zef
Center for
Development Research
University of Bonn

Working Paper 203

Abdelrahman Khidir Osman, Adil M. Ali

Sudan - Land, climate, energy, agriculture and development

A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security

ISSN 1864-6638 Bonn, January 2021

PARI

ZEF Working Paper Series, ISSN 1864-6638
Center for Development Research, University of Bonn
Editors: Christian Borgemeister, Joachim von Braun, Manfred Denich, Till Stellmacher and Eva Youkhana

Authors' addresses

Prof. Abdelrahman Khidir Osman
Ex-Director of the Drylands Research Center, Agricultural Research Corporation
Sudanese Environment Conservation Society and Freelancer
AbuAdam Residential Area, Quarter No. 1, House No.100, Khartoum, Sudan
Mobile: +24 9918092678,
arkosman@hotmail.com

Adil Mohamed, M. Sc.
Coordinator/Consultant with the UNDP
Khartoum Office for the GCF Readiness and Support Project
Sudanese Environment Conservation Society
Khartoum East, Burri Extension, House No.235/5, Khartoum, Sudan
Mobile: +24 9912642060
sanjak1956@gmail.com

Sudan – Land, climate, energy, agriculture and development

A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security

Abdelrahman Khidir Osman and Adil M. Ali

Abstract

Sudan is situated in Sub-Saharan Africa, covering an area of about 1.9 million km² and has a population of 43 million. It is regarded as one of the countries in the world where human development is least advanced with a poverty rate of about 46%. Sudan's economy is based on agriculture, which contributes about one-third of the (GDP). Sudan's agriculture has three distinct crop and three distinct livestock production systems. The Crop production systems are: irrigated, traditional and mechanized rain-fed farming. The livestock production systems are: nomadic, transhumant and sedentary systems. The annual cultivated land is around 20 million hectares, more than 85% of which are rain-fed. The livestock population is estimated at 105 million heads concentrated in nomadic and transhumant production systems. Water resources in Sudan are: river Nile and its tributaries, seasonal streams, underground water and surface water. Sources of energy are: biomass; electricity (hydro and fossil fuels) and petroleum products, accounting for about 78,8% and 14%, respectively, of the total energy balance. Sudan has significant renewable energy resources. Particularly solar energy is well distributed all over the country thus having the potential to facilitate the provision of energy services to rural settlements.

Sudanese land cover classes indicated that 51% of the country area is bare rocks and soil, agriculture land is 13%, and tree cover and herbaceous vegetation cover 36% of the total Sudan area. The annual crop cultivated area is around 20 million ha and the main crops occupying more than 90% of the cultivated area are sorghum, millet, wheat, sesame and groundnut. Rangelands are the backbone of the livelihood of pastoralists and agro-pastoralists producing annually about 73% of the total feed required for national herds. The forest area is about 22 million ha thus comprising three different classes: federal, state, and community/private forests. Sudan is one of the most seriously affected countries by desertification in Africa. Recent GIS and remote sensing results indicated that between 1958 and 2017 the desert boundary was moved more to the south pushing the country into a historical desertification disaster. Several attempts were made to formulate regulations and legislations to combat soil degradation and desertification. However, desertification in Sudan remains a major environmental threat.

Sudan is among the most vulnerable countries in the world to climate change, ranking 175th out of 181 countries. Analyses of rainfall and temperature have demonstrated a high rainfall variability and a clear rise in maximum and minimum temperature. Key climate change impacts include: reduced crops and livestock productivity, reduction in the duration of the growing season and socioeconomic impact such as conflict over resources and migration to urban centres.

Sudan has implemented several plans and policies which directly relate to climate change adaptation and development priorities. The focus of these plans and policies is: food security and raising productivity, reducing poverty and enhancing adaptation and resilience to climate change, protecting and developing natural resources, land tenure problems and strengthening governance and institutional capacity. These interventions had limited success in achieving their objectives. The main reasons are: a lack of political stability and fluctuating economic and financial policies as well as weak administrative and implementation capacity of the government institutions. The main lessons learnt are: agricultural-development programmes require increased and more effective public and private partnerships involving the main stakeholders. The low flow of finance to the agricultural sector remains one of the obstacles of agricultural growth. In addition to the poor rural infrastructure, the ongoing conflicts and social unrest in many parts of the country are strongly impacting the performance of the economy and constraining the development plans and policies.

Keywords: Sahel, energy, climate change, land degradation, innovation, policy

JEL codes: O30, Q24, Q25, Q42, Q54, Q55, Q58

Acknowledgments

The study was funded by the “Program of Accompanying Research for Agricultural Innovation” (PARI), which is funded by the German Federal Ministry of Economic Cooperation and Development (BMZ).

Table of Contents

List of Boxes, Figures, and Tables

Acronyms

ARC	Agricultural Research Corporation
AfDB	African Development Bank
CAADP	Comprehensive Africa Agriculture Development Programme
CAF	Cancun Adaptation Framework
CBD	Convention of Biological diversity
CSP	Concentrating solar power
DCG	Drylands Coordination Group
FAO	Food and Agriculture Organization of the United Nation
FNC	Forests National Corporation
GCF	Green Climate Fund
GDI	Gender Development Index
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIS	Geographic Information Systems
HDI	Human Development Index
HCENR	Higher Council for Environment and Natural Resources
IDPs	Internally Displaced Persons
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
l/d	Liters per day
MEAs	Multilateral environmental agreements
MW	Megawatt
NAP	National Adaptation Plan
NAIP	National Agriculture Investment Plan
NAPA	National Adaptation Plan of Action
NCS	National Comprehensive Strategy
NDDU	National Drought and Desertification Coordination Unit
NGOs	Non-Government Organizations
PV	Photovoltaic
RE	Renewable Energy
SMA	Sudan Meteorological Authority
SSA	Sub-Saharan Africa
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme

UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
USAID	U.S. Agency for International Development
WB	World Bank

1 Introduction

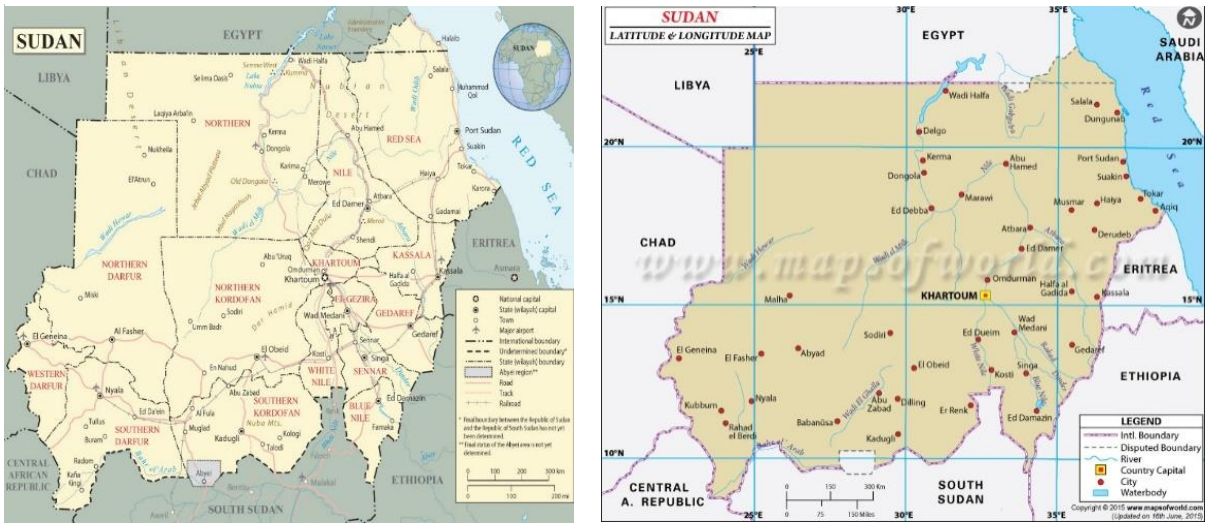
Sudan, like most countries in the Sahel region, faces multiple interlinked challenges, such as high poverty rates, poor access to services, a decline in agricultural productivity, significant environmental degradation, climate change and the incidence of extreme weather events, conflicts and social unrest.

This study presents an overview of the major environmental issues related to the energy situation, land degradation and agriculture, technological socioeconomic and policy actions for sustainable land management, climate change impacts and adaptation, evaluation of national policies and development and main lessons learned from recent investments. The study is based on an intensive review of relevant literature. The purpose of this study is to assist the planning and implementation of future projects related to the promotion of renewable energy, sustainable agricultural growth, land management and climate change adaptation and mitigation.

1.1 Background

Geographically, Sudan is a vast country that lies in northeast Africa between latitudes 10°N and 23° N and longitudes 21°45′E and 38°30′E. It covers an area of approximately 1.9 million km^2 and the majority of the land is composed of vast arid plains interrupted by a few widely separated ranges of hills and mountains. The country is bordered by South Sudan, Ethiopia, Eritrea, Egypt, Libya, Chad, the Central African Republic and Saudi Arabia across the Red Sea (Figure 1). The country has an estimated population of about 43 million with an annual population growth rate of 2.9%. The average household size is 5.7 people. The population is young, with people aged 14 years and younger representing 41% of the total. Approximately 66% of the population lives in rural areas. Administratively, Sudan is divided into 18 states with Khartoum as the capital city.

Figure 1: Map of Sudan



Source: Google Images for Sudan maps; United Nations (edited) by Geographic Guide Africa and maps of the world, 2019.

1.2 Human Development Index (HDI)

The Human Development Index (HDI) is an overall assessment used by the UN to measure all income and human development dimensions. According to the HDI, Sudan obtained 0.479 points in 2016, ranking 165th out of 187 countries published. It is therefore regarded as one of the least advanced countries in the world in terms of human development. Some HDI indicators of the country are shown in Table 1. Sudan lags behind most Sub-Saharan African (SSA) countries in all health, education and economic indicators, reflecting the poor access of Sudanese to basic social services.

Tab 1: Human Development Indicators

Gross domestic product (GDP) per capita (USD)	1,472
Life expectancy at birth (years)	63.5
Gender Development Index (GDI)	0.83
Vulnerable employment (% of total employment)	45.4
Total expenditure on health per capita (Intl $, 2014)	282
Total expenditure on health as % of GDP (2014)	8.4
Maternal mortality ratio (per 100,000 live births in 2010)	730
Infant Mortality Rate (deaths per 1,000 live births)	71
Proportion of population using an improved water source (%)	65
Proportion of population using improved sanitation facilities (%)	42

(UNDP-HDR, 2013-2014; SECAP, 2016)

1.3 Employment situation

In 2007, the labour force was estimated at nearly 11.92 million with the agriculture sector representing 80% of the total workforce, services representing 13% and industry 7%. Between 2016 and 2017, the unemployment rate decreased from 20.6% to 19.6%. However, more than 130,000 young people enter the labour market per year, yet only 30,000 positions are available, posing a serious challenge for the country (AfDB, 2016; CIA, 2020).

1.4 Poverty profile

Based on the latest available data, a large portion of the population in Sudan lives in poverty as shown in Table 2 below. The poverty rate is estimated to be 46% and is significantly higher in rural areas (58%) than in urban areas (26%) and markedly varies across states, from 26% in Khartoum to nearly 60% in conflict-affected states. Small-scale farmers and agro-pastoralists practicing traditional rain-fed agriculture are the most affected by rural poverty. The national severity of poverty is 7.8%, thus estimating the average gap relative to the poverty line while giving greater weight to those who are further below the poverty line (Table 2).

Tab 2: National Poverty Profile and Food Deprivation

State	Poverty Profile (%)			
	Incidence	Poverty gap	Severity	Poverty gap among the poor
All Country	46.5	16.2	7.8	34.8
Urban	26.5	7.1	2.7	26.6
Rural	57.6	21.3	10.6	36.9

(Sudan IMF Country Report, 2013)

1.5 Agriculture and livelihood

Sudan, like most developing countries, has an economy widely based on agriculture and the production of raw materials. Agriculture, including cropping, livestock and forestry, contributes about one-third of the national Gross Domestic Product (GDP) and generates around 90% of non-oil export earnings. It is the main source of employment, as more than 75% of the labour force is employed in agriculture and related activities. Moreover, it is the main livelihood source for more than two-thirds of the population and remains the key priority sector in Sudan's growth and poverty reduction agenda (Osman, 2017).

Sudan's agriculture has three distinct crop and livestock production systems. Crop production systems are irrigated, traditional rain-fed and mechanized rain-fed farming, while livestock production systems are nomadic, transhumant system and sedentary systems. The amount of land cultivated annually approximates 20 million hectares, of which more than 85% is rain-fed. The livestock population is estimated at 105 million heads (Osman, 2017). Crop and livestock production systems are inter-related through food, feed, investment, manure, fodder, labour and transportation linkages. The foremost challenges facing the agriculture sector are the need for the enhancement of agricultural productivity, public and private investment in rural infrastructure (e.g. irrigation systems, agro-processing facilities and markets), rehabilitation of rangelands and adaptation to climate change.

1.6 Food security and environmental degradation

Increasing food availability and improving food security, particularly in the traditional rain-fed sector, remains a great challenge. The main reason is that most of this sector is in the semi-arid zone, where rainfall is erratic and the natural resources essential for food production are severely degraded. Most of the land has been classified as moderately to severely affected by desertification and environmental degradation. The latest Integrated Food Security Phase Classification (IPC Report, 2019) estimated that 5.8 million people in Sudan are classified as "food insecure" and in "crisis" and "emergency" phases, with the majority of the affected population located in the western parts of the country, indicating that food insecurity is strongly correlated with Sudan's rain-fed agriculture, where desertification and environmental degradation are most severe.

1.7 Water and energy

The four types of water resources in Sudan are, namely, the River Nile and its tributaries, seasonal streams, underground water and surface water. Annual freshwater withdrawal is estimated at 27,000 million cubic meters. From this amount, only 940 million cubic metres (3.5%) is for domestic use. Access to improved drinking water sources varies from 50.2% in rural areas to 66% among urban areas. The water supply

situation indicates that national average per capita consumption of water is 37 litres per day (l/d). The urban average is 50 l/d, while rural average is only 24 l/d (FAO, 2013; MWRIE, 2017).

Fuelwood from natural forests and the desert scrub contributes 78% of the energy balance of Sudan; the rest consists of oil (8%), generated electricity (8%) and agricultural residues (6%). Rural inhabitants use most of the tree species for fuelwood (wood and charcoal). However, there is a recent increasing trend in liquefied petroleum gas (LPG), particularly in the capital city (Gorashi, 1998; UNEP, 2010).

2 Problem statement and methodology

Sudan faces multiple interlinked challenges. There is a clear decline in agricultural productivity, significant land degradation and desertification and a huge reduction in the range of resources and forest cover. Sudan recognized the problem of land degradation early in the twentieth century. Recurrent drought and climate change are threatening livelihoods throughout the dry land zones. Climate change is reflected in the shift of isohyets towards the south westerly direction resulting in land degradation, increasingly dry conditions and losses in agricultural land area. This report intends to review the current state of the livelihood of the Sudanese population to help identify key trends, problems and opportunities for sound interventions. This document was assembled based on a thorough desk review of the following documents:

1. Published and unpublished papers and reports covering a variety of topics in Sudan.
2. Thorough review of previous and present national studies and reports regarding food security, land degradation and climate change.
3. Research reports and documents on agriculture, livestock and water.
4. Records of the Ministry of Agriculture, Forests National Corporation, Agriculture Research Corporation, Ministry of Finance and the Bank of Sudan and others.
5. Climatic data, specifically rainfall data and temperature, over more than twenty years collected from the Sudan Meteorological Authority (SMA).
6. National, International, NGO, UNDP and internet-published documents.
7. Consultancy reports carried out by the report team and others.
8. Experience of the study team, who has worked on development issues for more than 20 years.

Constraints and Uncertainties: In preparing this document, there have been some constraints that have fortunately not affected the process and the outcome. However, weaknesses in the information systems of the country and the lack and/or absence of updated information in some areas presented a constraint. Additionally, some sources are inconsistent with no in-depth details and some information is dated more than seven years old. However, according to experts and observations, no significant changes have occurred to these figures. The experience of the team, review of the above-mentioned documents and discussion with experts help to overcome the information gap and limitations.

3 Situation and trends in rural energy and land use changes

3.1 Energy use and associated challenges and opportunities

In Sudan, there are generally three sources of energy, namely:

1. Biomass including fuel wood, charcoal, agricultural residues, and animal dung contributes 78% of the energy balance of Sudan. Rural inhabitants use most of the tree species for fuelwood. Removal of dead trees and branches is permitted for people living around forests. However, there is a recent increase in the use of liquefied petroleum gas (LPG), particularly in the capital city. Households consume more than 74% of total biomass (mostly in rural areas), followed by 16% in the service/commercial sector, and 10% in the industrial sector (AfDB, 2016).
2. Electricity is produced by a combination of hydro and thermal stations that use diesel and residual fuel oil. Together, hydro and fossil fuels account for about 8% of the total energy consumption. Since 1980, power generation has been growing at a rate of 6% per year, with thermal power generation increasing at roughly six times the rate of hydropower generation. (Gorashi, 1998; UN panel, 2009).
3. Petroleum products: Gasoline, diesel, residual fuel oil, kerosene, and jet kerosene account for about 14% of total energy consumption. The consumption of petroleum products has significantly increased since 2000, when the Khartoum Refinery began operations. The transport sector is the largest consumer of petroleum products, followed by agriculture, services, industry and households (HCENR, 2019; UNFCCC, 2013).

Fuelwood production is a major reason why vast areas have been deforested to meet the increasing demand of the growing rural population. The Forests National Corporation (FNC) estimates fuelwood consumption across Sudan to be 15,770,830 m^3 of round wood, giving 0.71 m^3 as the per-capita consumption per annum. Due to the lack/limited access to alternative energy sources and energy conservation technologies, the demand of firewood as energy is likely to continue. Table 3 indicates the production of firewood and charcoal during 2012-2016, as indicated by FNC.

Data from the National Forests Corporation (Farouk, 2017) indicates that overall production of firewood is 383,413 m^3, while total production of charcoal is 3,908,916 bags. Switching in recent years from wood/charcoal to LPG could reduce firewood and charcoal consumption. However, the rural population continues to overwhelmingly rely on wood fuels (firewood and charcoal) for cooking.

Tab 3: Firewood Production 2012-2016

Type	Unit	2012	2013	2014	2015	2016
Charcoal	Sack	4,318,951	4,259,504	2,908,916	2,959,488	2,213,974
Firewood	m^3	286,150	165,709	383,413	193,645	188,366

(FNC, 2016)

Sudan has a significant amount of renewable energy (RE) resources, particularly solar energy with the annual average estimated at 6-7.5 KWh/m^2 per day. It is well distributed all over the country, giving it the potential to facilitate the provision of energy services to remote and poor rural settlements that are unlikely to be reached by modern energy infrastructure. There have been recent plans by foreign investors to build a 2,000 MW (megawatt) concentrating solar power (CSP) plant.

The Sudan's power generation capacity is estimated at about 2250 MW, with about 43% generated from fossil fuels and about 57% from hydro. Additional MW output is expected due to currently ongoing infrastructure projects. The national electrification rate is 35.9%. Approximately 27.0 million people lack access to electricity in the country. Urban electrification is roughly 52% compared to 28% for rural

electrification, i.e. the majority of rural areas have no access to electricity. This remains a major challenge that hinders development efforts in the country, as the population scattered in thousands of villages across the country will remain without access to electricity. Additionally, Sudan's potential for hydropower output is estimated at 4,920 MW. However, only 10% of the hydroelectric power is currently utilized. Distribution of Electricity consumption in Sudan indicated that more than 54% of the generated power is consumed by households (Table 4).

Tab 4: Distribution of Electricity Consumption in Sudan (In GWh)

Sector	Share (%)
Households	54
Commercial/ industrial	41
Agriculture	5
Total	100

(Calculated by the Sudan country office; AfDB, 2016)

3.2 Current and potential status of renewables

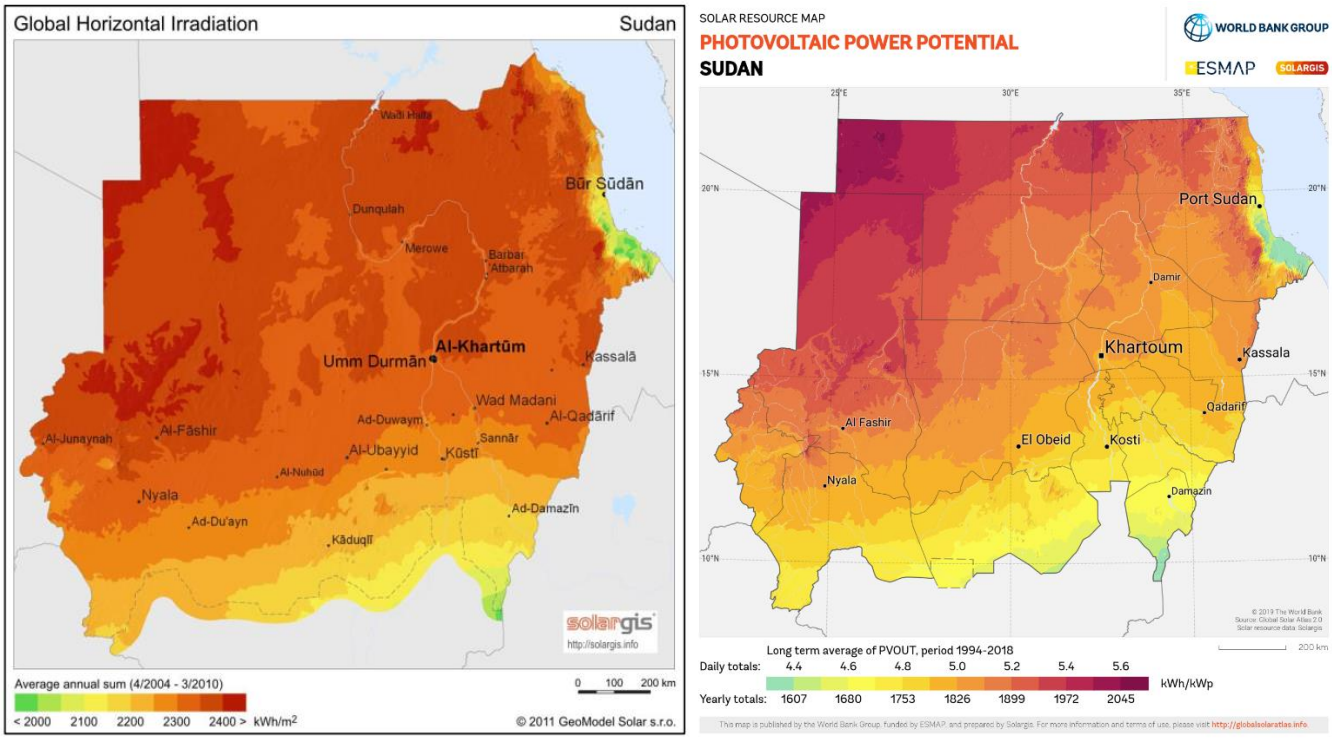
As indicated, Sudan has a very high technical potential for renewable energy resources (hydro, solar, wind), which presents a big opportunity to meet local energy demand and reduce energy poverty in the country. To promote RE, the Ministry of Water and Electricity established a Directorate for Renewable and Alternative Energy in 2010 consisting of four divisions: (1) Solar energy; (2) Wind energy; (3) Geothermal energy; and (4) Alternative energy.

