the federal and state institutions'.

Groundwater:

Due to the complexity and cost of groundwater investigations, previous studies have been preliminary and concentrated on specific locations hence, related data are imprecise. The bulk of groundwater in Sudan is fossilized with limited recharge therefore; its utilization should be taken with great care. According to (Adam and Abdo, 2017) renewable groundwater is estimated at about 2 bcm. The major groundwater aquifers include Nubian Sandstones, Umm Rwuaba Formation and alluvial deposits. Despite the impermeability of Basement Complex Formations, they may also contain groundwater in fractured or weathered zones.

Groundwater head ranges between 3 m to 20 m for the alluvial formations and from 10 to 200 m for the other formations. The seasonal variation of water level varies

between 1 m to 5 m for the alluvial formations. Since dissolved solids range from 100 to 800 ppm in Nubian Formations and alluvial deposits hence it could be concluded that the quality of groundwater is largely good in these formations. The range is between 100 to 5000 ppm for Umm Ruwaba Formation. The majority of the existing deep wells in the Nubian and Umm Ruwaba Formations showed high yields (10,000 and 20,000 gallons/ hour). Table 2 shows Sudan's groundwater storage, recharge and abstraction.

Table 2: Groundwater storage, recharge and abstraction in Sudan (millions m^3)

Major Aquifer	Groundwater storage	Annual recharge	Annual abstraction
Nubian sandstone basins	503,000	1,000	700
Um Rawaba/ Gezira basins	60,000	600	150
Alluvial	1,000	375	160
Total	564,000	1,975	1,010

Source: SoE, (2020)

Unconventional Water Sources:

The quantity of this type of water which is generated from the desalination of seawater or treated wastewater is still very limited and at an early stage. The country has five desalination plants with a total capacity of 0.02 million m^3 per day (Farah 2010). In Khartoum, water from sewage treatment plants is used to irrigate crops and trees on the peripheries of the city (Adam and Abdo, 2017). The future potential for such waters is great in the country.

Current water use and future demand:

It's estimated that the total annual surface water that Sudan can utilize is about 26 km^3. This includes the country's share from the Nile waters 20.5 km^3 (measured in the centre of Sudan), as stipulated in the 1959 Nile Water Agreement. In addition to that the flow from seasonal streams outside the Nile watershed amounts to 5.5 km^3 (Adam and Abdo, 2017, SoE 2020). Sudan's abstraction from the Nile system ranges between 12.1 km^3 and 14.3 km^3 as measured at Aswan depending on rainfall variability and its impacts on irrigation demands. Meanwhile, about 1.2 bcm is drawn from ground water and 2.5 bcm from seasonal streams. Abdalla, (2001) revealed the facts that demands for the Nile waters are anticipated to reach about 33.6 km^3 by the year 2027.

Domestic and industrial use

According to FAO, (2015) the municipal domestic sector consumes about 3.5% of the total water used in Sudan. Meanwhile, industry including oil production, sugar manufacturing, food processing and construction among others accounts for 0.3% (FAO 2015).

1.2 Development:

The major developments include the following:

- The victorious December 19 Revolution culminated in the constitution of a transitional civilian-led government and normalization of ties with the international community.

- Peace achievement especially in the region of Darfur.
- Initiation of various policies, strategies and programs at the international, regional and the national levels.
- Construction of the Ethiopian Grand Renaissance Dam (GERD).
- Relatively wide adoption of modern irrigation systems including drip irrigation and centre pivot sprinkler systems.
- Relative expansion in the use of green houses and environmentally controlled animal houses.

1.3 Challenges

According (SoE, 2020) the major challenges facing Sudan's water resources management include the following:

- Climate change.
- The general aridity of the country since about (94%) of its territory is located in the arid climates (hyper arid, arid and semi-arid).
- High seasonality of rain fall and surface water resources including the Nile system,
    - Rainfall: the country is characterized by very high rainfall variability specially in the northern parts
    - According to HCENR, (2013) about 75% of the annual flow of the Nile occurs during July to October.
- The high population growth rate and wide spread poverty that exaggerates pressures on the natural resources together with water resources.
- Overlapping of roles and responsibilities and inadequate cross-sectoral co-ordination
- Management of natural disasters:
    - Floods (river floods and flash floods).
    - Drought and desertification.
    - Watershed degradation, riverbank erosion and high sediment load.
- Weak institutional capacity, inadequate finance and use of obsolete technology
- Poor enforcement of laws and regulations,
- Inadequate regional cooperation.

According to SoE, (2020) groundwater management in the country is facing the following challenges:

- Poor, unreliable and limited information and lack of monitoring systems;
- Lack of comprehensive plans for development and utilization of groundwater
- Weak and fragmented legislations and low institutional capacity.
- Low public awareness on water issues viz. the economic value of groundwater and its vulnerability to depletion and contamination. Beside that the public opinion still view Sudan as a water rich country;
- The approach of conjugative use of surface and groundwater is almost absent despite the concurrent presence of both resources in many locations;
- High cost of abstraction by conventional diesel pumps particularly for deep aquifers, (use of renewable energy is still limited).