3.2.1 Solar energy

Sudan published a solar atlas in March 2012. Figure 2 below shows the potential for electricity generation from solar PV (photovoltaic) power throughout Sudan, as estimated in the World Bank Solar Atlas. The average duration of daily sunshine across Sudan is about 9 hours. The annual average solar radiation exceeds 2000 kWh/m^2, which is considered to be among the highest globally (Ministry of Water Resources, Irrigation and Electricity, 2012a).

Most of the solar installations in Sudan are photovoltaic cells. The total installed capacity is about 2 MW. About 50% of the installed capacity is managed by the telecommunications industry. All remote off-grid antennas and satellites are solar-powered.

Figure 2: Solar resource maps of Sudan' photovoltaic electricity potential



Source: The World Bank (2019).

3.2.2 Wind energy

Sudan published a wind atlas in March 2012. Based on this atlas, three areas with the potential to host wind power projects have been identified: (1) the Jabel Mara Mountains in Western Sudan; (2) Northern Sudan (Dongola); and (3) the Red Sea area. Studies indicate that mean wind speed is in the range of 5.1-7.1 m/s across the country (Ministry of Water Resources, Irrigation and Electricity, 2012b). UNDP with the Sudanese Government has implemented the Wind Energy Project (2015-2020), which aims to scale up wind power in Sudan.

Wind energy in Sudan is currently used for pumping water from both deep and shallow wells to provide water for drinking and irrigation. This application is presently being applied in the North, Khartoum, Central Butana and Nile States. The attractiveness of wind pumps is that they can be manufactured completely from locally available materials.

3.2.3 Biomass resources

Biomass refers to solid carbonaceous material derived from plants and animals. In Sudan, approximately 13.8 x 10^6 m^3 of biomass are consumed per year. Table 5 indicates that weeds, agricultural residues and animal waste represent more than 70% of biomass energy sources (Omer, 2018).

Tab 5: Annual biomass energy sources available in Sudan (10^6 tonnes)

Source	Volume of biomass (10^6 tonnes)
Natural and cultivated forestry	2.9
Agricultural residues	5.2
Animal wastes	1.1
Water hyacinth and aquatic weeds	3.2
Total	13.4

Annual biomass energy consumption pattern in Sudan (10^3 m^3)

Sector	Firewood	Charcoal	Total	Share per sector (%)
Residential	6,148	6,071	12,219	88.5
Industrial	1,050	12	1,062	7.7
Commercial	32	284	316	2.3
Quranic schools	209	0	209	1.5
Total	7,439	6,367	13,806	
Share per energy source (%)	54	46		100.0

(Omer, 2018)

Even though the technical potential for renewable energy is high, Sudan is far from being an emerging renewable energy market in the region. This can be demonstrated by the Regulatory Index for Sustainable Energy (RISE). This index is developed by the World Bank to assess countries' progress towards SDG7 by examining policies and regulations relating to energy access, energy efficiency, and renewable energy. Sudan's latest RISE score (2017) is 32/100, which is among the worst 25 countries globally and is also below-average for sub-Saharan Africa (35/100). However, the country is making efforts to further integrate renewable energy resources and aims to have 11% of electricity generation come from renewable energy by 2031 (Table 6), excluding from hydroelectric sources (RCREEE, 2012).

Tab 6: RE current and target profile

Current installed capacity							
	Wind	PV	CSP	Hydro	Total RE	Current total installed capacity (RE + Fossil fuel)	
NW	0	0	0	1590	1595	2723	
RE targets - year 2031 (excluding hydro)							
Wind	PV	CSP	BIOMASS	Small scale hydro	Waste to energy	Total	Target year
680	667	50	54	63	68	1582	2031

(RCREEE, 2012)

The current status of renewables in Sudan (as summarized by Alhaj, 2020) includes:

- The national renewable energy strategy and masterplan has not yet been finalized.
- Cumulative installed solar PV electric capacity is only 17 MW, which is less than 1% of installed hydropower capacity.
- The local market is currently almost exclusively focusing on solar-powered water pumping systems due to their economic competitiveness, while other applications of renewables are still underdeveloped.
- Wind and geothermal energy have zero share in the total electricity capacity.
- Customs and taxes on renewable energy equipment pose a burden on product importers and subsequently the customer. Moreover, Sudan's fragile economic conditions (high inflation rate, limited access to international funding, U.S. sanctions) have limited any kind of foreign investment in renewable energy.
- Data about renewable energy in Sudan is dispersed throughout several sources (missing or not published) and there is no central national database for researchers, investors and other stakeholders to refer to.

Most of the challenges can be attributed to poor governance and a dispersed institutional structure. An enabling environment for renewable energy in Sudan would include building institutions and developing human capacity, assessing resources and technology, mobilizing funds, and reforming policies, codes, and standards.

3.3 Land cover, land use and land degradation

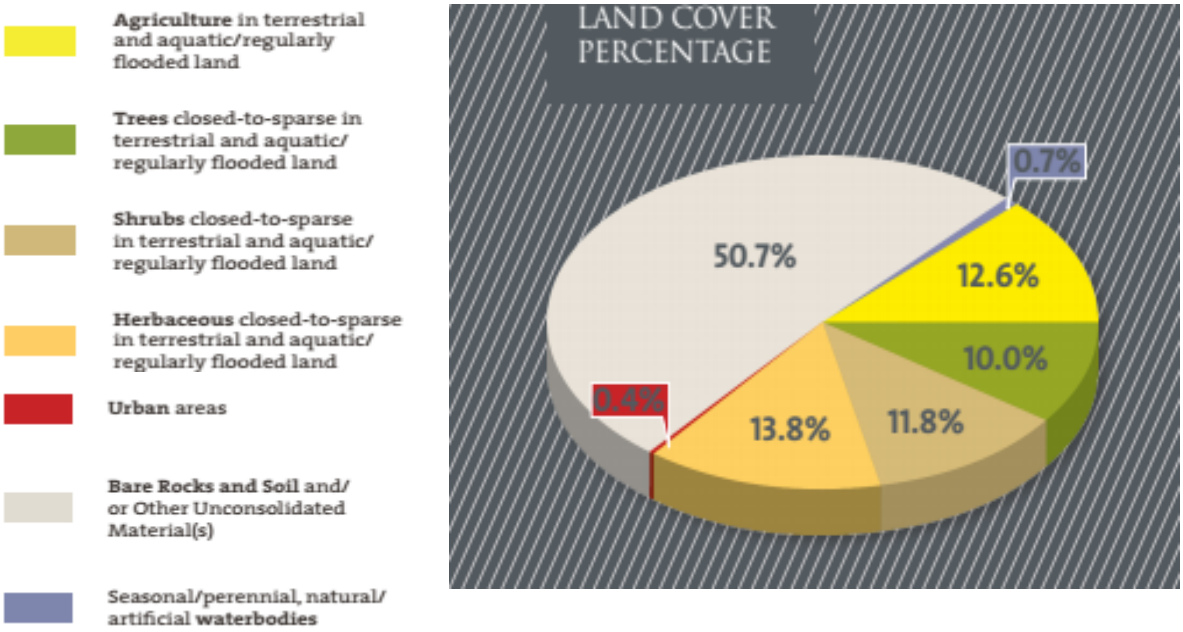
Sudan has an area of approximately 188 million ha. More than half of the country's overall land area (51%) consists of bare rocks and soil, while agriculture land consists of about 13%. Tree cover, shrubby vegetation and herbaceous vegetation all together constitute about 36% of Sudan's total land area (Table 7 and Figure 3).

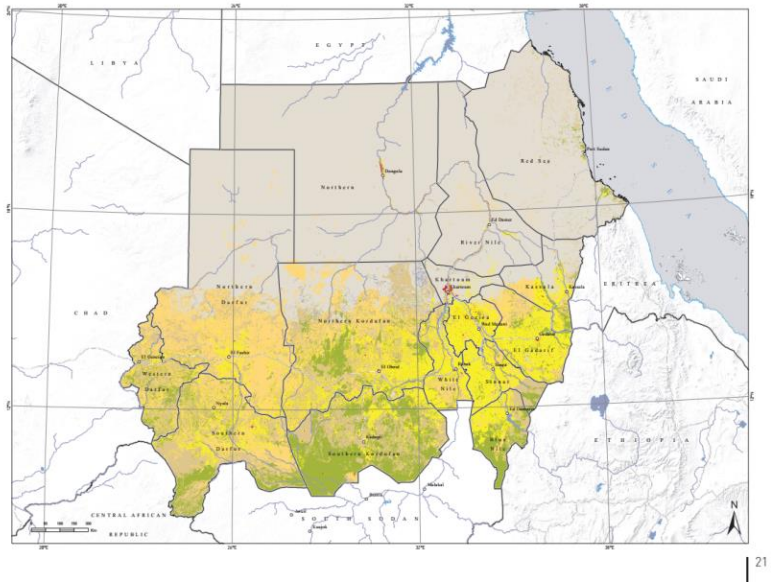
Tab 7: Sudanese land cover classes in hectares

Land Cover Class	Area (ha)	(%)
Agriculture in terrestrial and aquatic/regularly flooded land	23,710,025	12.6
Trees closed-to-sparse in terrestrial and aquatic/regularly flooded land	18,733,182	10.0
Shrubs closed-to-sparse in terrestrial and aquatic/regularly flooded land	22,231,327	11.8
Herbaceous closed-to-sparse in terrestrial and aquatic/ regularly flooded land	25,982,720	13.8
Urban areas	730,331	0.40
Bare Rocks and Soil and/or Other Unconsolidated Material(s)	95,277,727	50.7
Seasonal/perennial, natural/ artificial water bodies	1,290,000	0.70
Total Sudan area(ha)	187,955,312	100
Total Sudan area =1,879,553.12 km^2		

(FAO, 2012)

Figure 3: Sudanese land cover





Source: FAO (2012).

3.3.1 Land use

a. Farming land use

On average, cultivated land in the Sudan makes up around 20 to 22 million ha consisting of annual and permanent crops, which represents approximately 25% of the total arable land classified as suitable for agriculture (estimated at 85 million hectares). Traditional rain-fed agriculture covers the largest part of the cultivated land by far in Sudan, accounting for about 11-12 million ha. Mechanized rain-fed farming accounts for about 7-8 million ha, while irrigated farming accounts for about 2-2.5 million ha. The area actually cultivated and harvested in the rain-fed sector (traditional and mechanized) varies considerably from year to year depending on rainfall variability. The main cultivated crops, occupying more than 90% of the cultivated area, are sorghum, millet and wheat (cereals), as well as sesame, groundnut and sunflower

(oil crops). Sorghum is the dominant crop in terms of area, as it occupies more than 50% of the of total cropland area (Table 8).

Tab 8: Land use by major crops

Crop	Area Planted (000 ha)	Crop	Area Planted (000 ha)
Sorghum	10,708	Groundnut	2,526
Wheat	0,211	Sesame	2,683
Millet	3,555	Sunflower	0,114
Cereals Grand Total	14,474	Oilseeds Grand Total	5,323
Cereals+ Oilseeds Grand Total			19,797

(Osman, 2020)

Mechanized rain-fed farming is practiced in about 7-8 million hectares distributed across several states where rainfall exceeds 400mm and is composed of large to medium-size farming units of about 200-400 ha each. It is characterized by the use of machinery in land preparation and threshing but also by the dependence on seasonal labour. This system's share in the overall cultivated land area is 35% and accounts for about 65% of the sorghum, 53% of the sesame and almost 100% of the sunflower crops produced in Sudan. Historically, this has been a source of sorghum exports as well as meeting internal needs, particularly in urban areas.

Despite the major role of the mechanized rain-fed farming system in attaining food security, supplying raw materials and employing a considerable amount of the labour force in the country, the means for development of this sector are still limited. Farmers still use traditional tools and machinery as well as traditional cultural practices and suffer from low productivity. Major constraints in this sector include soil degradation and the spread of pests and diseases, poor infrastructure, poor untimely finance, poor services and lack of drinking water, which limits the permanent settlement of farmers.

The massive expansion of mechanized farming in Sudan has been accompanied by the large-scale destruction of natural forests and habitats. These practices have also been associated with the blocking of traditional stock routes, shrinking of rangelands and widespread soil degradation and conflicts. In the 1990s, the Ministry of Agriculture and Forestry articulated an obligation that 10% of each scheme area be allocated to shelterbelts. However, the enforcement of this requirement was slow due to a lack of awareness about the law, a lack of tree seeds, seedlings and equipment, and the scarcity of water.

b. Rangelands and pasture

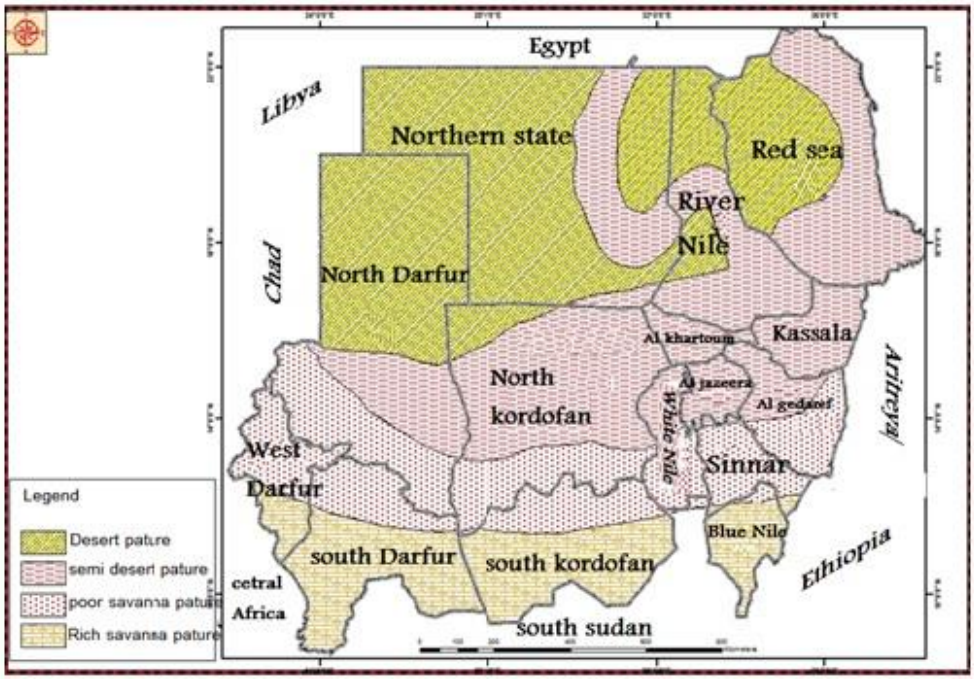
Rangelands form the backbone of the livelihoods of pastoralists and agro-pastoralists through the provision of feed resources are needed. Natural rangeland extends throughout the different ecological zones, including annual herbaceous plants with scattered trees and bushes and perennial herbaceous plants with dense stands of woody cover (Figure 4). However, nearly 80% of all rangelands are located in the semi-desert and low rainfall savannah ecological zones. An assessment done in 1997 estimated that rangeland areas cover about 117 million hectares (RPA, 1993). However, recent estimates indicate that natural range area is now about 67 million ha, i.e. about 36% of Sudan area (Table 9), producing below-average annual rainfall, and supplies about 73% or approximately 62 million tons of the total feed requirement for national herd (FAO, 2012; Sawsan, 2015).

Tab 9: Estimated available natural range area

Range type class	Area (million ha)	(%) of range area	(%) of Sudan area
Trees closed (dense) -to –sparse (dispersed) in terrestrial and aquatic/regularly flooded land	18,733,182	28.0	10.0
Shrubs closed (dense) -to -sparse (dispersed) in terrestrial and aquatic/regularly flooded land (shrubs close to open)	22,231,327	33.2	11.8
Herbaceous closed (dense) -to -sparse (dispersed) in terrestrial and aquatic/regularly flooded land (Herbaceous close to open vegetation)	25,982,720	38.8	13.8
Total natural range area	66,947,229	100	35.6

(Sawsan, 2015)

Figure 4: Natural Pastures in Sudan



Source: Abdel Razek (2017).

c. Forest

The FNC estimated the forest area to be about 22 million ha, comprising a forest cover of about 12% of total land mass. Forests in Sudan falls under three types (Sudan (ISP)):

1. Federal forests. Forest management is directly under the control of the central FNC. This includes riverine forests along the Nile and its tributaries, all other montane forests and forests north of 13 degrees latitude.
2. State forests. All state forests away from the rivers and all those forests under registration according to the National Comprehensive Strategy (NCS). The forest management is under the control of the FNC in the specified state where the forests are located.

3. Community/private forests: All forests established and to be established by communities and private sector.

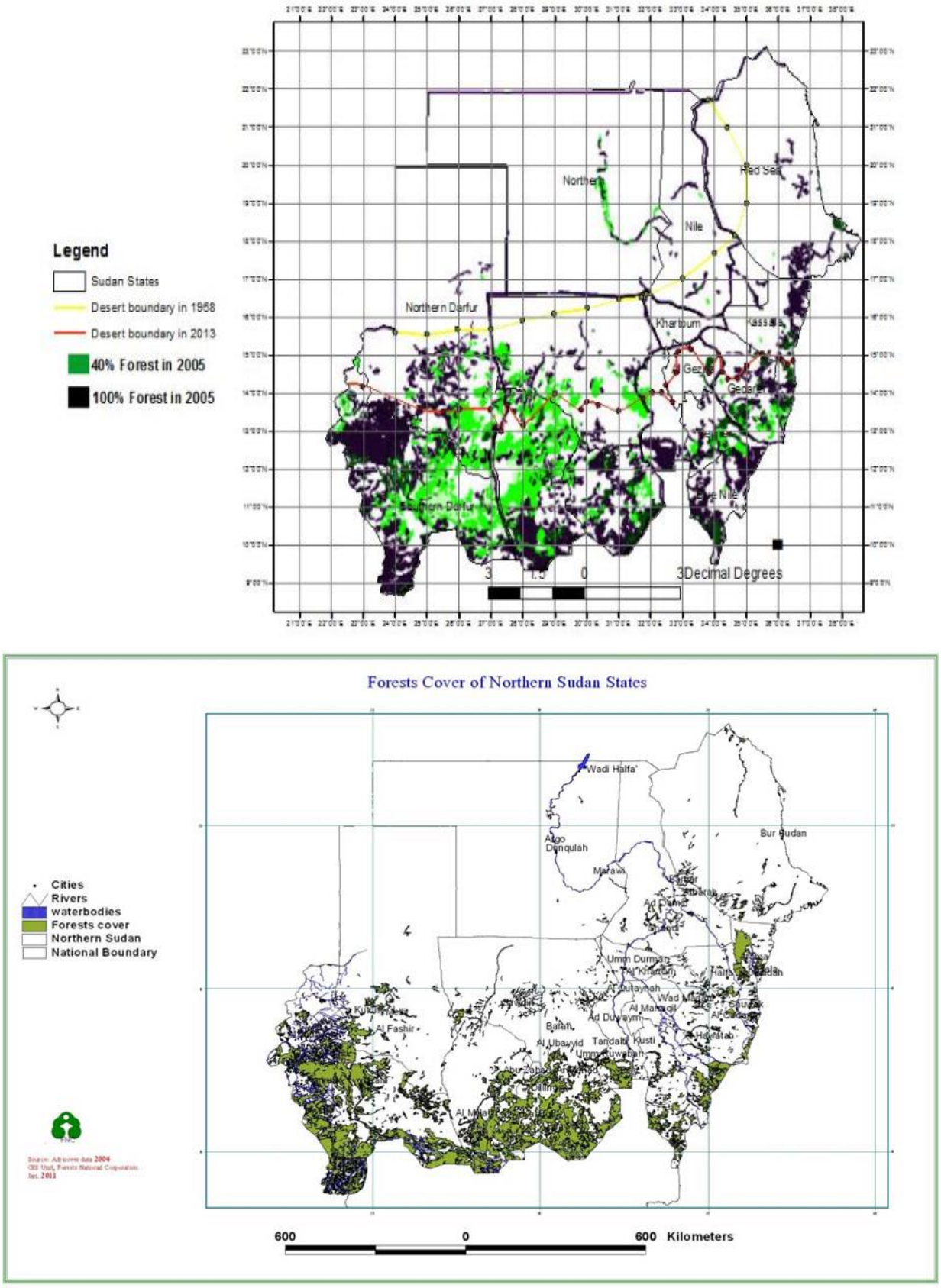
Since the early 1900s, extensive areas of woodland and forests have been converted to agricultural use. FAO data shows that total forests have decreased to 11.6% of the total country area between 1990 and 2005. The UNEP (2007) estimated an increase in deforestation at an annual rate of over 0.84% at the national level. In Darfur, one-third of the forest cover was lost during 1973–2006. UNEP indicates that forest cover could decline by > 10% per decade, with complete loss expected within the next 10 years in high pressure areas. The rate of afforestation and reforestation in Sudan is far behind the rate of tree felling at 250,000 vs. 1,301,970 feddans (1 feddan = 0.42 ha). The FNC estimates that annual deforestation is 2.4% and that deforestation has been significant. This has created conditions conducive to degradation, deforestation and desertification (Figures 5, 6, and 7). Despite the declining forest cover and loss of biodiversity, some efforts have been taken to conserve forest genetic resources as indicated by the increased number of seedlings produced and the number and area of reserved forests between 2012 and 2016 (Table 6). A land use category map is presented in (Figure 8).

Tab 10: Forest Reservation 2012-2016

Year	No. of reserved forests	Area of reserved forests (fed.)
2012	12,102,296	4,341
2013	29,695,498	4,526
2014	30,396,156	4,952
2015	31,502,356	5,268
2016	819,419	112

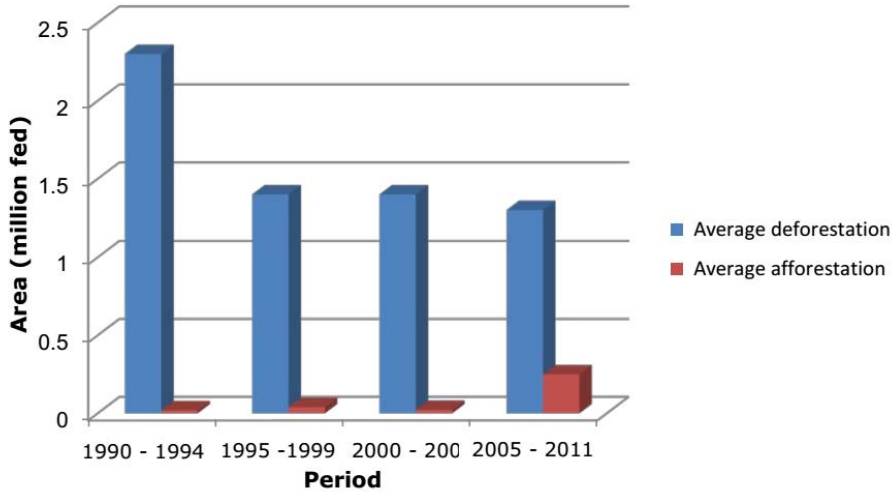
(FNC, 2016)

Figure 5: Sudan forest cover in 2005 (above) and in 2011 (below)



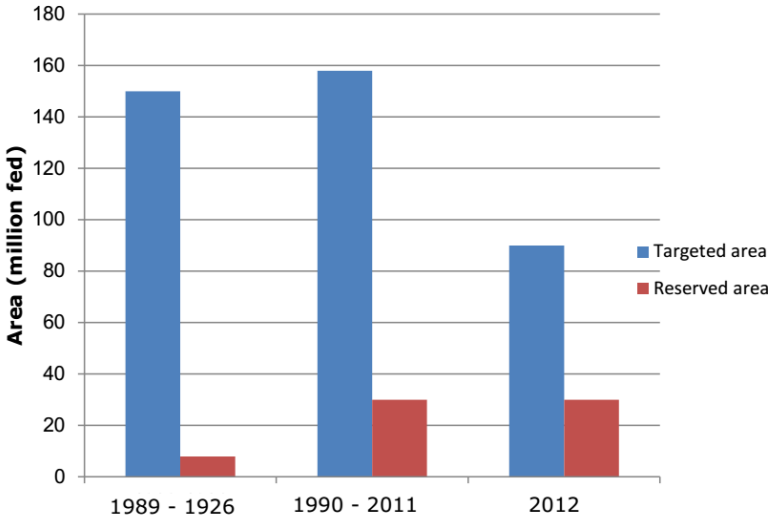
Source: FNC (2005, 2011).

Figure 6: Average afforestation area vs. average deforestation area



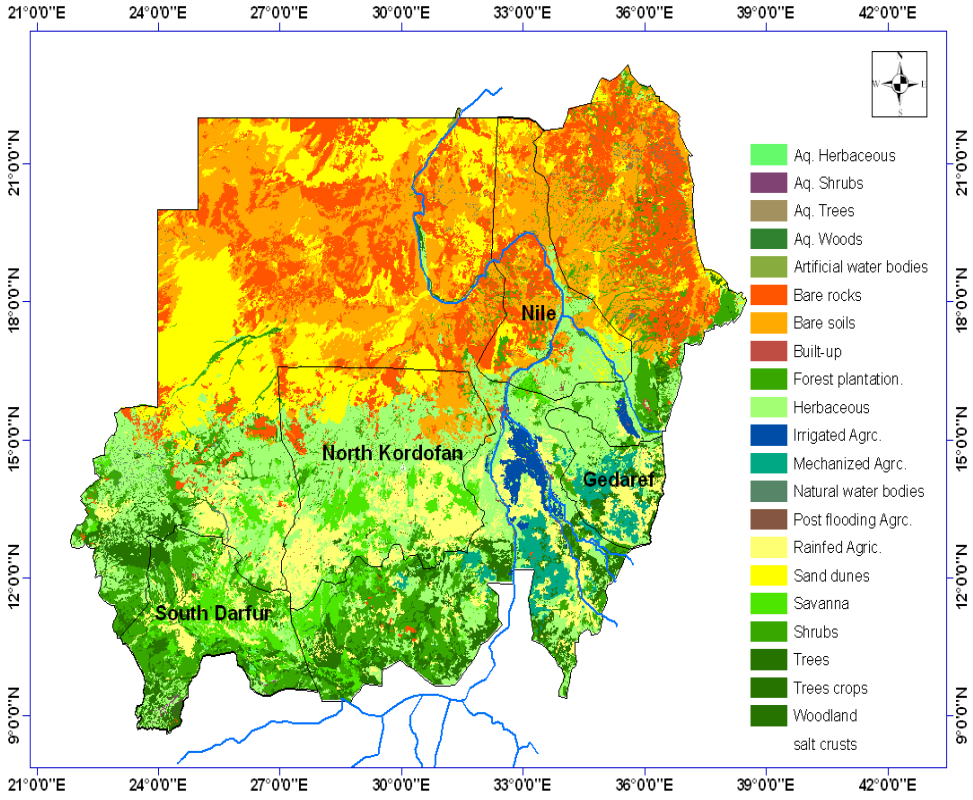
Source: Republic of Sudan & HCENR (2014).

Figure 7: Targeted vs. executed afforestation area



Source: Republic of Sudan & HCENR (2014).

Figure 8: Land use category map



Source: ARC (2007-2017).

3.3.2 Desertification and land degradation

Sudan is one of the African countries most seriously affected by desertification and the problem of land degradation has been recognized within Sudan since the early twentieth century. Evidence of land degradation is widespread and includes soil erosion, soil fertility mining, soil compaction, water logging and surface crusting. According to several studies, the major destructive features of human activities leading to noticeable change in aridity, desertification and land degradation in Sudan are: (1) overgrazing; (2) over and irrational cultivation (expansion of agriculture into forestlands); (3) wood cutting and deforestation i.e. mismanagement of forest resources; (4) uprooting of shrubs and trees; (5) lowering of water table due to increased water use; (6) burning of grasslands, forest and scrub; in addition to (7) droughts and high variability of rainfall (Ayoub, 1998; Laki, 1994).

a. Current status and extent of desertification in Sudan

- Desertification occurs to varying degrees in the areas (440,000 km^2) lying between latitudes 10 and 18 N and traverses the country from its eastern to its western borders. The most degraded zones are the arid and semi-arid zones in northern, central, eastern and western Sudan, where 76% of the human population lives (Wakeel, 2011).
- Deforestation is one of the main causes of desertification. Between the years 1990 and 2005, Sudan lost about 8.8 million hectares, or 11%, of forest, mainly because of subsistence activities such as overgrazing, trees cutting and expansion of traditional agriculture (Muneer, 2008).
- GIS and remote sensing technology have been used recently to evaluate and monitor the process of desertification in Sudan. Results indicate that, since 1958 up to 2017, most of the country was covered by desert and semi-desert. The desert boundary has moved further to the south since

initially observed in 1930, pushing the country towards a historical desertification disaster (Eltoum et al., 2015; Sarra et al., 2018; Eltoum, 2017).

- A classification map of Landsat data for the years of 2000 to 2014 indicates a significant decline in the vegetation cover in 2000, 2009, and 2014, which is consistent with those of other studies. Meanwhile, the desert areas have expanded rapidly into the southern parts of Sudan during the same temporal periods, at the expense of vegetation (Eltoum et al., 2015; Mohamed, 2016; Eltoum, 2017).

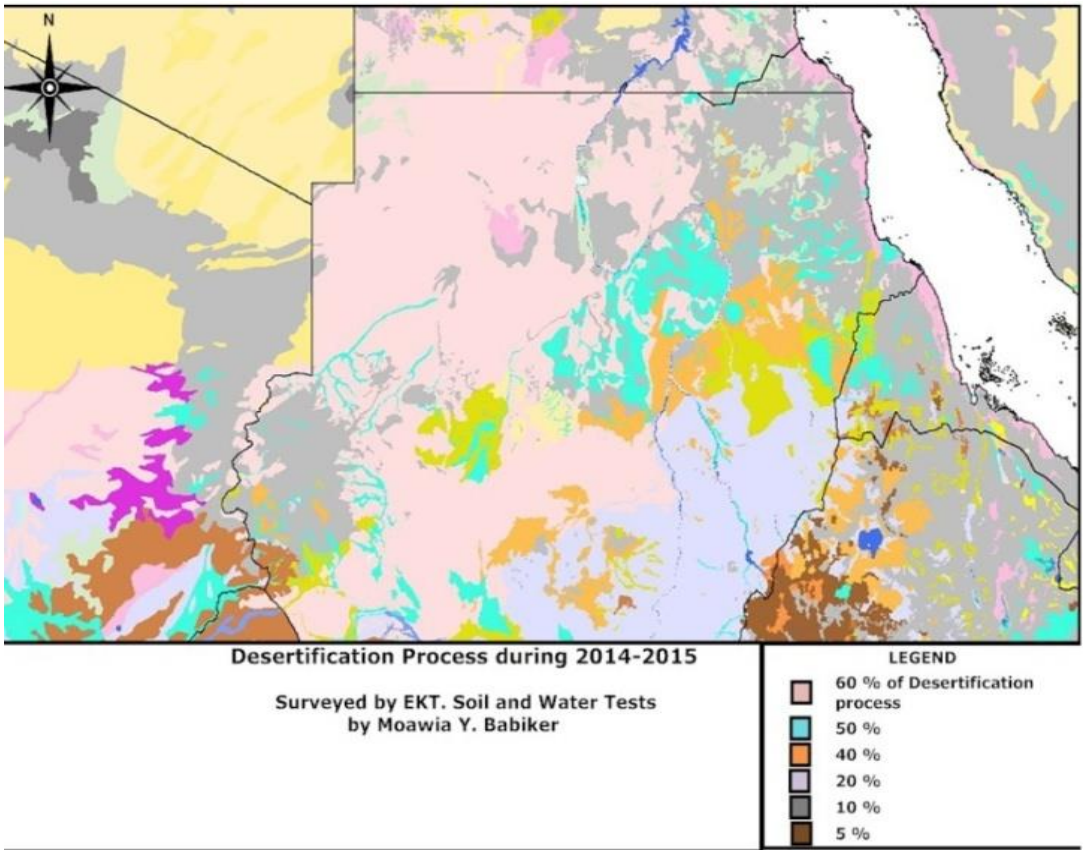
Tables 11 and 12 as well as Figures 9, 10 and 11 represent the movement of the desert boundary and the rate of this movement in several states of Sudan.

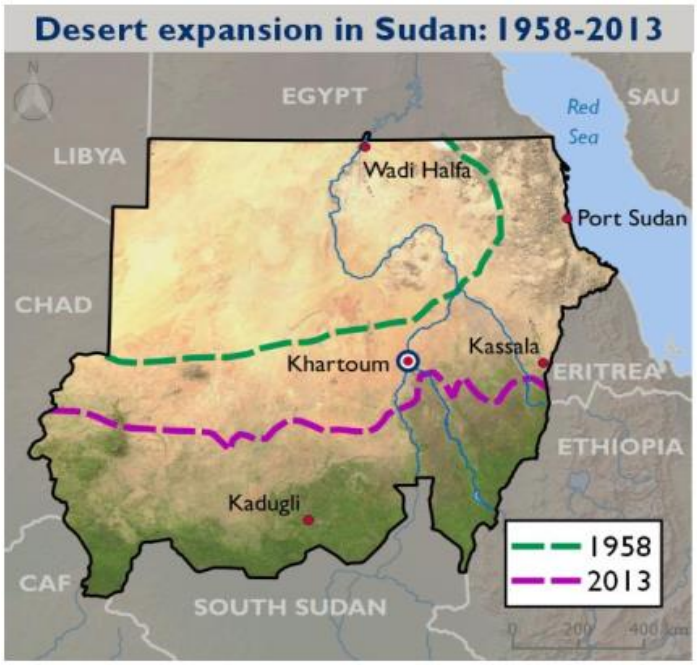
Tab 11: Desertification status in Sudan

Rainfall (mm)	Total area (1000 km^2)	Latitude (Deg. North)	Area affected (1000 km^2)	Recent Affected (%)	Desertification Class
0-100	307	14-18	74.91	24.4	Desert
100-300	414	13-14	136.21	32.9	Very severe
300-600	513	12-13	208.79	40.7	Moderate
600-800	25	11-12	0.5	2.0	Very Slight
>800	0.8	10-11	0.06	7.5	Very Slight
Total	1 260		420.41	33.3	

(Eltigani, 1996)

Figure 9: Desertification during 2014-2015





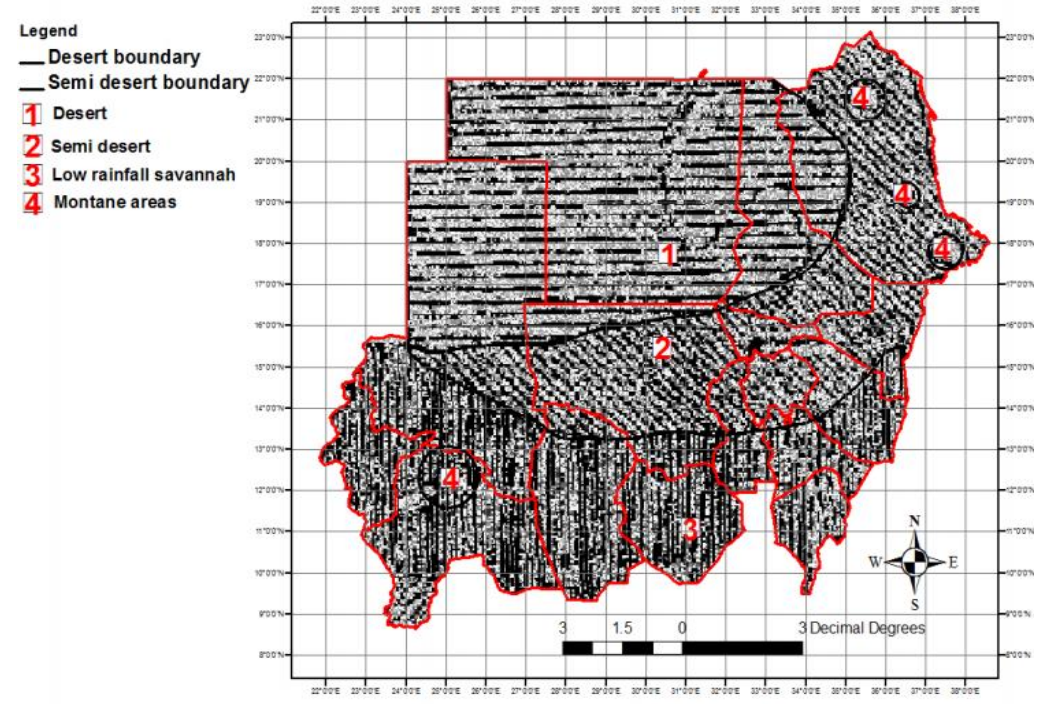
Source: Eltoum (2015), Sarra et al. (2018) and adapted from USAID Country Fact Sheet (2016).

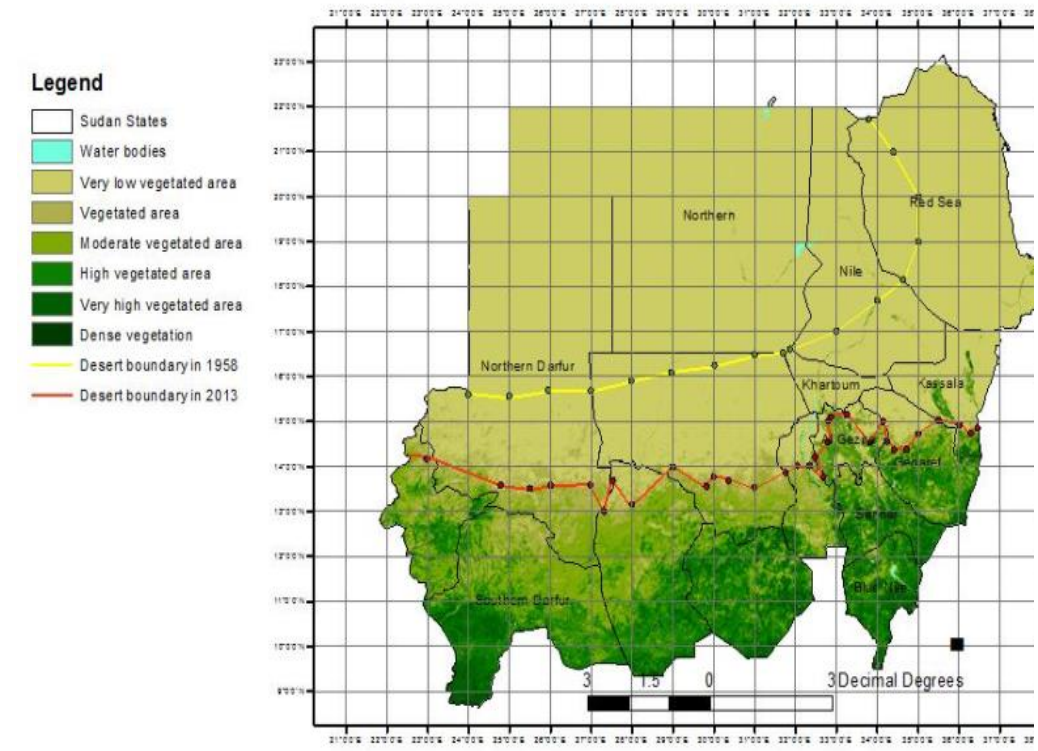
Tab 12: Movement of the desert boundary from 1958 to 2017

State	Location in 1958		Movement of the desert boundary in kilometers until 2017	Rate of movement in KM/year in 2017
	Longitude	Latitude		
Darfur	23.99	15.607	145	3.6
Darfur	24.99	15.562	220	5.5
Darfur	25.949	15.693	300	7.5
North Kordofan	26.99	15.693	320	8
North Kordofan	27.98	15.905	300	7.5
North Kordofan	28.967	16.09	290	7.2
North Kordofan	30.015	16.2444	300	7.5
North Kordofan	31	16.49	350	8.75
Khartoum	31.863	16.613	350	8.75
Khartoum	31.699	16.524	380	9.5
River Nile	33.001	17.018	350	8.75
River Nile	34	17.692	326	8.15
River Nile	34.635	18.154	450	11.25
Red Sea	35	19	430	10.75
Red Sea	35	20	540	13.5
Red Sea	34.398	21	675	16.9
Red Sea	33.792	21.725	775	19

(Eltoum, 2017; Eltoum et al., 2015)

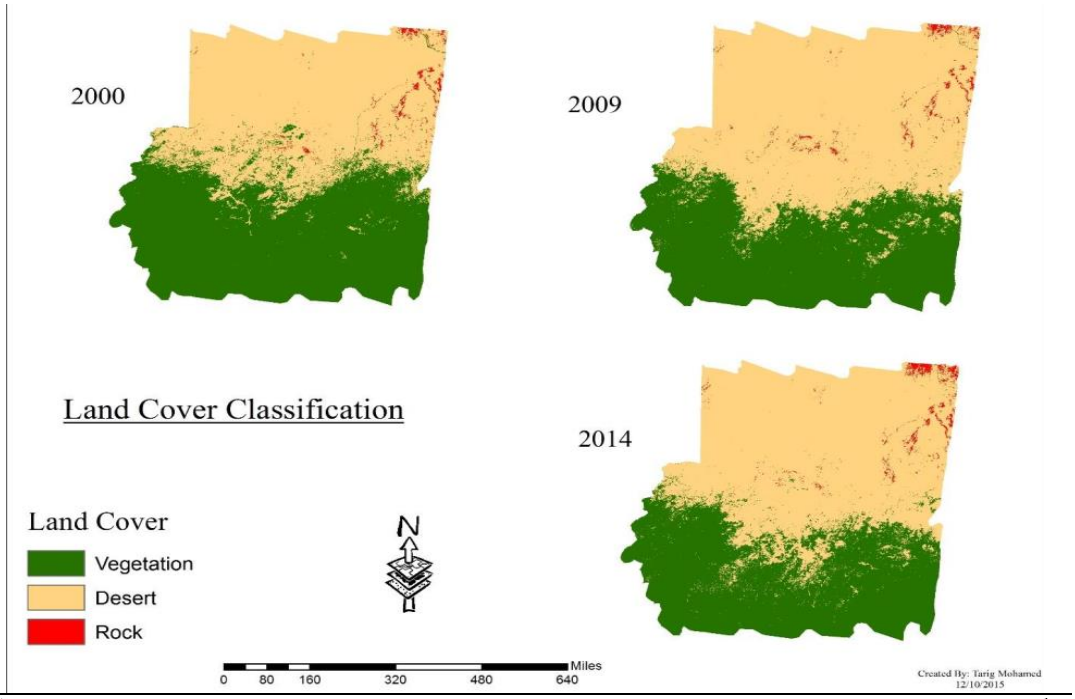
Figure 10: Sudan vegetation map 1958 and
Sudan vegetation map produced from MODIES EVI5 2013

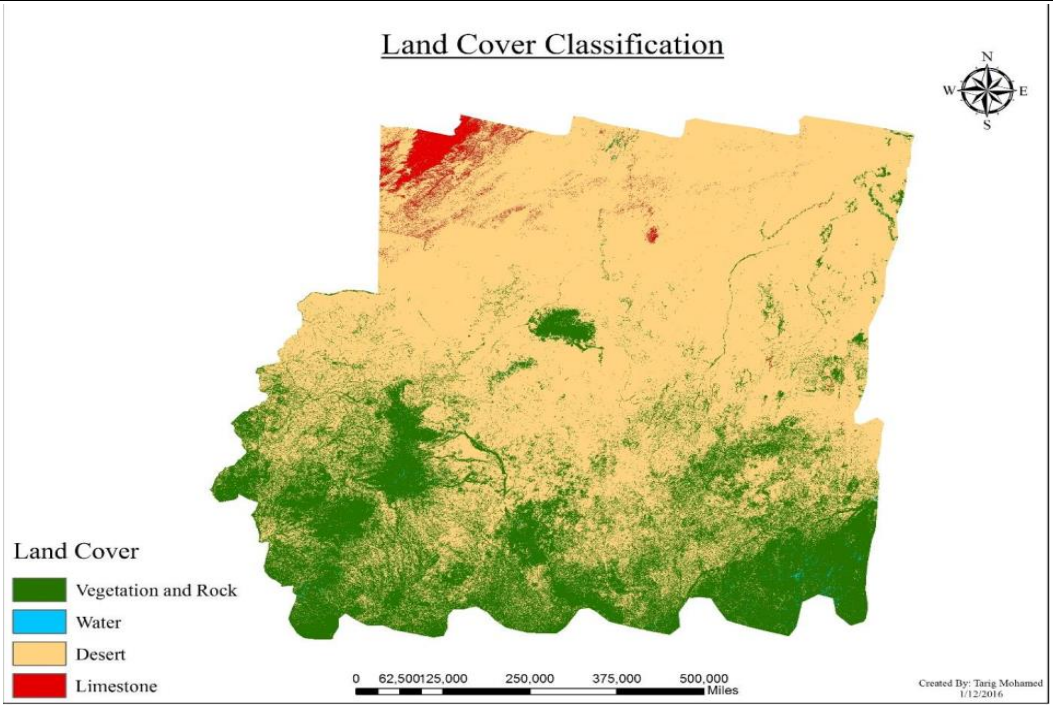




Source: Eltoum (2017) and Eltoum et al. (2015).

Figure 11: Land cover classification using ANN and MODIS in 2000, 2009, and 2014 and land cover classification of Landsat data 2014 (ANN)





Source: Mohamed (2016).

b. Impacts of desertification on food security, poverty and urbanization

Most of the population in the states affected by desertification rely heavily on natural resources (cultivation of marginal sandy soils, tree and vegetation cutting for fuel and construction of huts and overgrazing) for subsistence. Thus, there is a strong relationship between desertification and food security. Regions of severe land degradation coincide with regions of severe food insecurity and aggravated poverty (Wakeel, 2011). The food security situation in some states experiencing severe desertification indicate food

deprivation among 20 and 27% of the population and a hunger gap from 255 to 296 kcal/cap/day. The poverty incidence ranges from 55 to 60% (Table 13).