1.4 Opportunities

Post Revolution environment:

The uprising (December Revolution) and ouster of Muslim Brotherhood from power

created a new environment of transparency, accountability, normalization of relations with the international community (removal from the list of states sponsor terrorism and lifting of US sanctions), economic revival and willingness of international community to support the democratic transition in the country. Such developments will also encourage domestic and foreign investments.

Regional Cooperation:

Realizing the fact that boundaries for a river basin create a natural unit for water resources management Cap-Net, (2008) advocated for the adoption of integrated watershed management and establishment of river basin organizations (RBOs'). Nevertheless, the legal framework for Nile Cooperation is yet to be approved.

Recognizing the significance of basin (regional) cooperation NBI (2012) suggested the following basin-wide adaptation measures:

- Coordinated reservoir operation.
- Promotion of basin-wide agricultural trade and with other regions.
- Power and transport interconnection.
- Establishment of a joint mechanism for resource solicitation.
- Joint research.

Furthermore, the Nile Decision Support System (Nile DSS) will enable the riparian countries to evaluate trade-offs and consequences for basin developments (NBI, 2012). Regional cooperation should consider shared aquifers as well e.g. the Nubian Sandstone Aquifer which is shared by Sudan, Chad, Libya and Egypt.

Sustainable Development Goals (SDGs):

Out of the 17 SDGs 14 goals are related to water, sanitation and hygiene. Sudan's Water, Sanitation and Hygiene (WASH) Policy 2018, stresses the country commitment to achieving these goals by 2030. The policy, adhere to the globally accepted principles of decentralization, women empowerment, community participation and sustainability in the face of climate change. It has been crafted with a view of improving the living conditions and health of the people of Sudan and accelerating economic growth.

Green Climate Fund (GCF):

At COP 16 in Cancun in 2010, governments established a Green Climate Fund as an operating entity of the financial mechanism of the Convention under Article 11. The GCF will support projects, programmes, policies and other activities in developing country Parties. The Fund will be governed by the GCF Board.

Policy and legislation Reform:

- Involvement of water sector in the anticipated process to formulate the Sudan's Permanent Constitution is strongly advocated to eliminate Constitutional disparities regarding water resources management.
- Create mechanisms/ institutions to ensure data sharing at the inter-institutional (national) and regional levels.
- The overlap in water laws is to be resolved.
- Expedite development of the national IWRM strategy.
- Activation of the water laws e.g. Law of the Sudan Meteorological Authority especially the Provision that mandate the Authority the responsibility for the

specifications, installation and supervision of met stations and accessibility to data.

Other opportunities may include the following:

- Adoption of IWRM to ensure sustainability and equity while conserving the environment.
- Adoption of ecosystem-based approach for inland and marine water resources management.
- Upgrade of national technical capacity for home grown technologies and support the local manufacturing of water equipment.
- Greater emphasis is to be put on problem solving research, establishment of a national Research Fund and development a research master plan.
- Awareness raising and media engagement.
- Documentation and dissemination of success stories.
- Integration of sustainable development policies.

1.5 Institutional arrangements and legal frameworks

The Ministry of Water Resources, Irrigation and Electricity is the main water resources management institution in Sudan. The ministry is mandated to develop the national water resources policies, develops and monitors water resources projects, and enhances water management including irrigation and drainage. The National Council for Water Resources (NCWR) with its executive body viz. the Water Resources Technical Organ (WRTO) was established in 1995 as a result of the Water Resources Act of 1995. Beside that the Ministry of Agriculture and the Higher Council for Environment and Natural Resources are also involved in water resources management at the federal level (SoE, 2020).

Recently three water regulations were developed these are namely

- The Exploitation of Groundwater (Licensing) Regulations (2016),
- Irrigation and Drainage Licenses Regulations (2016), and
- Surface Water Regulations (2016).

As a consequent of adoption of decentralization in 1997 the states and in some cases the localities started establishing their water resources management institutions. However, state-level institutions lack essential capacity to manage water resources, due to inadequate funding and lack of clarity over roles (MENRPD, 2008 and SoE, 2020)

1.6 Other related issues.

Early Warning of Natural Disasters:

EW is known as the primary mechanism in disaster management. According to Pearson, (2012) an assessment carried out in 2011 showed that quarter of the countries of the globe are deficient of EWSs' while others require essential improvements. The country enjoys a central position in the Nile Basin hence; relatively long lead times for discharge forecast were permitted. Use of El Nino Southern Oscillation (ENSO) as a predictor boosted the probability of the Nile flood (Eltahir, 1996). Similar results were also achieved for the wadi discharge forecasts (El

Gamri et al., 2009). The high skills of Sea Surface Temperatures (SSTs') as predictors in hydrological predictions were demonstrated by El Gamri et al., (2010) and Habeib, (2011) and in rainfall predictions by Giannini, et al., (2003) and El Gamri et al., (2009b).