Tab 13: Food security situation and poverty incidence in some states experiencing very severe desertification

Region	Name	Food deprivation (%)	Hunger gap (kcal/cap/day)	Poverty incidence (%)
Darfur States	West Darfur	20	255	55.6
	East Darfur	32	296	61.2
	West Kordofan	27	256	60.0

(Extracted from: Bashir and Faki, 2014)

Furthermore, Ayoub (1999) indicated that in Sudan, regions of partial to severe food insecurity are those that experience high to very high soil degradation and nutrient depletion through top soil loss, mainly by wind erosion, while food insecurity and nutrient depletion is not experienced in areas where soil degradation is mild to moderate (Table 14).

Tab 14: Food insecurity and soil conditions in selected areas of Sudan

Region	Food Insecurity	Soil degradation	
		Type	Severity
Red sea	Major-severe	Top soil loss through water and wind erosion	High
Sennar	No problem	Top soil loss through water erosion	Light
Blue Nile	No problem	Top soil loss through water erosion	Light
North Kordofan	Partial-major	Top soil loss through wind erosion	very high
		Nutrient depletion	High
South Kordofan	No problem	Top soil loss through water erosion	Medium
North Darfur	Partial-major	Top soil loss through wind erosion	very high
		Nutrient depletion	High

(Ayoub, 1998)

In addition, desertification is considered one of the main factors driving the migration of rural populations to urban centres; thus, creating so-called “environmental refugees” (Black et al, 2008). There are an estimated six million internally displaced persons (IDPs) in Sudan, displaced largely by drought, desertification and famine, thereby encouraging the urbanization process (UNEP, 2007).

Several attempts were made to formulate regulations and legislations and to comply with international and regional agreements for combating soil degradation and desertification. These efforts include:

- 1972, 1979: Establishing the National Committee for Combating Drought and Desertification in 1972 and assigning a permanent Council for Desertification in 1979 to follow up on desertification control projects
- 1991: The Drought and Desertification Coordination Unit (NDDU) was established
- 1995: Sudan became one of the first countries to ratify the United Nations Convention to Combat Desertification (UNCCD)
- 2002: The National Action Program was submitted to the Secretariat of the International Convention to Combat Desertification
- 2009: The Desertification Law provided for the establishment of a national council under the auspices of the President of the Republic

- 2015: According to the 2015 Presidential Decree No. (32), the task of combatting desertification became the responsibility of the Ministry of Environment, Natural Resources and Urban Development

Despite these efforts, desertification in Sudan remains a major environmental threat. An integrated approach that combines and links sectors such as forestry, land use, agriculture and socio-economic planning is essential.

3.4 Empowering women: Closing gender disparities

Women constitute about 49% of Sudan's population. The country ranks 129th out of 147 countries on the Gender Inequality Index. This index ranking is a calculation of maternal mortality rate, adolescent fertility rate, females in the national parliament, portion of the population with at least a secondary education, and the labour force participation rate (UNCEF, 2017).

Historically, women, particularly in the traditional rain-fed agriculture sector, are active family members with very significant contributions to food security and family income. Table 15 indicates that women contribute 45% of crop production and that their contribution is increasing over time to reach more than 50 %.

However, their access to production resources and markets is limited due to cultural factors. Externally funded development projects have made significant contribution in gender main streaming and women empowerment over the last twenty years. The project experience of the International Fund for Agricultural Development (IFAD) has shown that where women have access to capacity building and microfinance, they perform outstandingly. Economic empowerment is still low; however, Sudan has made significant progress towards the gender empowerment related MDGs (Table 16). Overall, women's empowerment is hindered by illiteracy, customary law, social pressures, heavy workloads and enormous cultural and economic limitations.

Tab 15: Contribution of family members towards food security

Crop	Women	Men	Children (boys &girls)
Sorghum	**41.7**	**33.5**	**24.8**
Millet	**37.3**	**44.1**	**18.6**
Sesame	**53.2**	**33.9**	**12.9**
Groundnut	**52.8**	**26.4**	**20.8**
Field watermelon	**40.0**	**40.0**	**20.0**
Average	**45.0**	**35.58**	**9.42**
Promotion of women's contribution to agricultural production			
1988-1987	**45.9**	**36.2**	**15.7**
2007-2006	**52**	**28**	**20**

(Bushara, 2019)

Tab 16: Sudan's progress towards gender empowerment related MDGs

	Indicators	Current Status
MDG1.2	Proportion of the population below the national poverty line	46.5%
MDG3.1	Ratio of girls to boys in primary education	46.1. to 50.3%
	Ratio of girls to boys in secondary academic and technical education	51.6 to 49.4 %
	Ratio of girls to boys in tertiary education	54.1%
MDG3.2	Ratio of women to men in employment in non-agricultural sectors	59%
MDG3.3	Proportion of seats held by women in national parliament	25%

(The Republic of Sudan, 2010)

3.4.1 Women's empowerment and representation in decision-making positions

After independence, gender equality has become one of the priority issues for development in Sudan. During the period 1991-2005, several laws and regulations related to gender or women were established (Table 17). According to the 2018 United Nations Human Development Report, 31% of parliamentary seats are held by women, and 14.7% of adult women have reached at least a secondary level of education compared to 19.3% of their male counterparts. After the very recent 2019 political change, serious steps have been taken to upgrade women's status. This is demonstrated in that women comprise one third of the transitional ministerial council and are expected to hold 40% of national legislation council seats, and that the Sudanese government has repealed all laws restricting women's freedom of dress, movement, association, work and study. The main gender bottlenecks and barriers identified by UNICEF Sudan (2017) are women's and girls' lack of knowledge and limited access to information services, dual responsibilities, lack of participation in decision-making and limited access to resources and services.

Tab 17: Laws and regulations related to gender or women

Laws and regulations	Date	Content
Criminal Act	1991	• Several laws and regulation have been established to protect women. This includes some crimes against personal freedom, e.g., rape, abduction, abortion and kidnapping
Muslim Personal Status Act	1991	• Provides for women the rights to have custody, alimony, dowry, ownership over property and socialization with her close relative
Labour Act	1997	• Includes various women's rights, e.g., delivery leave, work conditions, daily rest hours, etc.
The Interim National Constitution	2005	• Includes numerous directives aimed at preserving motherhood and promoting gender equality • Obliges the State to adopt the appropriate policies and measures for ensuring social justice, healthcare, free basic education and welfare to all citizens
Political Parties Act	2007	• Secures female representation at all levels of workers' unions
National Civil Service Act	2007	• Provides the right to compete for the civil service for all, that is, gender equality
National Public Health Act	2008	• Includes women and children's right to free basic healthcare
National Elections Act	2008	• Provides affirmative actions for securing women's equality • Representation in the National and State Assemblies
Workers' Unions Act 2010	2010	• Provides affirmative provisions for securing female representation in workers' unions • Stipulates female representation in any trade union at the national or state level, which should not be less than 25%

(JICA, 2012)

4 Observed and projected impacts of climate change

4.1 Climate change

The Global Adaptation Index (ND-GAIN, 2015) indicates that Sudan is among the countries most vulnerable to climate change in the world, ranking 175th out of 181 countries. According to Sudan's National Adaptation Plan of Action (NAPA) and its First National Communication to the UNFCCC, the agriculture, water and health sectors have been identified as the three highest priority sectors that are most vulnerable to climate change and climate variability. In addition, vulnerability studies undertaken as part of Sudan's NAP indicate that within Sudan, the traditional rain-fed sector is the most vulnerable, as more than two-thirds of the population in this sector are directly dependent on climate-sensitive resources for their livelihood. Challenges that exacerbate this situation include: endemic poverty; limited access to capital, including markets, infrastructure and technology; mismanagement of natural resources and ecosystem degradation; and complex disasters and conflicts. These, in turn, have negatively affected the population and weakened their adaptive capacity, hence, increasing their vulnerability to projected climate change (Nimir & Elgizouli, 2011).

4.2 Climate change and trends

4.2.1 Extreme climate events

Table 18 summarizes the types of the extreme weather and climate events, vulnerable sectors and the observed negative impacts on community livelihoods in Sudan (NAPA, 2007).

Tab 18: Extreme climate events in Sudan – Sectors affected & impact categories

Event	Occurrence	Vulnerable areas	Sectors	Impacts
Drought	Frequent	North & Western Sudan (North Kordofan and Darfur), Kassala State and some parts of the rain fed areas in central Sudan	Agriculture, livestock, water resources and health	Loss of crops and livestock (food shortage); decline in the hydroelectric power; displacement; wildfires
Floods	Frequent	Areas within the River Nile basin and low areas from extreme South to far North; Mountain areas along Red Sea	Agriculture, livestock, water resources and health.	Loss of life, crops, livestock; insects & plant diseases; epidemic/vector diseases; decline in hydro power; damage to infrastructure & settlement areas
Dust storms	Frequent	Central and northern parts of Sudan	Aviation and Transport (land traffic)	Air and land traffic accidents and health
Thunder - storms	Infrequent	Rain-fed areas throughout all Sudan	Aviation	Loss of life and property
Heat waves	Rare	Northern, central parts of Sudan besides the Red Sea State	Health, agriculture & livestock	Loss of life, livestock and crops
Wind storms	Rare	Central and north central Sudan	Settlements and service infrastructure	Loss of life, property; damage to infrastructure (electricity and telephone lines)

(NAPA, 2007; Zakieldeen, 2009)

4.2.2 Historical and projected climate trends

The climate projections for Sudan indicate an increase in temperatures and a decrease in rainfall. Historical and projected climate trends are summarized in Table 19 below.

Tab 19: Historical and projected climate trends

Historical climate trends	Projected changes in climate
Steady rise of temperatures between 0.2°C and 0.4°C per decade from 1960–2009. Increase in annual dry season rainfall totals by 20–30 mm per decade in the extreme north and south. Decrease in annual rainy season rainfall totals by 10–30 mm per decade, primarily in the west. Increase in year-to-year variability in the amount and timing of rainfall. Increase in the frequency of extreme climatic events, particularly drought in Kordofan and Darfur, as well as in part of central Sudan. While highly unpredictable, the frequency of floods has increased noticeably. Rise in Red Sea levels over the past century, between 10–20 cm.	Rising temperatures, by 0.5°C to as much as 3°C by 2050, with a more extreme temperature rise in the north. Temperature increases will intensify the impacts of drought through increased evapotranspiration and reduced soil moisture. Slight increases in rainfall (4% per decade), coupled with increased variability. The Sahara Desert is advancing at an estimated rate of 1.5 kilometres a year, and if current rainfall trends continue, the desert will continue to advance southward. Continuing rising levels of the Red Sea, between 30–50 cm by 2050, depending on the increase in temperature.

(USAID, 2016)

4.2.3 Rainfall Analysis

Analysis of the rainfall records (Table 20) from four meteorological stations has indicated the high rainfall variability in these stations during the 35-year period of 1981-2015. The coefficient of variation ranged from 26% to 44%. Additionally, Abdalla (2011) compared two mean annual normal rainfall isohyets, namely, the 200mm and the 500mm isohyets, for both 1941-1970 and 1971-2000, and concluded that there is a remarkable shift in the rainfall belt in the country.

Tab 20: Rainfall minimum, maximum, mean and coefficient of variation from four meteorological stations representing different production systems (1981-2015/17)

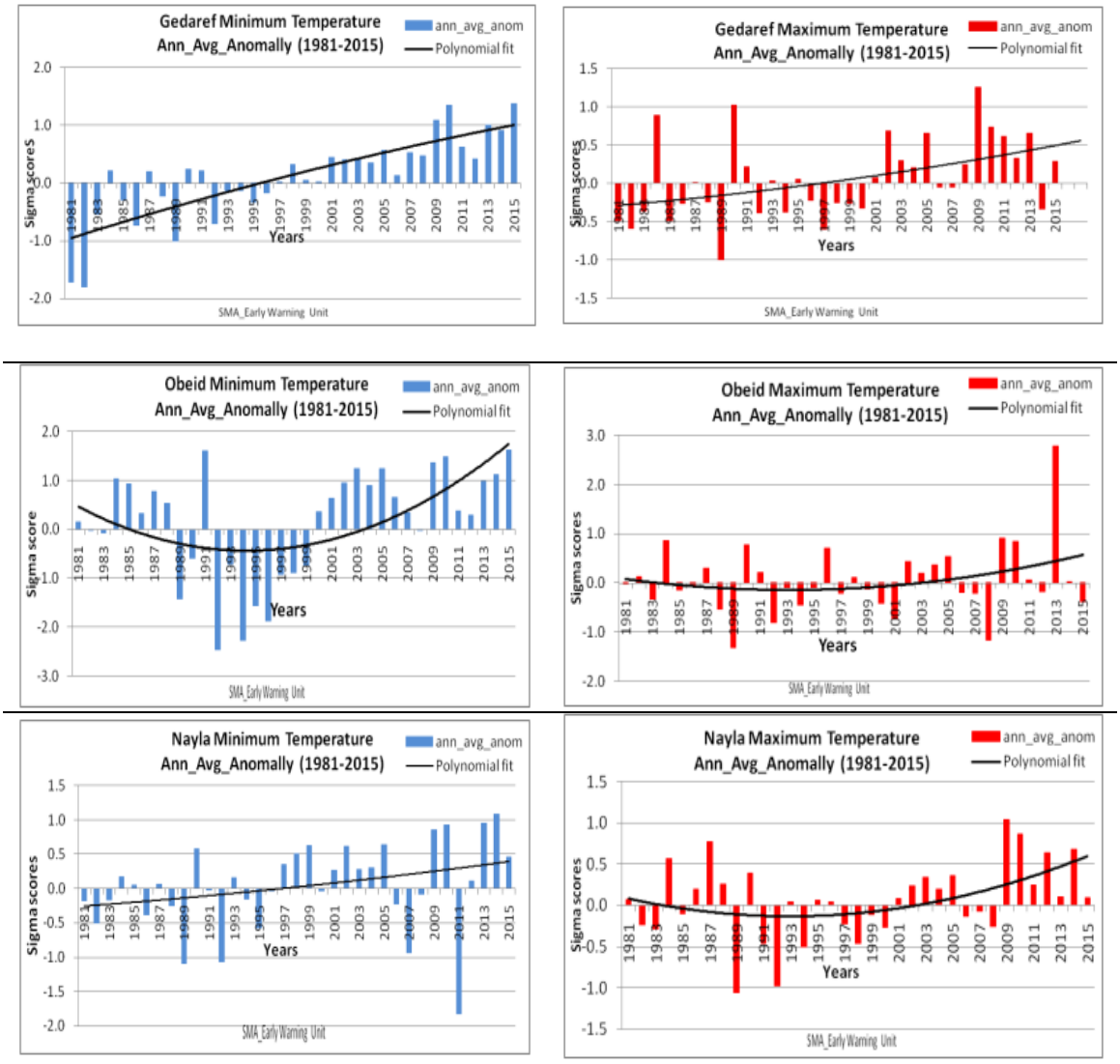
Station	Years	Min	Max	Mean	CV (%)	Production system
Gedarif	1981/2015	175	904	429	35	Mechanized rain-fed
Wad Medani	1981-2017	103	443	284	44	Irrigated
Nyala	1981/2015	197	626	384	26	Traditional rain-fed
El-Nohood	1981-2017	139	694	356	30	Traditional rain-fed

(Compiled and analyzed from: SMA, 2017; Osman and Ali, 2009)

4.2.4 Analysis of temperature

Analysis of maximum and minimum temperatures for the period (1981-2015) was carried out at three stations, Gedarif, Obeid and Nyala, and indicated clear rises in maximum and minimum temperature (Figure 12).

Figure 12: Pattern of maximum and minimum temperatures over 35 years (1981-2015) at three main stations in Sudan



Source: SMA (2017).

4.3 Key current and future climate change impacts on most vulnerable sectors

4.3.1 Reduced crops and livestock productivity

In Sudan, grain sorghum (*Sorghum bicolor* L. Moench) is the most important food security crop in terms of total acreage, production and consumption. Reduction in sorghum yields because of climate change was confirmed by UNFCCC (2003). The projections indicate that by 2060, rain-fed sorghum production will decrease by more than 75%. Furthermore, a significant correlation between sorghum yield and climate

parameters (rainfall, maximum and minimum temperature) was reported (Table 21) and 30% of the variability in sorghum yield could be explained by these climatic factors (Hudo, 2016).

Tab 21: Correlation between sorghum and climate parameters

Parameters	Correlation coefficient	Relationship description
Sorghum yield and rainfall	0.59	Significant
Sorghum yield and maximum temperature	-0.34	Significant
Sorghum yield and minimum temperature	-0.31	Significant

(Hudo, 2016)

Loss in livestock productivity due to climate change was reported. Heat stress has a direct effect on livestock performance, affecting delayed maturity, oestrus cycle, quality of semen and fertilization in the first five days of conception. Breeding age, the pre-weaning mortality rate, the adult mortality rate, milk yield and milking period rate in Nubian goats decreased by 30%, 9% ,12%, 72% and 50%, respectively (Faisal & Osman, 2017).

4.3.2 Increased risk of vector and water-borne diseases and the public health sector

The Intergovernmental Panel on Climate Change (IPCC, 2007) argues that heat stress and increases in water- and vector-borne diseases (e.g., malaria) due to climate change are likely to be harmful to the health of the population. Decreases in water availability and food production would lead to nutritional and hygiene issues. In Sudan, a warmer climate could expand the range of carriers of malaria, yellow fever, dengue fever, and other vector-borne diseases (Table 22). The lack of a strong public health infrastructure in some rural states will render them more vulnerable to projected increases in the lengths of epidemic seasons and the geographic range of vector-borne diseases. In addition, heat waves, water scarcity and poor water quality are likely to lead to an overall worsening of public health and, more generally, to a deterioration of the living conditions.

Tab 22: Climate stressors and risks in the public health sector

Stressors	Risks
Increased temperatures	Expansion of the geographic range of vector-borne diseases
Increased rainfall variability	Extension of the length of epidemic seasons
Drought	Deterioration of living conditions (e.g., poor water quality, worsening air quality, ozone formation)

(Adapted from USAID, 2016)

Other significant impacts due to climate change include:

- Reduction in duration of the growing season;
- Loss of productive land, pasture and water due to expanded desertification;
- Increased water requirements and reduced water supply;
- Changes in distribution and incidence of insect pests, diseases and weeds;
- Disruption of livelihoods and income sources and loss of biodiversity;
- Socio-economic impact (conflict over resources and migration to urban centres).

5 Technological, socioeconomic and policy actions for sustainable land management and climate change adaptation and mitigation

5.1 Key promising and improved technologies for sustainable land management and climate change adaptation and mitigation

The Agricultural Research Corporation (ARC) is Sudan's principal agricultural research institute, with its main objective being to generate, develop and adapt technologies that focus on the needs of the overall agricultural development and its beneficiaries. An important institutional feature of ARC is a set of technical committees that have representation from various stakeholders and are entrusted with the review, evaluation and approval of the release of agricultural technologies developed by ARC and other institutions involved in agricultural research. Over the last decades, the ARC has released a number of technologies dealing with sustainable land management, natural resource conservation and climate change adaptation and mitigation. These technologies and a sample of their impacts are presented below (Tables 23 to 32). However, the degree of their spread (area covered) is lacking because of the weak technology transfer system in the country. Increasing the efficiency of agricultural extension services is essential for the dissemination of proven technologies at the grass root-levels.

5.1.1 Water management practices (water harvesting techniques, small scale irrigation schemes, implementation of new or improved existing irrigation systems)

Table 23 shows the growth of sorghum plants and acacia trees using micro-catchment techniques. Micro-catchment techniques refer to the use of small structures across land slopes which capture surface runoff and store it in plant zones for subsequent plant use.

Tab 23: Growth of sorghum plants and acacia trees using micro-catchment and traditional techniques

Impact indicator	Unit	Micro-catchment technique	Traditional technique	Increase (%)
Grain yield	Kg/ha	743	304	144
Sorghum growth	Cm	100	79	27
Tree surviving rate	%	92	48	92
Tree growth	Cm	280	80	250
Grass yield (DM)	Kg/ha	1109	258	330
Total profile water content	Mm	120	50	140

(Omer et al., 2003)

5.1.2 Soil management practices: mulching, conservation tillage, CA, fallowing

Tab 24: Comparison of traditional and zero tillage systems (AAAID pilot farms)

Crop	Traditional system Yield (kg/ha)	Zero tillage system yield (kg/ha)	Yield increase (%)
Sorghum	329	470	42
Cotton	522	1080	106
Sunflower	261	509	95

(AAAID, 2004)

5.1.3 *Crop management practices: using high yielding, early maturing, drought tolerant, disease and heat-resistant crop varieties of acceptable quality; alternative crops; intercropping; agroforestry; seed priming and fertilizer micro-dosing; planting density and manipulation of planting dates; crop diversification and intensification*

Tab 25: Performance of early maturing crop varieties

Crop	Variety	Days to maturity	Yield kg/ha	% Yield increase over the local variety
Sorghum	Yarwasha	85	1319	88
	Zinnari (Local)	117	703	
Groundnut	Gubiesh	85	1115	19
	Barberton (local)	100-110	938	
Cowpea	Einelgazal	55	596	177
	Baffa (Local)	112	215	

(ARC-El Obeid Research Station Reports, 2009-2011)

Tab 26: Some recently released crop varieties adapted to dryland conditions

Crop/Variety	Rainfall (mm) Requirement	Days to maturity (no)	Traditional Yield (t/ha)	Potential Yield (t/ha)
Sorghum				
Yarwasha	250-400	75-80	0.09-0.195	0.4-1.8
Arfagadmk-8	300-450	80-85	0.09-0.195	0. 9-1.20
Millet				
Ugandi	250-400	75-80	0.05-0.101	0.4-0.8
Sesame				
El-Obeid1	250-400	70-75	0.05-0.120	0.255
Groundnut				
Sodiri	300-450	85-90	0.25	1.015
Cowpeas				
Einelgazal	200-300	55	0.077-0.110	0.4-1.0
Wheat				
Candor	Irrigated	80-90	0.9-1.3	1.8-2.5
Wadialnil	Irrigated	95-105	0.9-1.5	2.0-3.0

(Faisal & Osman, 2017)

On-farm evaluation of seed priming and micro-fertilizing on food and cash crops is presented in Table 27. Primed seeds were soaked in water overnight (8hrs) before being surface dried and sown. Fertilizer was applied with the seeds at the time of planting as a micro-dose, i.e. as a small amount in the plant pocket (hole).

Tab 27: On-farm evaluation of seed priming and micro-fertilizing on food and cash crops

Parameter	Treatments			Mean	Least Significant Difference (LSD (5%)
	Control	Priming	Priming + 0.3 g/hole		
Sorghum					
Yield (kg/ha)	328	435	556	440	16**
Millet					
Yield (kg/ha)	238	309	407	318	12**
Groundnut					
Yield (kg/ha)	749	884	1065	899	36**
Cowpea					
Yield (kg/ha)	337	423	521	427	35**
Sesame					
Yield (kg/ha)	386	-	565[£]	476	37**

Note: [£] Only fertilizer micro-dose was tested.
(Osman et al., 2016)

The land equivalent ratio (LERR) mentioned in Table 28 describes the relative land area required under sole cropping to produce the same yield as under intercropping.