2. Impacts, risks and vulnerabilities

2.1 Impacts

Rainfall:

The rains of the Sudan witnessed significant decline since early sixties of the 20th century with solid concurrence between dry seasons and the ENSO event (Osman *et al*., 2001). This is supported by the findings of Adam, (2000) who estimated that dry Sudan experienced a 19% reduction in rainfall upon comparing the two climatic normals of (1941-1970) and (1970-1999).

During of the second half of the 20th century rainfall for Fashir, Khartoum and Medani have decreased by 20%, 14.3% and 17.5% respectively. Moreover, a significant southward move of isohyets was witnessed between the two climatic eras' of 1941-1970 and 1971-2000 (Abdalla *et al.*; 2018).

June – September rainfall (JJAS) witnessed a drop of about 10 - 30 mm per decade. The reduction is most evident in central parts of the country.

Floods:

Despite the fact that Sudan suffers from chronic water scarcity, floods are also common in the country. The extremely overwhelming floods happen on the Blue Nile, due the hastened run off on the Ethiopia Plateau due to land degradation. According UNEP, (2007) severe riverbank erosion in the constricted yet fertile Nile riverine strip combines flooding.

Floods are of two types these are namely (Abdalla, 2010):

- River flooding that happen when elevated river waters overflow the river banks, and
- Flash floods caused by heavy rainfall over villages and urban areas.

The frequency of flooding increases by 6 folds. Vulnerable groups to floods include the thousands of communities that inhibit riverbanks and low lands.

Loss of property, inundation of crops and drowning of livestock are the major flood damages in the country with a cost estimate that ranges between 100 and 1000 million dollars. Moreover, human deaths' are witnessed during severe floods e.g. 1988, 2007, 2013, 2019 and 2020. It's worth mentioning that high floods are habitually coupled with extensive spread of water borne diseases e.g. malaria, diarrhea, bilharzias.

The most overwhelming river floods occurred in 1946, 1975, 1988, 1994, 1998, 1999, 2006, 2007, 2013, 2016, 2018, 2019 and 2020. Even though flash floods are less common however, they may lead to very severe impacts, the most serious of which occurred in 1978, 1999, 2007, 2009, 2013, 2016, 2018, 2019 and 2020. Lately flash floods caused more severe impacts than river floods e.g. the flood of 2007 that is believed to be the most terrible flooding recorded in recent history. Coincidence of flash and river flooding obscures flood control since natural drainage to the Nile is hindered.

Drought:

It has been projected by NSF, (2003) that severe drought will be a future climatic feature as it is used to be in the past with enormous socio-economic implications. In the Sudan the incidence of extreme climatic events is in escalation, particularly drought which stared to increase since mid-1980s'.
In its modern history Sudan has experienced a number of overwhelming droughts that jeopardized its' food security and stimulated displacement and initiated conflicts over the dwindling natural resources. Vulnerability to the impacts of drought is intensified by the attitude to capitalize on herd sizes rather than improving the herd and the husbandry practices, as well as the inadequate water sources such as deep boreholes and water storage facilities (El Gamri, 2012).

Temperature:
Temperatures are commonly high mainly in the Northern part where it may reach 52^0C in the course of summer. During winter season the mean daily temperature fluctuates between 16^0C in the North and 29^0C in the South. According to Bashar, (2008) the difference between the daily maximum and daily minimum temperatures varies between 18 and 24^0C in the North, and 12 and 14^0C in the South of the country. Air temperatures of Sudan have been slowly increasing during the period 1960 – 2009. Generally temperatures during the period 2000-2009 are almost 0.8^OC and 1.6^OC higher than that of the period 1960-1969 (HCENR, 2013). It's worth noting that rise in temperature will increase evaporative power and consequently crop water requirements will increase. In addition to that the vegetative cover (rangelands and forests) will be reduced and consequently water and wind erosion will increase.

2.2 **Risks**

The two regions of the semi-desert and low rainfall savannah on sand which represent about 25% of Sudan's agricultural land are at substantial risk of further desertification and significant reduction in food production that may reach up to 20%
According to (HCENR, 2013) the projected future droughts will lead to reduced productivity in mechanized and subsistence rain fed farms (19 million ha), along with pastoralist societies, predominantly in Darfur and Kordofan, and initiate conflicts.
It's projected that a reduction of about 6 mm per month on average rainfall will be witnessed in the Sudan. Khiyar *et al.*, (2018) concluded that increased temperatures and reduced precipitation are expected to retard economic development in Sudan.
Since climatic changes will decrease precipitation and increased temperatures and evaporation hence, ground water recharge is anticipated to be reduced. Correspondingly, soil moisture will also decline. Coupled with increased water consumption, population growth and high rainfall variability, such effects may lead to serious water crisis (HCENR, 2003; Zakieldeen, 2009).
The prevailing storage capability of the Nile System is small over and above; the high silt content for the duration of flood makes water storage a risky practice since it will decrease the storage capacity of the reservoirs. The heightening of Roseires Dam, construction of Merowe, Upper Atbara and Setit dams have improved the water storage capacity of the country. Meanwhile, construction of the Grand Ethiopia Renaissance Dam (GERD) will assist in flow regulation and silt control provided that an agreement will be reached on the filing and operation of the Dam.

2.3 **Vulnerabilities**

Similar to other Least Developing Countries (LDCs), Sudan is vastly vulnerable to the impacts of Climate Change and Variability. The vulnerability of the country is further intensified by the fact that the country is located in arid and semiarid regions of the globe. Previous investigations showed that vast areas of the country are highly sensitive to small changes in rainfall and temperature. Furthermore, food security is mainly dependent on the amount and distribution of rainfall. Moreover, the majority of the inhabitants of the country are almost entirely reliant on climate sensitive resources for their livelihoods.

Various Vulnerability Assessment approaches have been executed in the country. Nonetheless, the utmost inclusive one is that of the National Adaptation Plan (NAP). The NAP methodology was meticulously allied to the overarching objectives proposed in the Conference of the Parties (Durban decisions at COP-17). The prime objective of Sudan-NAP is to minimize vulnerability to the impacts of climate change by augmenting adaptive capacity and resilience building for state and federal institutions. A minor, still equally important objective is to support mainstreaming of climate change adaptation dimensions into current and new policies, strategies, plans, programs and activities.

Definitions:

Vulnerability is a function of the character, magnitude and rates of climate change and variability, to which a system is exposed, its sensitivity and its adaptive capacity.

Adaptive capacity is the ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities or to cope with the consequences.

Resilience is "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions." (UNISDR, 2009).

Non-climatic factors:

Due consideration of non-climatic factors is key for outlining adaptation interventions for reducing vulnerability and build resilience. Such factors are generally related to all resources of livelihoods, i.e. constituents of the activities of communities such as mismanagement of the natural resource systems, actions maintaining livelihoods (overgrazing, over-cultivation, truss cultivation, deforestation), poverty (through wealth ranking) sources and diversity of income, lack of skills, lack of access to financing, lack of infrastructure and basic services etc. to identify and assess non-climatic factors causing vulnerability.

Infrastructure (transport, power and water supply) is either completely lacking or underdeveloped (UNDP, 2006). Civil wars, tribal conflicts, and political instability in the East African region resulted into a huge number (over five million) of internally displaced persons (IDPs) and refugees. Therefore, Sudan is considered to have the highest displaced persons population in the globe and accordingly witnessed significant environmental impacts (UNEP, 2007).

Recently participatory techniques were used to evaluate the factors that bring about the vulnerability at community level. Particularly data and information were gathered on the following:

- Traditional EW methods
- Land and water management practices.
- Basic services and rural infra-structure especially roads.

- Food reserve facilities and traditional food storage practices.
- Accessibility to micro-finance and traditional systems of lending
- Mechanisms for helping the poor (Zakat, Thamarat etc.)
- Policies, legislations, institutions, land tenure and capacity gaps.
- Degradation of land resources and mismanagement of natural resources including overgrazing, deforestation, loss of soil fertility.

3. Adaptation priorities, strategies, policies, plans, goals and actions:

Adaptation priorities:

Adaptation priorities in the country consider the following:

- Control of land degradation including deforestation, overgrazing, soil erosion, and desertification.
- Improvement of agricultural productivity especially for small scale subsistence agriculture.

The First National Communication Report (SNC1) recognized agriculture, water and health as the top priority sectors for the country to confront the escalating impacts of climate change (HCENR, 2003). In a later development based on wide consultation at the federal and state level the NAPA process recognized 32 urgent adaptation interventions in the above-mentioned sectors to reduce the increasing vulnerability of the rural communities to current and future climatic risks (HCENR, 2007). It's worth noting that Sudan's NAPA has been submitted to the UNFCCC in July 2007 beside that some of the identified priority adaptation interventions were incorporated in various projects including the NAPA Fellow-up Project and the Canada funded Climate Change Adaptation Project (2014 - 2017) with main focus on achieving food security for rain fed farming and pastoral communities through building adaptive capacities of the rural population.