Tab 28: Land Equivalent Ratio (LER) and grain yield of Wad Ahmed sorghum and two cowpea varieties intercropped at different spatial arrangements

Arrangement (sorghum: cowpea)	Yield (kg/ha)		LER
	Sorghum	Cowpea	
Wad Ahmed: Einelgazal (2:1)	641	207	1.11
Wad Ahmed: Einelgazal (3:1)	687	164	1.05
Wad Ahmed: local cowpea (2:1)	645	234	1.10
Wad Ahmed: local cowpea (3:1)	683	185	1.04
Sole Wad Ahmed	1079	-	-
Sole Einelgazal	-	399	-
Sole Local cowpea	-	456	-

(Salah et al., 2011)

5.1.4 Livestock husbandry practices: strategic supplementary feeding of breeding ewes, mineral supplementation, lamb and kid fattening, and the foraging of legumes and grasses to improve rangelands' botanical composition and condition

Tab 29: Strategic supplementary feeding of breeding ewes

Parameter	Control Group	Strategically Supplemented Group
No. of Ewes	40	40
No. conceived	26 (65.0%)	32 (80.0%)
No. Aborted	9 (22.5%)	2 (5.0)
No. Lambed	22 (55.8%)	30 (75.0%)
No. Died lambs	6 (15.0%)	1 (2.5%)
Type of births		
Single births	21 (95.5%)	23 (71.9%)
Twin births	1 (4.5%)	7 (23.3%)
Lamb weight at birth (kg)		
Average birth weight of single lamb	2.15	2.98
Average birth weight of twin lamb	1.88	2.41
Overall average lamb birth weight	2.01	2.41

(Eco-Farm Project Report, 2011)

Tab 30: Effects of mineral supplementation on milk yield of lactating goats and cows

Parameter	Goats		Cows	
	Control group	Saltlick group	Control group	Saltlick group
Total no. of lactating animals	36	50	18	18
Milk yield (litres):				
Average total milk yield/goat/cow (litre)	16.46	24.68**	283.67	240.65**
Average daily milk yield/goat/cow (litre)	0.29	0.44**	3.82	4.50**
Increase in average daily milk yield (%)		51.7%		17.8%

(Eco-Farm Project Report, 2011)

5.1.5 Tree cover improvement husbandry practices

Tree cover improvement husbandry practices include technologies that can help increase food security while also maintaining or increasing forest cover. These technologies are**:** some tree species to be used in agroforestry systems; water harvesting techniques (micro-catchments) and water conservation methods to suite the agroforestry farming systems and tree establishment; identification of suitable tree species to combat desertification; nursery techniques; introduction and establishment of multipurpose exotic trees; and the assessment of regeneration of degraded soil seed bank areas.

Tab 31: *Acacia senegal* (gum arabic tree) in agroforestry system with annual crops

Land Equivalent Ratio (LER) and crop hay and gum arabic yields

Crop	Intercrop hay (kg/ha)	Pure crop hay (kg/ha)	Partial LER	Intercrop gum (kg/ha)	Pure gum (kg/ha)	Partial LER	Total LER
Karkade	120.9	462.2	0.26	118.4	69.0	1.7	1.96
Sesame	172.1	206.9	0.83	42.2	69.0	0.6	1.43
Cowpea	764.4	1277.4	0.60	86.0	69.0	1.2	1.80

(Eco-Farm Project Report, 2011)

Tab 32: Alley-cropping to improve microclimate of groundnut and sesame in the semi-desert region of northern Sudan

Treatments	Groundnut kernels kg\ha	Yield % of control	Sesame seed Kg/ha	Yield % of control	Max. Temp (°C)	RH (%)
Control	437		747		41.5	42
A. stenophylla-alley	602	+ 38	1043	+40	-1.9	+14
A. ampliceps-alley	523	+20	360	-52	-1.7	+10

(Shapo & Adam, 2008)

5.2 Technology transfer and extension

Extension and the Technology Transfer Administration in Sudan's Ministry of Agriculture are the principal institutes responsible for technology transfer and dissemination. However, ARC engages to a considerable extent in technology transfer and extension activities. Within its own research spectrum, technology transfer comprises the conducting of three main types of on-farm trials:

- Verification yield trials in plant breeding, integrated pest management and integrated disease management with participation of farmers;
- On-farm trials for various technologies including researcher-managed and farmer-managed trials;
- Pilot production/demonstration plots in farmers' fields mainly under farmer management and supervision and monitoring by researchers with active engagement of extension workers.

Furthermore, ARC undertakes a number of extension-related activities that include running farmers' field schools, conducting field days, producing extension leaflets and disseminating information via public media.

5.3 Policy and regulatory framework relevant to sustainable land management, environmental degradation and climate change adaptation and mitigation

Sudan implemented several activities under multilateral environmental agreements (MEAs) that directly relate to climate change adaptation and development priorities. Ratified multilateral environmental agreements (MEAs) include:

- Climate Change Convention,
- Conventions on Biological Diversity,
- Combating Desertification.

In the framework of these MEAs, issues concerning climate change adaptation – ecosystem resilience, reforestation, sustainable agriculture, and increased risk from drought – are of central concern in Sudan (NAP, 2016). Implementing the MEAs have led to the following major types of initiatives:

- 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 the 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 the Global Environment Facility (GEF), focused on capacity building and mainstreaming climate change within sectoral development priorities.

The specific aspects of the environmental policy measures are:

- Environmental issues must be embodied in all development projects;
- Preparation of land use maps, especially for marginal areas of forestry and food production;
- Enhancement of the role of community in resource management and improved environmental awareness and knowledge in rural areas;
- Strict enforcement of environmental laws and supporting legislations;
- Increasing of the capacity of both federal and state governments to monitor and enforce land lease conditions and cultivation in areas subject to desertification;
- Comprehensive land reform and security of title;
- Promotion of private investment in gum arabic production.

Table 33 below provides a summary of the previous, recent and ongoing investments in Sudan that aim to enhance food security, sustainable development, climate change mitigation and adaptation.

The object of these policy interventions, with planning emphasized, are:

- Achieving food security and raising levels of productivity of staple crops;
- Reducing poverty and enhancing community adaptation and resilience to climate change;
- Protecting and developing natural resources and adopting environmentally-sound agricultural practices;

- Addressing land tenure and land rights problems;
- Strengthening governance and institutional capacity.

Tab 33: Some recent and ongoing investments in Sudan for enhancing sustainable development, climate change mitigation and adaptation

Policy/intervention	Objective/ mandates
1) National Adaptation Plan (NAP, 2016)	Sudan developed its NAP in 2016 as a programmatic framework to address climate change adaptation. The objective of Sudan's NAP is threefold: (1) building institutional capacity to promote the development of climate change institutional arrangements for effective implementation of adaptation programs and activities; (2) broadening the response to climate change to encompass institutional, economic, planning, and analytical dimensions of climate risk management to facilitate mainstreaming of climate change adaptation into new and existing policies, programs and activities, within all relevant sectors and at different levels; (3) enhancing existing efforts to identify and prioritize potential adaptation initiatives at the regional level. The NAP provides information on actions to reduce climate change vulnerability regarding water resources, agriculture and food security, public health, coastal zones, and rural communities in all 18 states of Sudan.
2) Intended Nationally Determined Contribution (INDC, 2015)	With respect to the contribution to climate change mitigation, Sudan intends to pursue a low carbon development trajectory in the energy, forestry and waste sectors despite being a least developed country. In the energy sector, Sudan will integrate 20% renewable energy in power generation by 2030, increase energy efficiency, and promote electricity generation using natural gas. In the forestry sector, Sudan will conduct afforestation and reforestation to achieve the goal of 25% forest cover by 2030. In the waste sector, Sudan intends to collect waste to improve solid waste management, develop sanitary landfills with treatment facilities and a gas collection and capture system, and adopt a zero-waste concept that includes composting organic waste, sorting and recycling, making use of non-recyclable materials, and generating electricity or gas from waste.
3) Agricultural Revival Program (ARP, 2008-2014)	This is a comprehensive approach for agricultural development that advocates agriculture as the engine for effectively contributing to economic growth and export performance, and for simultaneously advancing people's livelihoods, reducing poverty, improving food security and nutrition and developing and protecting natural resources. The main targets are reflected in eight key success-indicators, namely: (a) the creation of an appropriate atmosphere for sustainable development of agricultural production; (b) capacity building of producers and institutions; (c) reforming the agricultural land-tenure system; (d) developing support services and modernizing agricultural systems; (e) protecting and developing natural resources; (f) achieving agricultural industrialization; (g) implementing quality control and safety measures; and (h) establishing international strategic partnerships (World Bank, 2009).
4) Sudan's Poverty Reduction Strategy Paper (2011-2016)	This Paper consists of four pillars: (i) strengthening governance and the institutional capacity of the public sector; (ii) reintegrating IDPs and other displaced populations; (iii) developing human resources; and (iv) promoting economic growth and employment creation.
5) Five–Year Development Strategy (2015-2019)	The strategic objective of this Strategy is to support the 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.
6) Sudan National Action Programme to Combat Desertification (SNAP, 2006)	Sudan was one of the first countries to ratify the United Nations Convention to Combat Desertification (UNCCD) in 1995, which was followed by the development of its National Action Programme to Combat Desertification (SNAP) submitted in 2006. The SNAP provides background information on the present environmental and natural resource conditions with specific attention to the impacts of the frequent drought periods that inflicted the country in recent decades on the socio-economic status of the population. It also provides insights into the main constraints, challenges, efforts and policies in order to streamline the optimum use of natural resources. It draws attention to the institutional setup and the large number of the national, international organizations and non-governmental organisations (NGOs) involved in combating desertification whose interventions are weakened by the lack of coordination. It highlights actions in the form of programmes and projects in accordance with the objective of the UNCCD and emphasizes that the

	financial resources needed to implement SNAP must be sought outside the normal national budget, which is often limited.
7) National Adaptation Program of Action (NAPA, 2004)	The overall goal of the NAPA was to identify urgent and immediate activities to address adaptation needs within the context of the country's economic development priorities. The NAPA identified 32 urgent adaptation initiatives in three priority sectors, namely agriculture, water and human health, and in five States to reduce the increasing vulnerability of the rural communities to current and future climatic risks.
8) National Biodiversity Strategy and Action Plan (NBSAP, 2015)	Sudan developed the second NBSAP in 2015, a key planning tool for conservation of the country's biodiversity and the fulfilling of its international obligations. The NBSAP provides a framework for taking actions by the different stakeholders in biodiversity to achieve the three objectives of the CBD, namely, conservation of biodiversity, sustainable use of its components, and fair and equitable sharing of benefits arising out of their use and to fulfil the global Biodiversity Vision of living in harmony with nature.
9) National Water Supply and Sanitation Policy (WASH, 2009/2010)	The objective of the water supply and environmental sanitation policy is to ensure adequate and sustainable domestic water supply and environmental sanitation services and hygienic practices for all rural, urban and nomadic people in the northern states of Sudan. The WASH's objectives are set to be achieved by 2031, starting with the achievement of water and environmental sanitation related MDGs targeting an increase in improved water supply and environmental sanitation access for 82% and 67% of the population, respectively. The policy also covers schools, health facilities and religious institutions.
10) Comprehensive Africa Agriculture Development Programme in Sudan (CAADP)	The CAADP is endorsed by African governments under the African Union's New Partnership for Africa's Development (NEPAD). 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. CAADP is comprised of four agricultural pillars, namely: I. Expand sustainable land management and reliable water control system. II. Improve rural infrastructure and trade-related capacities for more market access. III. Increase food supply, reduce hunger and improve response to food emergencies in case of crises. IV. Improve agricultural research, technology transfer and adoption.
11) DCG Sudan Eco-farm Research Project (2007-2011)	Drylands Coordination Group (DCG), based on its experience in the Sahelian zone, has recommended some simple technologies that can be used by poor-resource farmers to improve their food security. The objective of Eco-Farm Research Project (2007-2010) were to increase agricultural production, improve food security and the economic well-being of the farmers and agro-pastoralists in the dryland areas. (DCG is an NGO-driven forum for the exchange of practical experiences and knowledge on food security and natural resource management in the drylands of Africa. DCG facilitates this exchange of experiences between NGOs and research and policy-making institutions.)
12) Forestry Policy (FOP, 2006)	Part of the Renewable Energy Master Plan (REMP, 2005): Developed in 2005 to promote the use of renewable energy sources, including priority projects such as photovoltaic (PV) installations and biomass co-generation to avoid technological dependence on an oil-based market in energy sector development.

(HCENR, 2019; 2015)

5.4 Main lessons learned from recent investments

Based on the overall performance of some of the recent interventions, as well as the evaluation findings conducted for some activities, the main lessons that have been learned are:

- The evidence suggests that agricultural-development programs require increased and more effective public and private partnerships involving main stakeholders (farmers or farmers'

organizations, input suppliers, extension, research, financial institutions, agro-dealers, buyers, and traders) to achieve the goals of improving food security and adaptation to climate change.

- The flow of finance to the agricultural sector remains one of the obstacles to agricultural growth. The government must commit to increase public investment in agriculture, to allocate resources and to create a conducive environment (providing incentives for investment in the agricultural sector).
- In addition to the poor rural infrastructure, the ongoing conflicts and social unrest in many parts of the country are placing huge pressures on the performance of the economy and are constraining the development of agriculture.
- Key factors contributing to the success of some climate change adaptation interventions are: effectiveness (reducing vulnerability and increasing adaptive capacity), flexibility (building capacity to improve current climate resilience and access to financial resources), efficiency (improving nutritional status and generating income), and sustainability (including strong elements of community engagement and awareness-raising, as well as focusing on key sectors such as agriculture and water).

6 Evaluation of national policies and development

6.1 Key challenges for the agricultural sector: Enhancing productivity, production and improving food security

Low, variable and often declining productivity dominates Sudan's agriculture. This is apparent for the past three decades, especially for rain-fed crops. Table 34 provides a summary on main cereal yields compared with regional and international standards. For example, Sudan's current average sorghum yield of about 0.69 tons per hectare is less than half of the world average and only about 20% of yields in high-yielding countries. Millet yields (0.38 ton per hectare) are about half of the African average and 40% of India's average yield. The gaps between research yields and average national yields indicate a remarkable potential for yield increments.

Tab 34: Grain crop productivity (ton/ha) in the different production systems in comparison to world, regional, national, potential and research averages

Country/Location	Sorghum	Wheat	Millet
World	1.57	2.6	0.79
World drylands	0.80	-	0.60
Africa	0.87	0.85	0.67
USA	3.31	2.7	-
India	0.97	2.6	0.96
Sudan (National)	0.69	1.8	0.38
Sudan (Irrigated)	1.18	1.8	-
Sudan (Mechanized)	0.48	-	-
Sudan (Traditional)	0.69		0.38
Research yield (Irrigated)	2.3	2.6	-
Research yield (Traditional)	1.29	-	0.83

(Adopted from Osman & Ali, 2009)

The primary focus of the set plans and polices is to enhance the production, productivity and competitiveness of food and cash crops through several polices and interventions, such as:

1. Increasing access to basic agricultural services, such as markets, inputs, extension, technical advice and research services;
2. Establishing efficient value chains by enhancing local infrastructure;
3. Developing the capacity of farmers' organizations and enhancing producers' skillset (training, extension, scaling up FFSs);
4. Strengthening of extension services in the support of the upscaling of best practices and ensuring adoption of proven technologies;
5. Creating strong relationships among stakeholders through innovation platform approaches involving main actors (farmers, extension, financial institutions, and agro-dealers) to build a strong and comprehensive system for production at the local level and link policy makers, producers and agro-dealers.

Despite several attempts to improve Sudan's agricultural sector performance, the trends in agricultural production have shown noticeable deterioration. The average growth rate of real agricultural production over the past ten years was only 4.7% per annum and its contribution to the country's exports has declined sharply (Mustafa and Omer, 2015). This is caused by several obstacles, the most important of which are:

- The very limited and deteriorating flow of finance to the agricultural sector and the high cost of banking finance that is directed to agriculture.
- Most of the farmers, particularly in the traditional rain-fed agriculture sector, use traditional production technologies and lack the necessary capital and resources to effectively implement modern agricultural development, such as the use of mechanized agriculture.

6.2 Performance evaluation of the prominent interventions

In response to this continuing scenario, the government initiated several policies and reforms for the revival of the agricultural sector. The most prominent national-level policies and development plans relevant to agriculture, land use, climate change and food security are:

1. Agricultural Revival Programme (ARP: 2008 – 2014);
2. National Adaptation Plan of Action to Build Resilience in Agriculture and Water Sectors to the Adverse Impacts of Climate Change in Sudan (NAPA, 2004);
3. Eco-farm Research Project (2007-2011).

6.2.1 Agricultural revival programme (ARP: 2008 – 2014)

Sudan's Agricultural Revival Program (ARP) constitutes a comprehensive approach for agricultural development that advocates agriculture as the engine for effectively contributing to economic growth and export performance, and for simultaneously advancing people's livelihoods, reducing poverty, improving food security and nutrition and developing and protecting natural resources.

The ARP had six strategic objectives: (i) promoting exports of crops and livestock to reduce dependence on oil; (ii) increasing productivity and efficiency at the production and processing stages (in particular wheat, rice, sugar beet, sugarcane, oil seeds, organic fruits and vegetables and green and dry fodder, each in selected states); (iii) achieving food security; (iv) reducing poverty by 50% by 2015, by generating job opportunities and increasing per-capita income; (v) achieving balanced growth in all regions of the country; and (vi) developing and protecting natural resources to ensure renewal and sustainability.

The total cost of the ARP was put at SDG 4819.1 million (equivalent to about US$4.8 billion at the 2008 exchange rate). A summary of the projects, objectives and key components and costs of ARP are in Table 35.

Tab 35: Key components and cost of ARP

Area of Intervention/ Project	Objectives	Components	Cost in million Sudanese pound (intended amounts)
Water Harvesting	⇨ Using rainfall and annual streams for supplementary irrigation ⇨ Provision of drinking water for humans and animals ⇨ Restoration of plant and tree cover	⇨ Construction of 1000 dams at the rate of 250 per year and rehabilitation of 150 dams Construction of 5 thousand hafirs and rehabilitation of 1000 hafirs (manmade earth dugout reservoir for harvesting rainwater) ⇨ Installation of 750 filtres	486
Irrigation Projects	⇨ Increasing irrigated areas and intensification ⇨ Increasing hydroelectric power	⇨ Heightening of the Rosares Dam and construction of the Setit Dam ⇨ Establishment of new irrigation projects, rehabilitation and electrification of existing projects	1484.6
Feeder roads, ferries and livestock routes	⇨ Linking production areas with markets; connecting west and east banks in Nile states to facilitate marketing products and inputs	⇨ Paving 2000 km of all-weather roads	241.5
Capacity building	⇨ Building the capacity of the producers and their organizations to assume leadership roles in agricultural production	⇨ Training of producers	14.0
Supporting services	⇨ Improving production and product quality for competition in domestic and international markets	⇨ Technology transfer centers, crop protection and animal health services; agric. and livestock extension services; agric. and livestock research, information and communication technologies	411.3
Capacity building of Information Institutions and Informatics	⇨ Availability of information to support decision making	⇨ Complete agricultural census ⇨ Agricultural and livestock annual surveys	49
Food Security, poverty Reduction and rural Development	⇨ Improve standards of living and social welfare through reducing poverty, sustainable production and risk management	⇨ Programmes and projects in rural development areas	1417.2
Marketing and Export Infrastructure	⇨ Reduction of the costs of production and application of the quality standards to enhance competitiveness of production in local and international markets	⇨ Storage facilities, rehabilitation of markets, ginneries, abattoirs	330.2

Development and Modernization of Agricultural Systems	⇨ Increase productive efficiency of existing projects ⇨ Introduction of new improved technology	⇨ Irrigated and rain-fed intensive pilot farms (crops and livestock)	30.5
Development and Protection of Natural Resources	⇨ Rational use and sustainable development of natural resources	⇨ Preparation of land use maps, broadcasting of pasture seeds, rehabilitation of the gum arabic belt, reforestation and control of desertification	348.8
Commodity Development Councils	⇨ Integration of the commodity production, marketing, export and consumption chain to improve the competitiveness of Sudanese commodities	⇨ Establishment of development councils for commodities and commodity groups	16.0
Total			4819.1

(Government of Sudan, Ministry of Agriculture and Forestry, 2008)

Although no comprehensive evaluation was carried out on ARP and despite the strongly expanded political propaganda for the program, ARP plans had limited success in achieving their objectives and there was a wide gap between the stated objectives and those achieved. The associated weaknesses were:

- Secession of South Sudan in 2011, which led to a loss of oil revenues and subsequent downturn in the country's economy;
- The ARP structure was found to lack effective delegation of powers to states and to have an unclear distribution of responsibilities between the national and state governments to ensure fair and equitable share in budgets;
- Lack of political stability and fluctuating economic and financial policies;
- Failure to obtain sizeable necessary financial resources needed to implement the different components and activities of the programme;
- Weak administrative and implementational capacity of the government institutions (extension, financial institutions, etc.) to contribute to increasing production and productivity;
- Failure of the government to create a conducive environment (provision of incentives for investment in the agricultural sector);
- Failure in establishment of international partnerships and contacts to avail adequate resources from foreign sources;
- Limited participation of the private sector in developing support services;
- Weak involvement of other stakeholders;
- The states were found to have weak administrative and implementation capacities for achieving the ARP goals;
- Ineffective monitoring and evaluation system.

6.2.2 National Adaptation Plan (NAP, 2016)

In response to the Cancun Adaptation Framework (CAF) call for the development of National Adaptation Plans (NAP) in least developed countries, Sudan developed its NAP in 2016 as a programmatic framework

to address climate change adaptation. The objective of Sudan's NAP is threefold: (1) building institutional capacity to promote the development of climate change-related institutional arrangements for effective implementation of adaptation programs and activities; (2) broadening the response to climate change to encompass institutional, economic, planning, and analytical dimensions of climate risk management to facilitate mainstreaming of climate change adaptation into new and existing policies, programs and activities within all relevant sectors and at different levels; (3) enhancing existing efforts to identify and prioritize potential adaptation initiatives at the regional level. The NAP provides information on actions to reduce climate change vulnerability regarding water resources, agriculture and food security, public health, coastal zones, and rural communities in all 18 states of Sudan. The range of adaptation options has been defined through systematic and bottom-up consultative processes at the state level. The process itself has been a significant achievement in raising awareness, building technical and institutional capacities, and integrating adaptation concerns into national development dialogues at all levels. A SWOT analysis of NAP is shown in Table 36.

Tab 36: SWOT analysis of NAP, 2016

Strengths	Weaknesses
• Sudan's National Adaptation Plan is the product of a large member of institutions and individuals. • The design and implementation of the NAP process in Sudan has relied heavily on guidance from the Least Developed Countries Expert Group. • NAP process was designed as a highly inclusive and participatory process with extensive engagement of a wide range of stakeholders throughout the states. • Specific and high-priority adaptation policies and measures have been identified at the state level • Research gaps and innovation needs related to impacts from climate change in Sudan's agricultural sector have been identified. • In each of Sudan's 18 states, a focal point and inter-agency technical team of experts from related government, research, academic and civil society organizations have been established. • Attached to a foundational set of principles, namely gender sensitivity, transparency, science-based, participatory, attentiveness to indigenous knowledge, and focus on vulnerability.	• Slow integration of climate change adaptation into new and existing policies, programs and activities within all relevant sectors and at different levels.
Opportunities	**Threats**
• Sudan has made notable steps in addressing the risks posed by climate change to its communities, natural resources, and economy. • Global attention to adaptation and allocation of funds to Least Developed Countries • Enhancement of food security of the rural population, particularly of rain-fed farming and pastoral communities.	• Not considering climate change as a national priority. • Less awareness among the general public and policymakers regarding climate change. • Weak institutional capacities and enabling environments. • Poor allocation of resources.