According to HCENR, (2016) the, NAP, 2016 extended existing efforts to identify and prioritize potential adaptation interventions at the state level, as primarily assessed during the NAPA process. The NAP has divided the country into 6 regions (clusters of states) and identified water resources adaptation needs for each region as shown in Table (3):

Table (3): Major adaptations needs for water resources by region

Region	Adaptation needs
Darfur states: North Darfur West Darfur South Darfur Central Darfur East Darfur	ND: Conducting studies to improve water management around the most vulnerable areas. More wells and boreholes should be dug in areas that are safe from pollution and more efficient irrigation systems should be introduced. WD: Improved water harvesting techniques, provision of agricultural inputs to local farmers, afforestation, and building capacity. Assessment of groundwater reserves to inform the much needed new water projects (wells and dams) as well as the rehabilitation of existing water sources. SD: Establishment of rain gauge stations to monitor and provide hydrological information. Maintenance of reservoirs and rehabilitation of the water basin infrastructure to increase water storage capacity. CD: Capacity building on water harvesting techniques and

	introduction of sustainable cropping systems. ED: Execution of new geophysical studies, drilling of new water wells, rehabilitation of old wells, introduction of new water harvesting methods in north, construct earth dams in the south.
Kordofan states: North Kordofan South Kordofan West Kordofan	NK: Improved water management as well as improved livestock and agricultural techniques. Geo-physiological studies are needed to determine ideal sites for digging wells, trainings would enable water committees to adopt better management practices, and rehabilitating or constructing new boreholes, *hafirs* and water pipes would help alleviate water scarcity as well as new wells in Um Gawaseer and studies to identify water harvesting opportunities in Wadi Abu Dom. SK: Building of water infrastructure to meet current and future demand to increase resilience against water scarcity. WK:
Eastern states: Kassala Gedarif Red Sea	Kassala: Drilling more wells, improving water harvesting techniques, and eradicating invasive mesquite trees from water source areas. Introduction of efficient and modern irrigation system. Rehabilitation of four *hafirs* in the Aroma locality (Kilinda, Garadaieb, Gug Elfil, and Elaraish) to enable grazing on remote areas. Gedarif: Red Sea: Establishing desalination stations, constructing subsurface dams and improving water harvesting techniques. *Coastal zones:* Mangrove restoration and conservation; development of program for marine-related research; monitoring, education, and awareness-raising; introduction of policies to promote integrated coastal zone management; and support for mangrove-dependent communities to reduce mangrove destruction.
Nile states: Khartoum River Nile Northern	RN: Improved water harvesting techniques, construction of canals inside the River bed to enhance and lead water to irrigation pumps intakes, provision of small scale pumping units for irrigation to reduce the negative impacts of water recession, well drilling in rural areas, and control of river bank erosion. N: construction of new wells in Umm Gawaseer and other settled areas, underground storage of water, and conducting studies in Wadi Abu Dom for water harvesting and conducting socio-economic studies, digging boreholes for drinking purposes in low land areas. Khartoum: Capacity building, the adoption of water saving irrigation techniques, integrated water planning, awareness-raising among farmers about climate change.
Central states: Gezira Blue Nile White Nile Sennar	Gez.: Establish borehole irrigation, rainfall and water catchment basis to enhance communal water storage systems and to supplement rain fed agriculture. Improve already poor designs for water storage. Plant trees around water storages, raising awareness and capacity building. BN: Build water infrastructure, construction of contingency water storage facilities, and improving community awareness regarding water conservation.

	Sennar: Extension of water infrastructure, construction of contingency water storage facilities, implementation of water harvesting, and improving awareness in water conservation. WN: Introduction of water harvesting techniques, building of micro dams in some water valleys to improve water supply in vulnerable areas, and the construction of water wells and with solar pumps in water stressed areas for both human and animal use.

Adapted from HCENR, (2016)

Policies and strategies:

Regional

IGAD Regional Climate Change Strategy (IRCCS)
IGAD Regional Migration Policy Framework (RMPF)
IGAD Regional Infrastructure Master Plan (IRIMP)
IGAD Regional Maritime Security Programme (MASE)

National:

Water policy and laws:

National water policies and strategies were developed based on IWRM principles nevertheless, at initial phases of implementation. For the time being, State water policies are evolving and for the majority of the states the process is yet to be initiated. It's worth noting that, the National Constitution (2005), The Constitutional Decree, the existing water policy and water laws mandate the states to manage water resources (surface and ground) within their respective jurisdictions meanwhile, inter-state water resources management is vested in the Federal Government.

The relation of Sudan's water policy to climate resilience is clearly expressed in the major policy objectives e.g. advocacy for integrated watershed management and protection of the environment.

In the year 1995 an inclusive water resources law that governs the whole water resources and water uses for all purposes was ratified (El Gamri, 2018).

National IWRM Plan:

The impacts of climatic changes may challenge the current water management systems and hydraulic structures (Bates et al., 2008). Additionally, El Gamri, (2012) concluded that adoption of IWRM will synergize ecosystem based adaptation which is one of the vital approaches to realize resilience. Beside that adoption of IWRM will enhance local governance and the role of civil society specifically that of women (GWP, 2000). Currently Sudan as represented by the Ministry of Water Resources and Electricity (MWRE) is working together with JICA to develop the National IWRM plan.

Definition:
'IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.

Sudan National Adaptation Program of Action (NAPA):

According to HCENR, (2007) NAPA was a consultative process designed to identifying priority adaptation interventions for five ecological zones that equally support climate resilience such as adoption of water harvesting and water conservation in agriculture, capacity building and microfinance. During the NAPA process wide consultations were held in the five States of Central Equatorial, River Nile, Gedarif, South Darfur and North Kordofan demonstrating different ecological zones.
Several factors were found to exacerbate impacts of Climate Change and escalate the vulnerability. Such factors include land degradation and mismanagement of natural resources e.g. overgrazing and deforestation among others.

National Adaptation Plan (NAP):
Sudan's NAP has been prepared in accordance with the 2010 Cancun Agreement under the UNFCCC. The Plan reacts to the general objectives of the UNFCCC's NAP Guidelines for reducing vulnerability to the impacts of climate change through strengthening local adaptive capacity and resilience and expediting integration of climate change adaptation into the pertinent policies, strategies and programmes.
The Plan describes interventions to moderate vulnerability in the different sectors of water resources, agriculture and food security, public health, coastal zones, and rural communities all over the country. Such adaptation alternatives have been identified through bottom-up consultative processes. The NAP process has assisted in enhancing awareness and technical and institutional capacities, and integrating adaptation apprehensions into development discourses.

4. Review available data on adaptation projects

Regional projects:

- **African Investment Program (AIP):**

  The Assembly of the African Union Heads of State and Government adopted the Continental Africa Water Investment Programme (AIP) as part of Programme for Infrastructure Development in Africa – Priority Action Plan 2 (PIDA-PAP 2) during the 34th ordinary session of African Union summit on 7 February 2021.
  The goal of the AIP is to mobilise US$30 billion in ***climate-resilient*** water investments by 2030 and create 5 million jobs. The objective of the AIP is to enhance job creation through gender sensitive investments in water security, industrialisation, and climate resilient development. The project also contributes towards continental efforts on universal access to safe water, sanitation hygiene and integration of water security in COVID-19 economic recovery plans.

- **Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR):**

  The objective of the Initiative is to assess the impact of climate change on freshwater resources in the Arab Region through a consultative and integrated regional initiative that seeks to identify the socio-economic and environmental vulnerability caused by climate change impacts on water resources based on regional specificities. RICCAR aims to provide a common platform for assessing, addressing and informing response to climate change impacts on freshwater resources in the Arab region by serving as the basis for dialogue, priority setting and policy formulation on climate change at the regional level (ESCWA, 2017).

The other projects include the following:

- Strengthening the Resilience of the IGAD region to the adverse Impacts of CC through effective Adaptation and Mitigation Actions (RICCAMA), project (IGAD)
- Building Resilience through Disaster Risk Management and Climate Change Adaptation (IGAD).
- IGAD African Development Bank Drought Resilience and Sustainable Livelihoods Program II (DRSLP-II)
- IGAD Displacement Impacts Project in the HoA (DRDIP)

National:

- **ADAPT! Project:** This project aims to increase understanding and integration of climate resilience and environmental management into programme delivery, plans, and policy across the international humanitarian response, recovery and development programmes in Sudan. This will help the people of Sudan to cope with environmental stresses and climate change. Specifically, the project will work across three themes: climate change (CC), natural resource management (NRM), and integrated water resources management (IWRM).
- HCENR: NAPA
- HCENR: NAPA Fellow-up
- HCENR: Climate Change Adaptation Project (Canada Funded)
- HCENR: Climate Risk Finance Project
- HCENR: White Nile Ecosystem Based Adaptation Project
- HCENR: Strengthening Targeted National Capacities for Improved Decision
- Concern's Food Security and Livelihood Programme in Sudan
- Relief International RI: Program Title: Emergency and Early Recovery Resilience Assistance for Vulnerable Populations in North Darfur and East Darfur states.
- Save the Children International: Food Security and Livelihood Programme
- Partnership for Improving Prospects for Forcibly Displaced Persons and Host Communities (PROSPECTS) ILO+.
- Rural Livelihood's Adaptation to Climate Change in the Horn of Africa Project Phase II (RLACC II)
- Improving Livestock Production and Marketing Project (ILPMP) (IFAD).
- Livestock Marketing and Resilience Program (IFAD)
- Making and Mainstreaming of Global Environmental Obligations Project.
- Practical Action: Climate Change and Fragility project
- Practical Action: The Wadi Elku Catchment Management project
- The overall objective of the second phase of the project is to establish climate resilient livelihoods and reduce natural resource conflicts in North Darfur. The specific objective of the project is to further improve natural resource use and management in Wadi El Ku. Concretely, the project will aim to sustain increases in agricultural yields and related value chain productivity over the long-term while safeguarding ecosystem integrity and improving social cohesion.
- Practical Action: Integrated Improvement of Household Food Security in Gedaref, Kassala and Red Sea States, Sudan

- Practical Action: Building climate & conflict resilient livelihoods for rural communities in Wadi el Ku, North Darfur, Sudan, using Integrated Water Resource Management.