(Authors' analysis)

6.2.3 National Investment Plan for the Agricultural Sector (NAIP)

"The National Agriculture Investment Plan (NAIP) is a five-year investment plan for Sudan that maps the investments and activities needed to achieve 6% annual growth for the agricultural sector by 2020" (FAO, 2015a). The NAIP is a key component of Sudan's participation in the Comprehensive Africa Agriculture

Development Programme (CAADP), a pan-African initiative signed by Sudan in 2013, which commits the country to increase government spending on agriculture to 10% of GDP by 2020. CAADP is entirely African-led and African-owned, continental in scope, but realized through national efforts aimed to promote growth in the agriculture sector and economic development. The main goal of CAADP is to help African countries reach a higher path of economic growth through agriculture-led development. It provides a framework to guide country strategies, investment and development activities. CAADP works though four pillars:

- "Extending the area under sustainable land and water management".
- "Improving rural infrastructure and trade-related capacities for market access".
- "Increasing food supply and reducing hunger".
- "Agricultural research, technology dissemination and adoption" (NAIP, 2013, pp.8).

The key objectives of the NAIP include: (i) Promotion of crop and livestock exports; (ii) Increasing productivity and efficiency in agricultural production and processing; (iii) Realization of food and nutrition security; (iv) Reducing rural poverty by 50% by 2020, including through generation of job opportunities (especially for youth and women) and increasing per-capita income; (v) Achieving balanced growth in all regions of the country with the view to encourage settlement in rural areas; and (vi) Development and protection of natural resources to ensure their renewal and sustainability. "The NAIP pays close attention to the sector's core challenges related to agriculture and agro-industry development, and includes initiatives to increase access to local food, reduce poverty and malnutrition and boost income generation for rural families, especially for smallholders" (NAIP, 2013, pp.5).

Following the signing of the CAADP Compact in July 2013, Sudan embarked on the preparation of its NAIP and has prepared different policy documents and investment plans regarding agriculture and food security. Semi-mechanized and traditional rain-fed agriculture forms a major component of the plan. Table 37 includes the components/interventions of the five-year development plan for the rain-fed sector and the allocated budget (SDG). However, the plan was not implemented due to several reasons indicated below.

Tab 37: The total cost of the proposed programs for the base year 2015 for the five- year development plan

Component	Intervention	Allocated Budget (SDG) (1 USD = 5.97 SDG, 2015)
Research	Foundation seed multiplication, participatory technology development, innovation platforms, capacity-building, genetic resource conservation, development of rain-fed research stations	113,934,000
Technology transfer	Establishment of training centers, demonstration plots, farmer field schools, capacity-building	107,700,000
Plant protection	Equipment, capacity-building, chemical stores and lab development, station networks	29,430,000
Seed multiplication	Community and association-based seed multiplication, capacity-building, support to national seed administration	208,000,000
Intermediate technology development	Establishment and upgrading of training centers, equipment introduction, micro-finance system	325,560,000
Water harvesting	Training centers, equipment, group formation and capacity-building	163,540,000
Conservation agriculture	Group formation, demonstration plots, capacity-building, equipment, micro-finance	125,680,000
Agro-meteorology, weather forecasting, weather stations	Development of weather stations: Rain-gauge and communication systems and EWS capacity-building	27,000,000
Biodiversity conservation	Awareness campaigns (conservation and threat)	180,000
Climate change	Demonstration of climate-smart and adaptation technologies, awareness campaigns, monitoring	1,140,000
Access to market	Market development, feeder road connections to the main road	107,300,000
Policies and laws	Policies and regulations for rain-fed agriculture development, land use maps and workshops	400,000
Institutional development	Capacity building, restructuring, planning, M&E	500,000
Total		1,210,364,000

(NAIP, 2013)

Two major agreed-upon agenda among African countries under CAADP are commitments for a 10% minimum increase in public investment in agriculture and raising agriculture growth by a minimum of 6%. The program offers prospects for political, technical and financial support for countries with CAADP-aligned plans and strategies.

Despite the high participatory process and extensive engagement of a wide range of stakeholders in preparation of Sudan's NAIP (Rain-fed sector), the plan was not implemented. The most important reasons were:

- Flow of finance to agricultural sector remains one of the obstacles to agricultural growth.
- The government did not commit to a 10% minimum increase in public investment in agriculture and no priority was assigned to agriculture in the allocation of resources.
- Conflicts and social unrest across the rain-fed sector (mainly in Darfur, Blue Nile and South Kordofan).
- Lack of political stability and economic sanctions have aggravated the situation.
- Weak administrative and implementation capacity of the governmental institutions.

6.2.4 National Adaptation Plan of Action (NAPA, 2004) to Build Resilience in Agriculture and Water Sectors to the Adverse Impacts of Climate Change in Sudan

Based on the National Adaptation Plan of Action (NAPA), the project "Implementing Priority Interventions to Build Resilience in Agriculture and Water Sectors to the Adverse Impacts of Climate Change in Sudan" was developed by the Sudanese Government, UNDP and GEF. The project objective 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 to climate change, including variability" (pp.18).

The project was financed by the Least Developed Countries Fund for Adaptation to Climate Change (USD 3,300,000) and UNDP (USD 500,000). Committed co-financing from the Government of Sudan totalled USD 3,000,000. The project was implemented by the Higher Council for Environment and Natural Resources.

The project has reached vulnerable communities of diverse eco-socio-economic circumstances and introduced a set of adaptation-focused measures with vulnerable, poor small-scale farmers and pastoralists in four different regions in Sudan. The interventions and practices introduced by the project contain a wide variety of interventions covering changing natural resource management practices, raising awareness, promoting technology change, changing agricultural practices and gender empowerment as shown in Table 38 below.

Tab 38: Major Adaptation Measures Introduced by the Sector

Sector	Adaptation Measures
Water	• Water conservation: Rainwater harvesting techniques • Hafir rehabilitation, water tanks and water filters • Small scale irrigation (Water pumps and irrigation pipes for supplementary irrigation)
Agriculture and food security	• Improvement of irrigation techniques • Introduction of early maturing and drought-resistant crop varieties • Livestock production and management: promotion of small ruminants • Establishment of community vegetable and fruit tree farms • Fish farming (pond culture)
Natural Resource Management Practices	• Solar energy for irrigation • Village nurseries and HH tree planting • Fixation of sand dunes as shelter belts around villages and household trees • Supply of gas cylinders • Shifting from wood to permanent mud for renewable building • Range reserve establishment and management • Improved stoves
Empowering People	• Income-generating activities, including social cash transfers & livestock • Diversifying crops and income sources • Training and capacity-building • Raising stakeholders' awareness of climate change and the specific climate

(HCENR, 2014)

The evaluation of the project indicated that overall, the project has been implemented effectively and efficiently in accordance with the workplan and budget. Notably, the implementation has been overall very

strong and effective on a day-to-day basis, achieving impressive local results. Table 39 below lists some of the keys to this success.

Box 1: Key Factors behind project success at village and site level

- The initial focus was on grassroots action, rather than on planning and assessment;
- There was a considerable focus on actions that have a *visible* impact for beneficiaries;
- The project activities were designed to be simple, manageable and aligned to local needs;
- The use of committed State coordinators, embedded in State government, to provide continuous support and to link villages to national Project management;
- The use of multi-sector, state-level Technical Committees to ensure good backstopping and linkages; and,
- The continuous support and dialogue are maintained by the PCU at all levels.

(UNDP/HCENR, 2015)

Generally, the project has been successful in the following:

1. Established a growing awareness and understanding amongst targeted farmers and various stakeholders as to the impacts of climate change and benefits of adaptation practices.
2. Demonstrated climate change adaptation interventions gained political support and were widely accepted at community level. The replication and up-scaling potential of the project interventions is promising. Women were not neglected and well-involved in the introduced project activities.
3. One of the feasible interventions of the project is the small-scale irrigation. This intervention improved farmers' access to water and enabled them to diversify and grow higher-value crops, such as fruits and vegetables for human consumption and also to promote income generation through the sale of production surplus.
4. The project promoted rainwater harvesting practices, thus providing the potential to improve water availability for domestic and agricultural production.
5. Strengthening of the local informal saving system to improve income-generating potential and supply women with emergency consumption needs and a source for making small investments.
6. Introduction of solar power as energy sources for pumping water. Solar power generates clean reliable power with little maintenance and is more economically efficient for small-scale applications than diesel pumping systems. However, the switch to solar power generally requires higher initial investments.

Some challenges and weaknesses associated with the project:

- Some of the input required, such as water harvesting systems, supplementary irrigation and water pumps and irrigation units, and solar energy are affected by high investment costs. Since poverty and the low economic status of farmers are predominant features in the highly vulnerable areas, these interventions cannot be scaled up without help from financial institutions.
- Small-scale irrigation introduction is based on surface irrigation, which involves diverting water from the source to an open channel to the cropped area. Water losses in surface irrigation are high. Drip or pipe irrigation systems emit water at or near the cropped area, thus improving energy and water use efficiency.

6.2.5 Eco-Farm Research Project (2007-2011)

Traditional dry-land farming is the major production system in western Sudan, and it is the main source of income for more than 80 % of the population (DCG/CC, 2011). The major food crops grown are millet and

sorghum, while groundnut and sesame are the major cash crops. The productivity of these crops is very low. Thus, the major challenge has been how to increase productivity and improve food security and incomes of communities in dry areas. Addressing this challenge, the Drylands Coordination Group (DCG), based on its experience in the Sahelian zone, has recommended some simple climate-smart technologies that can be used by poor-resource farmers to improve their food security. DCG is an NGO-driven forum for exchange of practical experiences and knowledge on food security and natural resource management in the drylands of Africa. DCG facilitates this exchange of experiences between NGOs and research and policy-making institutions. The DCG activities, which are carried out by DCG members in Ethiopia, Mali and Sudan, aim to contribute to improved food security of vulnerable households and sustainable natural resource management in the drylands of Africa. The project was financed by DCG-Norway with a budget of about USD 300,000, including co-financing from the Government of Sudan. The project was implemented by El-Obeid Research Station (ARC)/Dryland Research Centre.

Project activities included:

a) Testing, verifying and introducing eco-farm technologies in the area and extrapolating that to similar areas.

b) Testing of early maturing and drought-resistant new crops and varieties and new dual-purpose (forage and food) crop varieties.

c) Increasing awareness and providing training to farmers, agro-pastoralists and extensionists on eco-farm technologies.

The overall evaluation analysis informs that introduced eco-farm techniques were not only adopted sustainably by the former DCG participant households, but they were also picked up and widely used by nonparticipants within the visited villages. Seed priming and improved seeds were the most adopted techniques by farming households while mineral blocks as sources of minerals for livestock was the most adopted technique among livestock owners. The adoption of micro-fertilizers by participants and non-participants was extremely weak, for it had been dropped out by most of the former project participants.

The impact of the DCG project on different segments of communities is noticeable in a number of ways. There is a significant improvement of yields for different cash and food crops, as well as an increase in livestock production, particularly milk production. These improvements increase the overall production and income of households in particular, and therefore of the entire community including men, women and children.

Sustained adoption, up-scaling and expansion of DCG's introduced eco-farm techniques within the greater Kordofan region and beyond is evidently traceable. Several enabling factors contributed to this, including (i) successful trials and field demonstrations of the tested results; (ii) most of those techniques are cost effective and simple to handle with tangible positive results; (ii) most of the DCGs techniques were adopted by other organizations and integrated in their packages; and (iv) there is a wide dissemination of extension pamphlets of eco-farm techniques to different partners and users.

To conclude, understanding that the DCG main product is knowledge, it is possible to state that the impact of the DCG-introduced set of eco-farm techniques is likely to have far-reaching and multiple positive repercussions on rural communities in the drylands of Sudan in the longer foreseen future and beyond. This is essentially so, as useful knowledge, know-how, and technologies/techniques require longer timeframes before they are comprehended, accepted and adopted at full scale by recipients like the traditional farming and pastoral communities.

7 Summary and conclusion

Geographically, Sudan is a vast country with an area of about 1.9 million km² and an estimated population of about 43 million. Approximately 66% of the population lives in rural areas. In terms of the Human Development Index, Sudan has 0.479 points, ranking 167th out of 187 countries published. Based on the latest available data, the poverty rate is estimated to be 46%. Small-scale farmers and agro-pastoralists practicing traditional rain-fed agriculture are the most affected by rural poverty. Sudan, like most developing countries, has an economy largely based on agriculture and the production of raw materials. Agriculture, including cropping, livestock and forestry, contributes about one-third of the national Gross Domestic Product. It serves as the main livelihood for more than two-thirds of the population and remains the key priority sector in the growth and poverty reduction agenda of Sudan. Sudan's agriculture has distinct crop and livestock production systems. The amount of cultivated land is approximately 20 million hectares and the livestock population is estimated at 105 million heads. Annual water resources in Sudan are summarized into four main categories, namely, the River Nile and its tributaries, seasonal streams, groundwater and surface water in dry parts. Access to improved drinking water sources varies from 50.2% in rural populations to 66% among the urban population. Fuelwood from natural forests and the desert scrub contributes 78% of the energy balance of Sudan; the rest consists of oil at 8%, generated electricity at 8% and agricultural residues at 6% of the overall energy balance. Sudan has significant RE resources, particularly solar energy with the annual average estimated at 6-7.5 KWh/m^2 per day, which is widely distributed all over the country. The national electrification rate is 35.9%.

Land cover and use indicate that nearly more than half of the country area (51%) consists of bare rocks and soil, while agricultural land makes up about 13%. Tree cover, shrubby vegetation and herbaceous vegetation altogether constitute about 36% of Sudan's total area. On average, cultivated land in the Sudan comprises around 20 million ha, representing approximately 25% of the total arable land classified as suitable for agriculture. Rain-fed agriculture covers about 90% of the area. Sorghum is the dominant crop, as it occupies more than 50% of the national total cropped area. Natural rangelands form the backbone of the livelihoods of pastoralists and agro-pastoralists by providing necessary feed resources. Recent estimates indicate that the natural range area is about 69 million ha, or about 36% of Sudan's total area, and supplies about 73% of the total feed requirement for Sudan's livestock. The Forests National Corporation (FNC) estimates the forest area to be about 22 million ha, making a forest cover of about 12% of total land mass.

Sudan is one of the African countries most seriously affected by desertification. Recent GIS and remote sensing results indicate that from 1958 to 2017, most of the country was covered by desert and the desert boundary has moved more towards the south since first observed in 1930, which is pushing the country towards a historical desertification disaster. Most of the population in the desertification-affected states relies heavily on natural resources. Thus, there is a strong relationship between desertification, poverty and food security. Several attempts have been made to formulate regulations and legislation, and to coordinate with international and regional agreements on combating soil degradation and desertification. Despite these efforts, desertification remains a major environmental threat in Sudan.

The Global Adaptation Index indicates that Sudan is among the countries in the world most vulnerable to climate change, ranking 175th out of 181 countries. The agriculture, water and health sectors have been identified as the sectors most vulnerable to climate change and climate variability. Key climate change impacts on the most vulnerable sectors include reduced agricultural productivity, an increased risk of vector and water-borne diseases and the disruption of livelihood and income sources. Over the last several decades, the Agricultural Research Corporation has released a number of technologies, including crop and water management practices, tree cover improvement and livestock husbandry practices to improve the resilience of community and physical resources in the face of climate change. Sudan has also developed and implemented several policies and activities relevant to sustainable land management, environmental degradation and climate change adaptation and mitigation, as the agricultural sector is the major productive sector and is also the object of many policies, plans and interventions. The primarily focus of the

set plans and polices is to enhance the production, productivity, resilience to climate change and competitiveness of the food and cash crops.

Sudan faces multiple interlinked challenges. There is a clear decline in agricultural productivity, significant land degradation and desertification, climate change, and a huge reduction in range resources and forest cover. Despite these challenges, opportunities for agricultural development include a rich natural resource base (millions of hectares of potential cultivable land; millions of heads of animals and ground and surface water supplies) and a large yield potential to increase agricultural production and the inflow of foreign direct investment. Increasing food availability, combating environmental degradation and improving food security, particularly in the traditional rain-fed sector, remains a great challenge.

8 References

AAAID (2004). Introducing Zero-Tillage Farming Systems in Rain fed Sector in Sudan. Arab Authority for Agricultural Investment and Development, AAID). www.researchgate.net/publication/332410545.

Abdalla, K.A. (2011). Indicators of climate change in Sudan, DCG workshop on Climate Change and Implications for Dry Lands Management in Sudan, Khartoum, July 2011.

Abdel Razek, F.A. (2017). Vegetation and forest cover of Sudan. The Geography of Sudan| Economic Resources in Sudan.

AfDB, African Development Bank Group, Sudan Country Office (2016). Private sector-led, economic diversification, and development in Sudan.

Alhaj, M. (2020). Renewable Energy in Sudan: Status and Potential. Renewables in Africa, 6 January, 2020. Retrieved September 8, 2020, from https://www.renewablesinafrica.com/renewable-energy-in-sudan-status-and-potential-part-1/.

ARC (2007-2017), modified and updated by ARC (2007). Vegetation cover classes were derived from analysis and interpretation of MODIS 8-day surface reflectance time series for the period 1st January to 31st December 2017. Dryland Research Centre. ARC, Sudan.

ARC-El Obeid Research Station Reports (2009-2011). Agriculture Research Corporation, Wadmedani, Sudan.

Government of Sudan, Ministry of Agriculture and Forestry (2008). Agricultural Revival Programme (ARP).

Ayoub, A.T. (1998). Extent, severity and causative factors of land degradation in Sudan. Journal of Arid Environments 138:397-409.

Ayoub, A.T. (1999). Land Degradation, rainfall variability and food production in the Sahelian Zone of Sudan. Land Degradation and Development 10:459-500.

Bashir, A. & Faki, H. (2014). Role of agricultural sector in poverty reduction and food security in Sudan: A POLICY BACKGROUND PAPER, 17 February 2014.

Black, R. et al. (2008). Demographics and Climate Change: Future Trends and their Policy Implications for Migration. UK DFID.

Bushara, A. (2019). Women in Agriculture. Partner in Development Services (PDS) Forum-Khartoum-Sudan (2-11-2019). Organized by: Sudanese Encyclopaedia of Agriculture in Cooperation with Friedrich Elbert Stiftung (FES).

Republic of Sudan & HCENR (Republic of Sudan, Ministry of Environment, Forestry and Physical Development & Higher Council for Environment and Natural Resources) (2014). Sudan fifth national report to the convention on biological diversity (CBD) - Khartoum, Sudan. Retrieved on September 8, 2020, from https://www.cbd.int/doc/world/sd/sd-nr-05-en.pdf

CIA (Central Intelligence Agency) (2020). The World Factbook: Sudan. Retrieved September 8, 2020, from https://www.cia.gov/library/publications/the-world-factbook/geos/su.html.

DCG/CC (2011). Climate Change and Adaptive Production Technology Package for Crop and Livestock Production in Kordofan Region (project proposal).

Eco-Farm Project Report (2011). Eco-farm Research Project in North Kordofan State, Sudan (Drylands Coordination Group-DCG). Annual Report, 2011.

Eltigani, M.S. (1996). Sudan Drought Review, DCG Report. Drylands Coordination Group.

Eltoum, M.A. (2017). Use of GIS and remote sensing techniques to study the ecological zones of Sudan in 2017. Sudan Journal on Computing and Geoinformatics 1(1). ISSN:1858-8328(text), ISSN:1858-8336(online).

Eltoum, M.A., Dafalla, M.S., & I.S. Ibrahim (2015). The role of ecological factors in causing land surface desertification: The case of Sudan. Journal of Agriculture and Ecology Research 4(3):105-116.

Hag, F.M. & Osman, A.K. (2017). Adaptation Options to Reduce Climatic Risks in Rain-fed Agriculture Pamphlet. Climate risk finance for sustainable and climate resilient rain-fed farming and pastoral systems project (HCENR).

FAO (2012). The Land Cover Atlas of Sudan. Retrieved September 8, 2020, from http://www.fao.org/3/a-be896e.pdf.

FAO (2013). Sudan: Geography, climate and population.

FAO (2015). Moving forward on Sudan's National Agriculture Investment Plan. Retrieved September 8, 2020, from http://www.fao.org/sudan/news/detail-events/en/c/327739/.

Farouk, A.R. (2017). Vegetation and forest cover of Sudan. The Economic Resources in Sudan.

FNC (Forests National Corporation) (2005, 2011). Soudan Forest cover. Sudan's Forests National Corporation (FNC), part of the country's Ministry of Agriculture and Forestry.

FNC (Forests National Corporation) (2016). Forestry National Corporation Republic of Sudan, Agricultural Economics Department annual report, Ministry of Agriculture, 2016.

Gorashi, A.R. (1998). State of Forest Genetic Resources in Sudan. Prepared for the Sub-Regional Workshop FAO/IPGRI/ICRAF on the conservation, management, sustainable utilization and enhancement of forest genetic resources in Sahelian and North-Sudanian Africa, Ouagadougou, Burkina Faso, 22-24 September 1998.

HCENR (2014). Building resilience to the adverse impacts of climate change (successful stories and interventions achieved under the NAPA-Sudan implementation-2010/2013).Sudan's Higher Council for Environment and Natural Resources.

HCENR (2015). National Adaptation Plan (NAP). Sudan's Higher Council for Environment and Natural Resources.

HCENR (2019). Sudan country programme for the green climate fund (draft). Sudan's Higher Council for Environment and Natural Resources.

Hudo, N.A. (2016). Assessing the Impact of Climate Variability and Change on Sorghum Yield over Gadaref Area in Sudan. Master Thesis, University of Nairobi-Kenya.

IMF (2013). Sudan: Interim Poverty Reduction Strategy Paper. IMF Country Report no. 13/318.

IPC Report (2019). Integrated Food Security Phase Classification (IPC issued September 2019). IPC analysis Partners FAO, WFP et al.

IPCC (2007). (Intergovernmental Panel on Climate Change) 2007. Synthesis Report. An Assessment of the Intergovernmental Panel on Climate Change.

JICA (Japan International Cooperation Agency) (2012). Sudan: Country Gender Profile. www.jica.go.jp › thematic issues › gender

Laki, S.L. (1994). Desertification in the Sudan: causes, effects and policy options. International Journal of Sustainable Development & World Ecology 1(3): 198-205.

Mohamed, T.A. (2016). Monitoring and Analyzing of Desertification Trend in North Sudan Using Modis Images from 2000 to 2014. Master Thesis, Southern Illinois University Carbondale.

Muneer, S.E.T. (2008). Factors affecting adoption of agroforestry farming system as a mean for sustainable agricultural development and environment conservation in arid areas of Northern Kordofan State, Sudan. Saudi Journal of Biological Sciences 15 (1) 137-145.

MWRIE (Ministry of Water Resources, Irrigation and Electricity) (2017). Comprehensive report 2017.