5. Status of the implementation of adaptation actions and plans

5.1 Progress and results achieved

5.2 Adaptation efforts: Good practices, lessons learned (suitable for sharing and recognition of Sudan efforts);

Good practices:

Improvement of the Water Productivity:

Rain fed Agriculture (Water Harvesting and deep ploughing):

In South Darfur State terracing together with chiseling (to enhance soil moisture retention) was practiced during two consecutive years 2015 (dry year) and 2016 (wet year). Although the productivity of grains (cereals) is more than doubled during the wet year however, the improvement is more noticeable during the dry year since productivity increased by 8.5 folds.

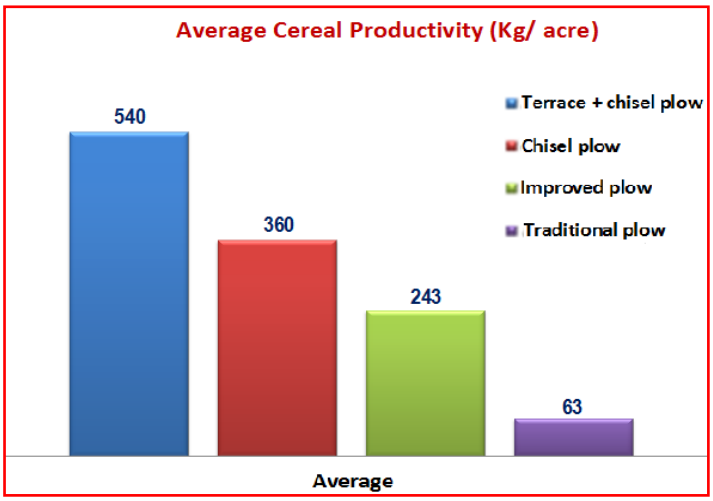

Fig. 2: Average cereal productivity during the 2015

In the Gedarif State the same intervention of deep ploughing and terracing resulted in yield increment by 4.7 folds and 3.3 folds for sorghum and sesame respectively.

Irrigated Agriculture (Shelterbelts):

In the River Nile State Construction of shelterbelts (mainly Eucalyptus spp.) around small farms in the upper terraces assisted to:

- Protect farms from excessively hot winds and wind–blown sands
- Create favorable micro-climate and reduced water consumption,
- Increased availability of biomass for firewood and charcoal, and
- Increased productivity of sorghum fodder, Alfa Alfa and wheat by 20%, 25% and 67% respectively.

Plate 4: Shelterbelt around small farms in the River Nile State

Irrigated Agriculture (Demonstration farms):
Direct application of the recommended improved production packages within the farms of the beneficiaries proved to excel traditional agricultural extension approaches e.g. awareness raising campaigns'. Such an approach achieved tremendous improvement in the productivity of some crops as follows:

- ***Faba beans***: from 405 kg to 990 kg.
- ***Broad beans***: from 660 kg to 1265 kg

Resilience Building by establishing women collective farms:
Introduction of solar pumping, underground pipe systems and integrated pest management techniques together with other interventions greatly enhanced agricultural productivity in the semi desert climates of Bara locality. This practiced reduced significantly seepage losses that otherwise will be encountered if earthen channels were used. Crops grown include potato, tomato, pumpkin, okra, pigeon pea, sweet pepper and others. The project also introduced improved fruit tree seedlings and constructed composting basins to produce organic manure.

Lessons learnt:

- The potential for climate change adaptation through including improving the water use efficiency/ productivity is great
- Sustainability of revolving funds is a real challenge.
- Community orientation and capacity building in the participatory approach is of prime importance.
- Special concern should be given to establishment and registration of Community Based Organizations' (CBOs') e.g. Village Agricultural Committees (VACs').
- Provision of basic services and infrastructure including marketing facilities will boost the coping capacities.
- Subsidies were highly required to assist in the adoption of solar pumping for irrigated agriculture e.g. Bara locality.

5.3 Barriers, challenges and gaps related to the implementation of adaptation;

Barriers and gaps:

- Deep poverty
- Low individual and institutional capacities

- Under-developed infrastructure especially roads
- Occurrence of COVID 19 and the resultant global economic recession and lock downs.
- Inadequate coordination between the relevant institutions and between the federal and state authorities,
- Lack of flash flood control structures.
- Low level of awareness.
- Lack of standardization and import of low quality devices.
- Inadequate power supplies.
- Lack of incentives for the adoption of renewable energy and water conserving devices and irrigation systems.
- Poor planning.
- Shortage of funding.
- Huge Displacement of people.
- Lack of clear policy for Water and Sanitation Sectors.
- Improper collection and management of water charges.
- Village water charges (money) may be used for other purposes.
- Leadership of women in community water supply is still lagging behind.

6. Sudan water sector vulnerability and adaptation baselines

7. Concluding Remarks:

It's evident that the country has always been subjected to hard hits by impacts of climate changes. For instance, rain fall showed significant decrease since the sixties of the previous century. Generally it was estimated that on average the country witnessed a reduction of about 20% of its total annual rain fall accompanied with southward shifts of isohytes and agro-ecological zones. The achievements of Sudan's adaptation projects include improvement of water productivity in irrigated farming and terraced rain fed agriculture. Farmers School and the demonstration farms approaches also assisted in boosting water and crop producivities. Tremendous increases in the crop yield have been achieved both at the research and farmer's application levels viz. the yield of sorghum has increased by 8.5 folds through the use of the combination of water harvesting (WH) and Chiseling as compared to the traditional practices. The advent of irrigated agriculture in the sandy soils of the semi desert climates in North Kordofan proved to be lucrative, assisted in up-grading the technical knowhow of the beneficiaries and created job opportunities.

Conclusions and recommendations drawn from the implementation of various climate change projects in Sudan are the following:

- The potential for climate change adaptation through including improving the water use efficiency/ productivity is great
- Sustainability of revolving funds is a real challenge.
- Community orientation and capacity building in the participatory approach is of prime importance.
- Special concern should be given to establishment and registration of Community Based Organizations' (CBOs') e.g. Village Agric Committees (VACs').
- Provision of basic services and infrastructure including marketing facilities will boost the coping capacities.

- Subsidies were highly required to assist in the adoption of solar pumping for irrigated agriculture e.g. Bara locality
- Coordination between the different project partners (federal, state and UN agencies) contributed to the success of the projects.
- Community engagement proved to an efficient approach in CCA.
- Proper PCM is of crucial importance to ensure sustainability.
-

What is water security?

A water secure world harnesses water's productive power and minimises its destructive force. It is a world where every person has enough safe, affordable water to lead a clean, healthy and productive life. It is a world where communities are protected from floods, droughts, landslides, erosion and water-borne diseases. Water security also means addressing environmental protection and the negative effects of poor management.

A water secure world means ending fragmented responsibility for water and integrating water resources management across all sectors – finance, planning, agriculture, energy, tourism, industry, education and health. This integration is at the heart of GWP's strategy.

A water secure world reduces poverty, advances education, and increases living standards. It is a world where there is an improved quality of life for all, especially for the most vulnerable—usually women and children—who benefit most from good water governance.

GWP 2010

References:

Abdalla, A.K , El Gamri, T. and Saeed, A.B. 2018. Impacts of Climate Variability and Change and the Rains of the Old Sudan. Annals of Arid Zone 57(3&4): 111-120, 2018

Adam, A.M. and Abdo, G.M., (2017). Chapter 2: Water and Hydrology (Surface and Groundwater). In Water Resources in Sudan. Water Research Centre, University of Khartoum.

Abraham E. M. 2018. Status of Research on Adaptation (Water) in Africa: Approaches and Methodology. International Conference on Adaptation Metrics and Techniques for Water, Agriculture and Resilient Cities October 26-27, 2018. UM6P, Morocco.

Adam, H.S. 2000.Conservation of dry lands. Proceedings of the Symposium on the Role of Agricultural Research in Combating Desertification in the Sudan (In Arabic). Arab Organization for Agricultural development (AOAD), Khartoum pp 46-54. Ministry of Science and Technology, Khartoum, Sudan.

El Hag, F.M.A., Elhassan, M.S.M., Khatir, A.A. 2012. NAPA Best Practices in Sudan: A documentary Study. HCENR, UNDP (Sudan Country Office), GEF.

El Gamri, T. 2016. *Adaptation at a Glance*. Climate Change Adaptation Project, HCENR, UNDP (Sudan Country Office).

ESCWA (Economic and Social Commission for West Asia), 2017.Arab Climate Change Assessment Report.E/ESCWA/SDPD/2017/RICCAR/ Report. https://www. unescwa.org/publications/riccar-arab-climate-change-assessment-report.

Farah, S.M. and Ali, I.A. 2000. The role of improved production packages in combating desertification in the rainfed sector of the Sudan (in Arabic).Proceedings of the Symposium on the Role of Agricultural Research in Combating Desertification in the Sudan. Ministry of Science and Technology, Sudan.

GWP 2004.Catalyzing Change: A handbook for developing integrated water resources management (IWRM) and water efficiency strategies. GWP, Sweden.

Higher Council for Environment and Natural Resources (HCENR), 2003. Sudan's First National Communications under the United Nations Framework Convention on Climate Change, Volume I: Main Communications, HCENR, Sudan.

Higher Council for Environment and Natural Resources (HCENR), 2007.National Adaptation Programme of Action (NAPA).HCENR, Ministry of Environment and Physical Development, Sudan.

Higher Council for Environment and Natural Resources (HCENR), 2013. Sudan's Second National Communications under the United Nations Framework Convention on Climate Change, HCENR, Sudan. Sudan Currency Printing Press.

Higher Council for Environment and Natural Resources (HCENR), 2017. Final Technical Report. Climate Change Adaptation Project, HCENR.

IPCC (Intergovernmental Panel on Climate Change), 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Zakieldeen, S.A. 2009. Adaptation to Climate Change: A Vulnerability Assessment for Sudan. Gatekeeper 142, International Institute for Environment and Development (IIED), UK.