NAIP (2013). National Investment Plan for the Agricultural Sector Document (NAIP, 2013): The five-year development plan for the rain-fed sector (2015-2020). Sudan's Ministry of Agriculture and Forestry.

NAPA (2004). Sudan National Adaptation Programme of Action (NAPA). Implementing NAPA Priority Interventions to Build Resilience in the Agriculture and Water Sectors to the Adverse Impacts of Climate Change in Sudan. UNDP Project document. Government of Sudan and UNDP. Higher Council for Environment and Natural Resources.

Republic of the Sudan (Republic of the Sudan, Ministry of Environment and Physical Development, Higher Council for Environment and Natural Resources (2007). National Adaptation Plan for Action. Retrieved September 8, 2020, from https://www.preventionweb.net/files/8575_sdn01.pdf.

ND-GAIN (2015). University of Note Dame Global Adaptation Index (ND-GAIN) (http//index.gain.org/).

Nimir, M.B. & I.A. Elgizouli (2011). Climate Change Adaptation and Decision Making in the Sudan. Washington, DC, World Resources Institute.

Omer, A. Mekki, Farah M Saed, Fadil H & Ahmed Salih (2003). Sudanese Experience in Water Harvesting. Paper presented at the conference on Water Harvesting and Future Development in Sudan. Friendship Hall, Khartoum, August 2003.

Omer, A.M. (2018). Agricultural Residues for future energy option in Sudan. Annals of Advances in Chemistry, 2:017-03.

Osman, A.K. (2020). Calculated by the authors using the Agricultural Economics Department, Ministry of Agriculture Records (not published).

Osman, A.K, Ahmed, M.T., & M.A. Omer (2016). Adaptation Options to Reduce Climatic Risks in Rain-fed Agriculture. Scaling –out of Climate-smart Extension Packages to Reduce Food Insecurity and Climatic Risks in CRFP Target States. Dryland Research Centre, ARC, Khartoum, Sudan.

Osman, A.K. & M.K. Ali. (2009). Crop production under traditional rain-fed agriculture. Proceedings of the National Symposium on Sustainable Rain-Fed Agriculture in Sudan. Published by UNESCO Chair of Desertification Studies, U of K.

Osman, A.K. (2017). Climate Change and Drylands Farming in Sudan: Trend, Impact and Adaptation. UK Journal of Natural Resources and Environmental Studies Special Issue Oct 2017: 1-10.

RCREEE (2012). Sudan Renewable Energy Country Profile. Regional Centre for Renewable Energy and Energy Efficiency. www.rcreee.org

Republic of Sudan, Ministry of Agriculture, Agricultural Economics Department (2016). Agricultural statistics.

Salah, A.A., Osman, A. K, & S.E. Elsheikh (2011). Intercropping of Some Sorghum and Cowpea Varieties at Different Spatial Arrangements in South Kordofan. Presented at the 50th National Crop Husbandry Committee Meeting, Conference Hall, ARC - Wadmedani, Sudan, 21, July 2010.

Sarra, S.A.M., Seedahmed, A.M.A, Ahmed, A., Osman, S.A.M, & Eldoma, A.M.A. (2018). Combating desertification in Sudan: Experiences and lessons learned, WSAD 16th International Conference, Geneva, 10-13 April 2018.

Sawsan, K.A. (2015). Expected feed gap, range and pasture administration. Range and Pasture Administration. Sudan' Ministry of Animal Wealth.

SECAP (2016). Social Environment and Climate Assessment Procedures, Review Notes, Projects programmes. IFAD (draft).

Shapo, H. & Adam, H. (2008). Modification of Microclimate and Associated Food Crop Productivity in an Alley-cropping System in Northern Sudan. Toward Agroforestry Design, pp 97-109. In: Jose S., Gordon A.M. (eds) Toward Agroforestry Design. Advances in Agroforestry, vol 4. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-6572-9_7

SMA (Sudan Meteorological Authority) (2017). SMA records. Khartoum, Sudan.

The Republic of Sudan (The Republic of Sudan, National Population Council NPC/GS, Ministry of Welfare & Social Security) (2010). Sudan Millennium Development Goals Progress Report 2010. Retrieved September 8, 2020, from http://www.sd.undp.org/doc/Sudan%20MDGs%20Report%202010.pdf.

Ministry of Water Resources, Irrigation and Electricity (2012a) Sudan solar atlas.

Ministry of Water Resources, Irrigation and Electricity (2012b). Sudan wind atlas.

The World Bank (2019). Global Solar Atlas 2.0, solar resource data: Solaris [Global Solar Atlas 2.0, a free, web-based application is developed and operated by the company Solargis s.r.o. on behalf of the

World Bank Group, utilizing Solargis data, with funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalsolaratlas.info]

UN panel (2009) on science and technology for development. RENEWABLE ENERGY TECHNOLOGIES for SUSTAINABLE RURAL DEVELOPMENT“. Submitted to 2009-2010 CSTD inter-Sessional panel meeting, 9-11/11/2009, Geneva. By Secretary General, Ministry of Science & Technology, Sudan.

UNDP-HDR (2013-2014). Sudan Human Development Report. UNDP.

UNEP (2007). Sudan: Post-Conflict Environmental Assessment, 2007, United Nations Environment Programme. SBN: 978-92-807-2702-9.

UNEP (2010). Liquefied Petroleum Gas (LPG). Demand, Supply and Future Perspectives for Sudan, Synthesis report of a workshop, Khartoum, December 2010.

UNFCCC (2003). Sudan's First National Communication under the United Nations Framework Convention on Climate Change. REPUBLIC OF THE SUDAN, Ministry of Environment, Forestry &Physical Development, Higher Council for Environment and Natural Resources.

UNFCCC (2013). Sudan's Second National Communication under the United Nations Framework Convention on Climate Change. REPUBLIC OF THE SUDAN, Ministry of Environment, Forestry &Physical Development, Higher Council for Environment and Natural Resources. Khartoum January 2013.

UNICEF Sudan (2017). Gender Programmatic Review. Retrieved September 8, 2020, from https://www.unicef.org/sudan/media/991/file/Gender-Programmatic-Review-2017.pdf

USAID (2016). Climate Change Risk Profile: Sudan. Fact Sheet. Retrieved September 8, 2020, from https://www.climatelinks.org/sites/default/files/asset/document/2016%20CRM%20Fact%20Sheet-%20Sudan.pdf

Wakeel, A.S. (2011). Biodiversity in Sudan: Status and Trends. SECS-Khartoum, 5 February 2011.

Zakieldeen, S.A. (2009). Adaptation to Climate Change: A Vulnerability Assessment for Sudan. Published by: International Institute for Environment and Development.

ZEF Working Paper Series, ISSN 1864-6638
Center for Development Research, University of Bonn
Editors: Christian Borgemeister, Joachim von Braun, Manfred Denich, Till Stellmacher and Eva Youkhana

1. Evers, Hans-Dieter and Solvay Gerke (2005). Closing the Digital Divide: Southeast Asia's Path Towards a Knowledge Society.
2. Bhuiyan, Shajahan and Hans-Dieter Evers (2005). Social Capital and Sustainable Development: Theories and Concepts.
3. Schetter, Conrad (2005). Ethnicity and the Political Reconstruction of Afghanistan.
4. Kassahun, Samson (2005). Social Capital and Community Efficacy. In Poor Localities of Addis Ababa Ethiopia.
5. Fuest, Veronika (2005). Policies, Practices and Outcomes of Demand-oriented Community Water Supply in Ghana: The National Community Water and Sanitation Programme 1994 – 2004.
6. Menkhoff, Thomas and Hans-Dieter Evers (2005). Strategic Groups in a Knowledge Society: Knowledge Elites as Drivers of Biotechnology Development in Singapore.
7. Mollinga, Peter P. (2005). The Water Resources Policy Process in India: Centralisation, Polarisation and New Demands on Governance.
8. Evers, Hans-Dieter (2005). Wissen ist Macht: Experten als Strategische Gruppe.
8.a Evers, Hans-Dieter and Solvay Gerke (2005). Knowledge is Power: Experts as Strategic Group.
9. Fuest, Veronika (2005). Partnerschaft, Patronage oder Paternalismus? Eine empirische Analyse der Praxis universitärer Forschungskooperation mit Entwicklungsländern.
10. Laube, Wolfram (2005). Promise and Perils of Water Reform: Perspectives from Northern Ghana.
11. Mollinga, Peter P. (2004). Sleeping with the Enemy: Dichotomies and Polarisation in Indian Policy Debates on the Environmental and Social Effects of Irrigation.
12. Wall, Caleb (2006). Knowledge for Development: Local and External Knowledge in Development Research.
13. Laube, Wolfram and Eva Youkhana (2006). Cultural, Socio-Economic and Political Con-straints for Virtual Water Trade: Perspectives from the Volta Basin, West Africa.
14. Hornidge, Anna-Katharina (2006). Singapore: The Knowledge-Hub in the Straits of Malacca.
15. Evers, Hans-Dieter and Caleb Wall (2006). Knowledge Loss: Managing Local Knowledge in Rural Uzbekistan.
16. Youkhana, Eva; Lautze, J. and B. Barry (2006). Changing Interfaces in Volta Basin Water Management: Customary, National and Transboundary.
17. Evers, Hans-Dieter and Solvay Gerke (2006). The Strategic Importance of the Straits of Malacca for World Trade and Regional Development.
18. Hornidge, Anna-Katharina (2006). Defining Knowledge in Germany and Singapore: Do the Country-Specific Definitions of Knowledge Converge?
19. Mollinga, Peter M. (2007). Water Policy – Water Politics: Social Engineering and Strategic Action in Water Sector Reform.
20. Evers, Hans-Dieter and Anna-Katharina Hornidge (2007). Knowledge Hubs Along the Straits of Malacca.
21. Sultana, Nayeem (2007). Trans-National Identities, Modes of Networking and Integration in a Multi-Cultural Society. A Study of Migrant Bangladeshis in Peninsular Malaysia.
22. Yalcin, Resul and Peter M. Mollinga (2007). Institutional Transformation in Uzbekistan's Agricultural and Water Resources Administration: The Creation of a New Bureaucracy.
23. Menkhoff, T.; Loh, P. H. M.; Chua, S. B.; Evers, H.-D. and Chay Yue Wah (2007). Riau Vegetables for Singapore Consumers: A Collaborative Knowledge-Transfer Project Across the Straits of Malacca.
24. Evers, Hans-Dieter and Solvay Gerke (2007). Social and Cultural Dimensions of Market Expansion.
25. Obeng, G. Y.; Evers, H.-D.; Akuffo, F. O., Braimah, I. and A. Brew-Hammond (2007). Solar PV Rural Electrification and Energy-Poverty Assessment in Ghana: A Principal Component Analysis.

26. Eguavoen, Irit; E. Youkhana (2008). Small Towns Face Big Challenge. The Management of Piped Systems after the Water Sector Reform in Ghana.

27. Evers, Hans-Dieter (2008). Knowledge Hubs and Knowledge Clusters: Designing a Knowledge Architecture for Development

28. Ampomah, Ben Y.; Adjei, B. and E. Youkhana (2008). The Transboundary Water Resources Management Regime of the Volta Basin.

29. Saravanan.V.S.; McDonald, Geoffrey T. and Peter P. Mollinga (2008). Critical Review of Integrated Water Resources Management: Moving Beyond Polarised Discourse.

30. Laube, Wolfram; Awo, Martha and Benjamin Schraven (2008). Erratic Rains and Erratic Markets: Environmental change, economic globalisation and the expansion of shallow groundwater irrigation in West Africa.

31. Mollinga, Peter P. (2008). For a Political Sociology of Water Resources Management.

32. Hauck, Jennifer; Youkhana, Eva (2008). Histories of water and fisheries management in Northern Ghana.

33. Mollinga, Peter P. (2008). The Rational Organisation of Dissent. Boundary concepts, boundary objects and boundary settings in the interdisciplinary study of natural resources management.

34. Evers, Hans-Dieter; Gerke, Solvay (2009). Strategic Group Analysis.

35. Evers, Hans-Dieter; Benedikter, Simon (2009). Strategic Group Formation in the Mekong Delta - The Development of a Modern Hydraulic Society.

36. Obeng, George Yaw; Evers, Hans-Dieter (2009). Solar PV Rural Electrification and Energy-Poverty: A Review and Conceptual Framework With Reference to Ghana.

37. Scholtes, Fabian (2009). Analysing and explaining power in a capability perspective.

38. Eguavoen, Irit (2009). The Acquisition of Water Storage Facilities in the Abay River Basin, Ethiopia.

39. Hornidge, Anna-Katharina; Mehmood Ul Hassan; Mollinga, Peter P. (2009). 'Follow the Innovation' – A joint experimentation and learning approach to transdisciplinary innovation research.

40. Scholtes, Fabian (2009). How does moral knowledge matter in development practice, and how can it be researched?

41. Laube, Wolfram (2009). Creative Bureaucracy: Balancing power in irrigation administration in northern Ghana.

42. Laube, Wolfram (2009). Changing the Course of History? Implementing water reforms in Ghana and South Africa.

43. Scholtes, Fabian (2009). Status quo and prospects of smallholders in the Brazilian sugarcane and ethanol sector: Lessons for development and poverty reduction.

44. Evers, Hans-Dieter; Genschick, Sven; Schraven, Benjamin (2009). Constructing Epistemic Landscapes: Methods of GIS-Based Mapping.

45. Saravanan V.S. (2009). Integration of Policies in Framing Water Management Problem: Analysing Policy Processes using a Bayesian Network.

46. Saravanan V.S. (2009). Dancing to the Tune of Democracy: Agents Negotiating Power to Decentralise Water Management.

47. Huu, Pham Cong; Rhlers, Eckart; Saravanan, V. Subramanian (2009). Dyke System Planing: Theory and Practice in Can Tho City, Vietnam.

48. Evers, Hans-Dieter; Bauer, Tatjana (2009). Emerging Epistemic Landscapes: Knowledge Clusters in Ho Chi Minh City and the Mekong Delta.

49. Reis, Nadine; Mollinga, Peter P. (2009). Microcredit for Rural Water Supply and Sanitation in the Mekong Delta. Policy implementation between the needs for clean water and 'beautiful latrines'.

50. Gerke, Solvay; Ehlert, Judith (2009). Local Knowledge as Strategic Resource: Fishery in the Seasonal Floodplains of the Mekong Delta, Vietnam

51. Schraven, Benjamin; Eguavoen, Irit; Manske, Günther (2009). Doctoral degrees for capacity development: Results from a survey among African BiGS-DR alumni.

52. Nguyen, Loan (2010). Legal Framework of the Water Sector in Vietnam.

53. Nguyen, Loan (2010). Problems of Law Enforcement in Vietnam. The Case of Wastewater Management in Can Tho City.

54. Oberkircher, Lisa et al. (2010). Rethinking Water Management in Khorezm, Uzbekistan. Concepts and Recommendations.

55. Waibel, Gabi (2010). State Management in Transition: Understanding Water Resources Management in Vietnam.

56. Saravanan V.S.; Mollinga, Peter P. (2010). Water Pollution and Human Health. Transdisciplinary Research on Risk Governance in a Complex Society.

57. Vormoor, Klaus (2010). Water Engineering, Agricultural Development and Socio-Economic Trends in the Mekong Delta, Vietnam.

58. Hornidge, Anna-Katharina; Kurfürst, Sandra (2010). Envisioning the Future, Conceptualising Public Space. Hanoi and Singapore Negotiating Spaces for Negotiation.

59. Mollinga, Peter P. (2010). Transdisciplinary Method for Water Pollution and Human Health Research.

60. Youkhana, Eva (2010). Gender and the development of handicraft production in rural Yucatán/Mexico.

61. Naz, Farhat; Saravanan V. Subramanian (2010). Water Management across Space and Time in India.

62. Evers, Hans-Dieter; Nordin, Ramli, Nienkemoer, Pamela (2010). Knowledge Cluster Formation in Peninsular Malaysia: The Emergence of an Epistemic Landscape.

63. Mehmood Ul Hassan; Hornidge, Anna-Katharina (2010). 'Follow the Innovation' – The second year of a joint experimentation and learning approach to transdisciplinary research in Uzbekistan.

64. Mollinga, Peter P. (2010). Boundary concepts for interdisciplinary analysis of irrigation water management in South Asia.

65. Noelle-Karimi, Christine (2006). Village Institutions in the Perception of National and International Actors in Afghanistan. (**Amu Darya Project Working Paper No. 1**)

66. Kuzmits, Bernd (2006). Cross-bordering Water Management in Central Asia. (**Amu Darya Project Working Paper No. 2**)

67. Schetter, Conrad; Glassner, Rainer; Karokhail, Masood (2006). Understanding Local Violence. Security Arrangements in Kandahar, Kunduz and Paktia. (**Amu Darya Project Working Paper No. 3**)

68. Shah, Usman (2007). Livelihoods in the Asqalan and Sufi-Qarayateem Canal Irrigation Systems in the Kunduz River Basin. (**Amu Darya Project Working Paper No. 4**)

69. ter Steege, Bernie (2007). Infrastructure and Water Distribution in the Asqalan and Sufi-Qarayateem Canal Irrigation Systems in the Kunduz River Basin. (**Amu Darya Project Working Paper No. 5**)

70. Mielke, Katja (2007). On The Concept of 'Village' in Northeastern Afghanistan. Explorations from Kunduz Province. (**Amu Darya Project Working Paper No. 6**)

71. Mielke, Katja; Glassner, Rainer; Schetter, Conrad; Yarash, Nasratullah (2007). Local Governance in Warsaj and Farkhar Districts. (**Amu Darya Project Working Paper No. 7**)

72. Meininghaus, Esther (2007). Legal Pluralism in Afghanistan. (**Amu Darya Project Working Paper No. 8**)

73. Yarash, Nasratullah; Smith, Paul; Mielke, Katja (2010). The fuel economy of mountain villages in Ishkamish and Burka (Northeast Afghanistan). Rural subsistence and urban marketing patterns. (**Amu Darya Project Working Paper No. 9**)

74. Oberkircher, Lisa (2011). 'Stay – We Will Serve You Plov!'. Puzzles and pitfalls of water research in rural Uzbekistan.

75. Shtaltovna, Anastasiya; Hornidge, Anna-Katharina; Mollinga, Peter P. (2011). The Reinvention of Agricultural Service Organisations in Uzbekistan – a Machine-Tractor Park in the Khorezm Region.

76. Stellmacher, Till; Grote, Ulrike (2011). Forest Coffee Certification in Ethiopia: Economic Boon or Ecological Bane?

77. Gatzweiler, Franz W.; Baumüller, Heike; Ladenburger, Christine; von Braun, Joachim (2011). Marginality. Addressing the roots causes of extreme poverty.

78. Mielke, Katja; Schetter, Conrad; Wilde, Andreas (2011). Dimensions of Social Order: Empirical Fact, Analytical Framework and Boundary Concept.

79. Yarash, Nasratullah; Mielke, Katja (2011). The Social Order of the Bazaar: Socio-economic embedding of Retail and Trade in Kunduz and Imam Sahib

80. Baumüller, Heike; Ladenburger, Christine; von Braun, Joachim (2011). Innovative business approaches for the reduction of extreme poverty and marginality?

81. Ziai, Aram (2011). Some reflections on the concept of 'development'.

82. Saravanan V.S., Mollinga, Peter P. (2011). The Environment and Human Health - An Agenda for Research.

83. Eguavoen, Irit; Tesfai, Weyni (2011). Rebuilding livelihoods after dam-induced relocation in Koga, Blue Nile basin, Ethiopia.

84. Eguavoen, I., Sisay Demeku Derib et al. (2011). Digging, damming or diverting? Small-scale irrigation in the Blue Nile basin, Ethiopia.

85. Genschick, Sven (2011). Pangasius at risk - Governance in farming and processing, and the role of different capital.

86. Quy-Hanh Nguyen, Hans-Dieter Evers (2011). Farmers as knowledge brokers: Analysing three cases from Vietnam's Mekong Delta.

87. Poos, Wolf Henrik (2011). The local governance of social security in rural Surkhondarya, Uzbekistan. Post-Soviet community, state and social order.

88. Graw, Valerie; Ladenburger, Christine (2012). Mapping Marginality Hotspots. Geographical Targeting for Poverty Reduction.

89. Gerke, Solvay; Evers, Hans-Dieter (2012). Looking East, looking West: Penang as a Knowledge Hub.

90. Turaeva, Rano (2012). Innovation policies in Uzbekistan: Path taken by ZEFa project on innovations in the sphere of agriculture.

91. Gleisberg-Gerber, Katrin (2012). Livelihoods and land management in the Ioba Province in south-western Burkina Faso.

92. Hiemenz, Ulrich (2012). The Politics of the Fight Against Food Price Volatility – Where do we stand and where are we heading?

93. Baumüller, Heike (2012). Facilitating agricultural technology adoption among the poor: The role of service delivery through mobile phones.

94. Akpabio, Emmanuel M.; Saravanan V.S. (2012). Water Supply and Sanitation Practices in Nigeria: Applying Local Ecological Knowledge to Understand Complexity.

95. Evers, Hans-Dieter; Nordin, Ramli (2012). The Symbolic Universe of Cyberjaya, Malaysia.

96. Akpabio, Emmanuel M. (2012). Water Supply and Sanitation Services Sector in Nigeria: The Policy Trend and Practice Constraints.

97. Boboyorov, Hafiz (2012). Masters and Networks of Knowledge Production and Transfer in the Cotton Sector of Southern Tajikistan.

98. Van Assche, Kristof; Hornidge, Anna-Katharina (2012). Knowledge in rural transitions - formal and informal underpinnings of land governance in Khorezm.

99. Eguavoen, Irit (2012). Blessing and destruction. Climate change and trajectories of blame in Northern Ghana.

100. Callo-Concha, Daniel; Gaiser, Thomas and Ewert, Frank (2012). Farming and cropping systems in the West African Sudanian Savanna. WASCAL research area: Northern Ghana, Southwest Burkina Faso and Northern Benin.

101. Sow, Papa (2012). Uncertainties and conflicting environmental adaptation strategies in the region of the Pink Lake, Senegal.

102. Tan, Siwei (2012). Reconsidering the Vietnamese development vision of “industrialisation and modernisation by 2020”.

103. Ziai, Aram (2012). Postcolonial perspectives on ‘development’.

104. Kelboro, Girma; Stellmacher, Till (2012). Contesting the National Park theorem? Governance and land use in Nech Sar National Park, Ethiopia.

105. Kotsila, Panagiota (2012). “Health is gold”: Institutional structures and the realities of health access in the Mekong Delta, Vietnam.

106. Mandler, Andreas (2013). Knowledge and Governance Arrangements in Agricultural Production: Negotiating Access to Arable Land in Zarafshan Valley, Tajikistan.

107. Tsegai, Daniel; McBain, Florence; Tischbein, Bernhard (2013). Water, sanitation and hygiene: the missing link with agriculture.

108. Pangaribowo, Evita Hanie; Gerber, Nicolas; Torero, Maximo (2013). Food and Nutrition Security Indicators: A Review.

109. von Braun, Joachim; Gerber, Nicolas; Mirzabaev, Alisher; Nkonya Ephraim (2013). The Economics of Land Degradation.

110. Stellmacher, Till (2013). Local forest governance in Ethiopia: Between legal pluralism and livelihood realities.

111. Evers, Hans-Dieter; Purwaningrum, Farah (2013). Japanese Automobile Conglomerates in Indonesia: Knowledge Transfer within an Industrial Cluster in the Jakarta Metropolitan Area.

112. Waibel, Gabi; Benedikter, Simon (2013). The formation water user groups in a nexus of central directives and local administration in the Mekong Delta, Vietnam.

113. Ayaribilla Akudugu, Jonas; Laube, Wolfram (2013). Implementing Local Economic Development in Ghana: Multiple Actors and Rationalities.

114. Malek, Mohammad Abdul; Hossain, Md. Amzad; Saha, Ratnajit; Gatzweiler, Franz W. (2013). Mapping marginality hotspots and agricultural potentials in Bangladesh.

115. Siriwardane, Rapti; Winands, Sarah (2013). Between hope and hype: Traditional knowledge(s) held by marginal communities.

116. Nguyen, Thi Phuong Loan (2013). The Legal Framework of Vietnam’s Water Sector: Update 2013.

117. Shtaltovna, Anastasiya (2013). Knowledge gaps and rural development in Tajikistan. Agricultural advisory services as a panacea?

118. Van Assche, Kristof; Hornidge, Anna-Katharina; Shtaltovna, Anastasiya; Boboyorov, Hafiz (2013). Epistemic cultures, knowledge cultures and the transition of agricultural expertise. Rural development in Tajikistan, Uzbekistan and Georgia.

119. Schädler, Manuel; Gatzweiler, Franz W. (2013). Institutional Environments for Enabling Agricultural Technology Innovations: The role of Land Rights in Ethiopia, Ghana, India and Bangladesh.

120. Eguavoen, Irit; Schulz, Karsten; de Wit, Sara; Weisser, Florian; Müller-Mahn, Detlef (2013). Political dimensions of climate change adaptation. Conceptual reflections and African examples.

121. Feuer, Hart Nadav; Hornidge, Anna-Katharina; Schetter, Conrad (2013). Rebuilding Knowledge. Opportunities and risks for higher education in post-conflict regions.

122. Dörendahl, Esther I. (2013). Boundary work and water resources. Towards improved management and research practice?

123. Baumüller, Heike (2013). Mobile Technology Trends and their Potential for Agricultural Development

124. Saravanan, V.S. (2013). “Blame it on the community, immunize the state and the international agencies.” An assessment of water supply and sanitation programs in India.

125. Ariff, Syamimi; Evers, Hans-Dieter; Ndah, Anthony Banyouko; Purwaningrum, Farah (2014). Governing Knowledge for Development: Knowledge Clusters in Brunei Darussalam and Malaysia.

126. Bao, Chao; Jia, Lili (2014). Residential fresh water demand in China. A panel data analysis.

127. Siriwardane, Rapti (2014). War, Migration and Modernity: The Micro-politics of the Hijab in Northeastern Sri Lanka.

128. Kirui, Oliver Kiptoo; Mirzabaev, Alisher (2014). Economics of Land Degradation in Eastern Africa.

129. Evers, Hans-Dieter (2014). Governing Maritime Space: The South China Sea as a Mediterranean Cultural Area.

130. Saravanan, V. S.; Mavalankar, D.; Kulkarni, S.; Nussbaum, S.; Weigelt, M. (2014). Metabolized-water breeding diseases in urban India: Socio-spatiality of water problems and health burden in Ahmedabad.

131. Zulfiqar, Ali; Mujeri, Mustafa K.; Badrun Nessa, Ahmed (2014). Extreme Poverty and Marginality in Bangladesh: Review of Extreme Poverty Focused Innovative Programmes.

132. Schwachula, Anna; Vila Seoane, Maximiliano; Hornidge, Anna-Katharina (2014). Science, technology and innovation in the context of development. An overview of concepts and corresponding policies recommended by international organizations.

133. Callo-Concha, Daniel (2014). Approaches to managing disturbance and change: Resilience, vulnerability and adaptability.

134. Mc Bain, Florence (2014). Health insurance and health environment: India's subsidized health insurance in a context of limited water and sanitation services.

135. Mirzabaev, Alisher; Guta, Dawit; Goedecke, Jann; Gaur, Varun; Börner, Jan; Virchow, Detlef; Denich, Manfred; von Braun, Joachim (2014). Bioenergy, Food Security and Poverty Reduction: Mitigating tradeoffs and promoting synergies along the Water-Energy-Food Security Nexus.

136. Iskandar, Deden Dinar; Gatzweiler, Franz (2014). An optimization model for technology adoption of marginalized smallholders: Theoretical support for matching technological and institutional innovations.

137. Bühler, Dorothee; Grote, Ulrike; Hartje, Rebecca; Ker, Bopha; Lam, Do Truong; Nguyen, Loc Duc; Nguyen, Trung Thanh; Tong, Kimsun (2015). Rural Livelihood Strategies in Cambodia: Evidence from a household survey in Stung Treng.

138. Amankwah, Kwadwo; Shtaltovna, Anastasiya; Kelboro, Girma; Hornidge, Anna-Katharina (2015). A Critical Review of the Follow-the-Innovation Approach: Stakeholder collaboration and agricultural innovation development.

139. Wiesmann, Doris; Biesalski, Hans Konrad; von Grebmer, Klaus; Bernstein, Jill (2015). Methodological review and revision of the Global Hunger Index.

140. Eguavoen, Irit; Wahren, Julia (2015). Climate change adaptation in Burkina Faso: aid dependency and obstacles to political participation. Adaptation au changement climatique au Burkina Faso: la dépendance à l'aide et les obstacles à la participation politique.

141. Youkhana, Eva. Postponed to 2016 (147).

142. Von Braun, Joachim; Kalkuhl, Matthias (2015). International Science and Policy Interaction for Improved Food and Nutrition Security: toward an International Panel on Food and Nutrition (IPFN).

143. Mohr, Anna; Beuchelt, Tina; Schneider, Rafaël; Virchow, Detlef (2015). A rights-based food security principle for biomass sustainability standards and certification systems.

144. Husmann, Christine; von Braun, Joachim; Badiane, Ousmane; Akinbamijo, Yemi; Fatunbi, Oluwole Abiodun; Virchow, Detlef (2015). Tapping Potentials of Innovation for Food Security and Sustainable Agricultural Growth: An Africa-Wide Perspective.

145. Laube, Wolfram (2015). Changing Aspirations, Cultural Models of Success, and Social Mobility in Northern Ghana.

146. Narayanan, Sudha; Gerber, Nicolas (2016). Social Safety Nets for Food and Nutritional Security in India.

147. Youkhana, Eva (2016). Migrants' religious spaces and the power of Christian Saints – the Latin American Virgin of Cisne in Spain.

148. Grote, Ulrike; Neubacher, Frank (2016). Rural Crime in Developing Countries: Theoretical Framework, Empirical Findings, Research Needs.

149. Sharma, Rasadhika; Nguyen, Thanh Tung; Grote, Ulrike; Nguyen, Trung Thanh. Changing Livelihoods in Rural Cambodia: Evidence from panel household data in Stung Treng.

150. Kavegue, Afi; Eguavoen, Irit (2016). The experience and impact of urban floods and pollution in Ebo Town, Greater Banjul Area, in The Gambia.

151. Mbaye, Linguère Mously; Zimmermann, Klaus F. (2016). Natural Disasters and Human Mobility.

152. Gulati, Ashok; Manchanda, Stuti; Kacker, Rakesh (2016). Harvesting Solar Power in India.

153. Laube, Wolfram; Awo, Martha; Derbile, Emmanuel (2017). Smallholder Integration into the Global Shea Nut Commodity Chain in Northern Ghana. Promoting poverty reduction or continuing exploitation?

154. Attemene, Pauline; Eguavoen, Irit (2017). Effects of sustainability communication on environments and rural livelihoods.

155. Von Braun, Joachim; Kofol, Chiara (2017). Expanding Youth Employment in the Arab Region and Africa.

156. Beuchelt, Tina (2017). Buying green and social from abroad: Are biomass-focused voluntary sustainability standards useful for European public procurement?

157. Bekchanov, Maksud (2017). Potentials of Waste and Wastewater Resources Recovery and Re-use (RRR) Options for Improving Water, Energy and Nutrition Security.

158. Leta, Gerba; Kelboro, Girma; Stellmacher, Till; Hornidge, Anna-Katharina (2017). The agricultural extension system in Ethiopia: operational setup, challenges and opportunities.

159. Ganguly, Kavery; Gulati, Ashok; von Braun, Joachim (2017). Innovations spearheading the next transformations in India's agriculture.

160. Gebreselassie, Samuel; Haile Mekbib G.; Kalkuhl, Matthias (2017). The Wheat Sector in Ethiopia: Current Status and Key Challenges for Future Value Chain Development.

161. Jemal, Omarsherif Mohammed, Callo-Concha, Daniel (2017). Potential of Agroforestry for Food and Nutrition Security of Small-scale Farming Households.

162. Berga, Helen; Ringler, Claudia; Bryan, Elizabeth; El Didi, Hagar; Elnasikh Sara (2017). Addressing Transboundary Cooperation in the Eastern Nile through the Water-Energy-Food Nexus. Insights from an E-survey and Key Informant Interviews.

163. Bekchanov, Maksud (2017). Enabling Environment for Waste and Wastewater Recycling and Reuse Options in South Asia: the case of Sri Lanka.

164. Kirui, Oliver Kiptoo; Kozicka, Martha (2018). Vocational Education and Training for Farmers and Other Actors in the Agri-Food Value Chain in Africa.

165. Christinck, Anja; Rattunde, Fred; Kergna, Alpha; Mulinge, Wellington; Weltzien, Eva (2018). Identifying Options for the Development of Sustainable Seed Systems - Insights from Kenya and Mali.

166. Tambo, Justice A. (2018). Recognizing and rewarding farmers' creativity through contests: experiences and insights from four African countries.

167. von Braun, Joachim (2018). Innovations to Overcome the Increasingly Complex Problems of Hunger.

168. Bechanov, Maksud; Evia, Pablo (2018). Resources Recovery and Reuse in Sanitation and Wastewater Systems: Options and Investment Climate in South and Southeast Asian Countries.

169. Kirui, Oliver K.; von Braun, Joachim (2018). Mechanization in African Agriculture: A Continental Overview on Patterns and Dynamics.

170. Beuchelt, Tina; Sarah Nischalke (2018). Adding a gender lens in quantitative development research on food and non-food biomass production: A guide for sex-disaggregated data collection

171. Daum, Thomas (2018). Of Bulls and Bulbs: Aspirations and perceptions of rural youth in Zambia.

172. Salvatierra-Rojas, Ana; Torres-Toledo, Victor; Mrabet, Farah; Müller, Joachim (2018). Improving milk value chains through solar milk cooling.

173. Desalegn, Gashaw; Ali, Seid Nuru (2018). Review of the Impact of Productive Safety Net Program (PSNP) on Rural Welfare in Ethiopia.

174. Muli, Celestine; Gerber, Nicolas; Sakketa, Tekalign Gutu; Mirzabaev, Alisher (2018). Ecosystem tipping points due to variable water availability and cascading effects on food security in Sub-Saharan Africa.

175. Njiraini, Georgina; Ngigi, Marther; Baraké, Evelyn (2018). Women in African Agriculture: Integrating Women into Value Chains to Build a Stronger Sector.

176. Bekchanov, Maksud; Evia, Pablo; Hasan, Mohammad Monirul; Adhikari, Narayan; Gondhalekar, Daphne (2018). Institutional framework and financial arrangements for supporting the adoption of Resource Recovery Reuse technologies in South Asia.

177. Mirzabaev, Alisher; Njiraini, Georgina Wambui; Gebremariam, Gebrelibanos; Jourdain, Damien; Magaia, Emílio; Julio, Felita; Mosse, Gerivásia; Mutondo, João; Mungatana, Eric (2019). Transboundary Water Resources for People and Nature: Challenges and Opportunities in the Olifants River Basin.

178. Gupta, Anil; Shinde, Chintan; Dey, Anamika; Patel, Ramesh; Patel, Chetan; Kumar, Vipin; Patel, Mahesh (2019). Honey Bee Network in Africa: Co-creating a Grassroots Innovation Ecosystem in Africa.

179. Kabran, Estelle Gnankon; Eguavoen, Irit (2019). Ferry transportation in Abidjan: Establishment, operation and sustainability of a paratransit system.

180. Sakketa, Tekalign Gutu; von Braun, Joachim (2019). Labor-intesive public works programs in sub-Saharan Africa: Experiences and implications for employment policies.

181. Legesse, Ermias Engida; Srivastava, Amit; Kuhn, Arnim; Gaiser, Thomas (2019). Household income implications of improved fertilizer accessibility and lower use inefficiency: Long-term scenarios for Ethiopia.

182. Daum, Thomas; Capezzone, Filippo; Birner, Regina (2019). The forgotten agriculture-nutrition link: Estimating the energy requirements of different farming technologies in rural Zambia with time-use data.

183. Ganguly, Kavery; Gulati, Ashok; von Braun, Joachim (2019). Making Skill Development Aspirational: Indian Agriculture and Food Sector.

184. Gulati, Ashok; Juneja, Ritika (2019). Agricultural Credit System in India: Evolution, Effectiveness and Innovations.

185. Chaudhry, Rabia (2019). "An island of excellence?" How the Pakistan military reflects on its presence in the development sector.

186. Mai Le, Quyen; Kelboro, Girma (2019). When heritage goes ways apart: Heritagization and local involvement at the Complex of Monuments in Hue, Vietnam.

187. Eguavoen, Irit; Attemene, Pauline; Kouame, Fulgence; Konan, Eugène Kouadio; Madhy, Chérif Aidara; Gleisberg-Gerber, Katrin (2019). Dernier refuge ou presqu'île d'opportunités? Démographie et conditions de vie à Adjahui-Coubé, une habitation spontanée à Abidjan.

188. Von Braun, Joachim (2019). AI and Robotics Implications for the Poor.

189. Daum, Thomas; Birner, Regina (2019). African agricultural mechanization Myths, realities and an emerging research agenda.

190. Wortmann-Kolundžija, Eli (2019). Empowering smallholder farmers through farmer organizations: Insights from Kenya and Burkina Faso.

191. Youkhana, Eva (2020). Actors networks in critical urban studies – protest against the subprime crisis in Madrid.

192. Tegegne, Azage; Feye, Getachew Legese (2020). Study of selected livestock innovations in Ethiopia.

193. Purwaningrum, Farah; Tayeb, Azmil; Rahmat, Siti Rahyla; Hornidge, Anna-Katharina (2020). Orientation shift? Understanding the 'Third Mission' of the University in Malaysia's Science System.

194. Seré, Carlos (2020). Investing Sustainably in African Livestock Development: Opportunities and Trade-Offs.

195. Gulati, Ashok; Das, Sandip (2020). India-Africa Partnership in Trade and Investment: With Focus on the Agriculture and Food Sector.

196. Scheiterle, Lilli; Birner, Regina (2020). Considerations on the role of institutions and networks in the bioeconomy: three case studies from Ghana and Brazil.

197. **Sylla, Mouhamadou Bamba; Dimobe, Kangbéni; Sanfo, Safietou (2021). Burkina Faso – Land, climate, energy,** agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.
198. **Admassie, Assefa; Abebaw, Degnet (2021). Ethiopia – Land, climate, energy, agriculture and development: A** study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.
199. **Coulibaly, Ousmane (2021). Mali – Land, climate, energy, agriculture and development: A study in the Sudano-**Sahel Initiative for Regional Development, Jobs, and Food Security.
200. Adamou, Rabani; Ibrahim, Boubacar; Bonkaney, Abdou Latif; Seyni, Abdoul Aziz; Idrissa, Mamoudou; Bello, Nassourou (2021). Niger – Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.
201. **Olayide, Olawale Emmanuel (2021). Nigeria – Land, climate, energy, agriculture and development: A study in** the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.
202. **Faye, Amy; Dièye, Mohamadou; Diakhaté, Pape Bilal; Bèye, Assane; Sall, Moussa; Diop, Mbaye (2021). Senegal** – Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.
203. **Osman, Abdelrahman Khidir; Mohamed, Adil (2021). Sudan – Land, climate, energy, agriculture and** development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.

http://www.zef.de/workingpapers.html

ZEF Development Studies

edited by
Solvay Gerke and Hans-Dieter Evers

Center for Development Research (ZEF),
University of Bonn

Shahjahan H. Bhuiyan
Benefits of Social Capital. Urban Solid Waste Management in Bangladesh
Vol. 1, 2005, 288 p., 19.90 EUR, br. ISBN 3-8258-8382-5

Veronika Fuest
Demand-oriented Community Water Supply in Ghana. Policies, Practices and Outcomes
Vol. 2, 2006, 160 p., 19.90 EUR, br. ISBN 3-8258-9669-2

Anna-Katharina Hornidge
Knowledge Society. Vision and Social Construction of Reality in Germany and Singapore
Vol. 3, 2007, 200 p., 19.90 EUR, br. ISBN 978-3-8258-0701-6

Wolfram Laube
Changing Natural Resource Regimes in Northern Ghana. Actors, Structures and Institutions
Vol. 4, 2007, 392 p., 34.90 EUR, br. ISBN 978-3-8258-0641-5

Lirong Liu
Wirtschaftliche Freiheit und Wachstum. Eine international vergleichende Studie
Vol. 5, 2007, 200 p., 19.90 EUR, br. ISBN 978-3-8258-0701-6

Phuc Xuan To
Forest Property in the Vietnamese Uplands. An Ethnography of Forest Relations in Three Dao Villages
Vol. 6, 2007, 296 p., 29.90 EUR, br. ISBN 978-3-8258-0773-3

Caleb R.L. Wall, Peter P. Mollinga (Eds.)
Fieldwork in Difficult Environments. Methodology as Boundary Work in Development Research
Vol. 7, 2008, 192 p., 19.90 EUR, br. ISBN 978-3-8258-1383-3

Solvay Gerke, Hans-Dieter Evers, Anna-K. Hornidge (Eds.)
The Straits of Malacca. Knowledge and Diversity
Vol. 8, 2008, 240 p., 29.90 EUR, br. ISBN 978-3-8258-1383-3

Caleb Wall
Argorods of Western Uzbekistan. Knowledge Control and Agriculture in Khorezm
Vol. 9, 2008, 384 p., 29.90 EUR, br. ISBN 978-3-8258-1426-7

Irit Eguavoen
The Political Ecology of Household Water in Northern Ghana
Vol. 10, 2008, 328 p., 34.90 EUR, br. ISBN 978-3-8258-1613-1

Charlotte van der Schaaf
Institutional Change and Irrigation Management in Burkina Faso. Flowing Structures and Concrete Struggles
Vol. 11, 2009, 344 p., 34.90 EUR, br. ISBN 978-3-8258-1624-7

Nayeem Sultana
The Bangladeshi Diaspora in Peninsular Malaysia. Organizational Structure, Survival Strategies and Networks
Vol. 12, 2009, 368 p., 34.90 EUR, br. ISBN 978-3-8258-1629-2

Peter P. Mollinga, Anjali Bhat, Saravanan V.S. (Eds.)
When Policy Meets Reality. Political Dynamics and the Practice of Integration in Water Resources Management Reform
Vol. 13, 2010, 216 p., 29.90 EUR, br., ISBN 978-3-643-10672-8

Irit Eguavoen, Wolfram Laube (Eds.)
Negotiating Local Governance. Natural Resources Management at the Interface of Communities and the State
Vol. 14, 2010, 248 p., 29.90 EUR, br., ISBN 978-3-643-10673-5

William Tsuma
Gold Mining in Ghana. Actors, Alliances and Power
Vol. 15, 2010, 256 p., 29.90 EUR, br., ISBN 978-3-643-10811-1

Thim Ly
Planning the Lower Mekong Basin: Social Intervention in the Se San River
Vol. 16, 2010, 240 p., 29.90 EUR, br., ISBN 978-3-643-10834-0

Tatjana Bauer
The Challenge of Knowledge Sharing - Practices of the Vietnamese Science Community in Ho Chi Minh City and the Mekong Delta
Vol. 17, 2011, 304 p., 29.90 EUR, br., ISBN 978-3-643-90121-7

Pham Cong Huu
Floods and Farmers - Politics, Economics and Environmental Impacts of Dyke Construction in the Mekong Delta / Vietnam
Vol. 18, 2012, 200 p., 29.90 EUR, br., ISBN 978-3-643-90167-5

Judith Ehlert
Beautiful Floods - Environmental Knowledge and Agrarian Change in the Mekong Delta, Vietnam
Vol. 19, 2012, 256 S., 29,90 EUR, br, ISBN 978-3-643-90195-8

Nadine Reis
Tracing and Making the State - Policy practices and domestic water supply in the Mekong Delta, Vietnam
Vol. 20, 2012, 272 S., 29.90 EUR, br., ISBN 978-3-643-90196-5

Martha A. Awo
Marketing and Market Queens - A study of tomato farmers in the Upper East region of Ghana
Vol. 21, 2012, 192 S., 29.90 EUR, br., ISBN 978-3-643-90234-4

Asghar Tahmasebi
Pastoral Vulnerability to Socio-political and Climate Stresses - The Shahsevan of North Iran
Vol. 22, 2013, 192 S., 29.90 EUR, br., ISBN 978-3-643-90357-0

Anastasiya Shtaltovna
Servicing Transformation - Agricultural Service Organisations and Agrarian Change in Post-Soviet Uzbekistan
Vol. 23, 2013, 216 S., 29.90 EUR, br., ISBN 978-3-643-90358-7

Hafiz Boboyorov
Collective Identities and Patronage Networks in Southern Tajikistan
Vol. 24, 2013, 304 S., 34.90 EUR, br., ISBN 978-3-643-90382-2

Simon Benedikter
The Vietnamese Hydrocracy and the Mekong Delta. Water Resources Development from State Socialism to Bureaucratic Capitalism
Vol. 25, 2014, 330 S., 39.90 EUR, br., ISBN 978-3-643-90437-9

Sven Genschick
Aqua-`culture´. Socio-cultural peculiarities, practical senses, and missing sustainability in Pangasius aquaculture in the Mekong Delta, Vietnam.
Vol. 26, 2014, 262 S., 29.90 EUR, br., ISBN 978-3-643-90485-0

Farah Purwaningrum
Knowledge Governance in an Industrial Cluster. The Collaboration between Academia-Industry-Government in Indonesia.
Vol. 27, 2014, 296 S., 39.90 EUR, br., ISBN 978-3-643-90508-6

Panagiota Kotsila
Socio-political and Cultural Determinants of Diarrheal Disease in the Mekong Delta. From Discourse to Incidence
Vol. 28, 2014, 376 S., 39.90 EUR, br., ISBN 978-3-643-90562-8

Huynh Thi Phuong Linh
State-Society Interaction in Vietnam. The Everyday Dialogue of Local Irrigation Management in the Mekong Delta
Vol. 29, 2016, 304 S., 39.90 EUR, br., ISBN 978-3-643-90719-6

Siwei Tan
Space and Environment in the Industrialising Mekong Delta. A socio-spatial analysis of wastewater management in Vietnam
Vol. 30, 2016, 240 S., 29.90 EUR, br., ISBN 978-3-643-90746-2

http://www.lit-verlag.de/reihe/zef

zef
Center for
Development Research
University of Bonn

Working Paper Series

Authors: ABDELRAHMAN KHIDIROSMAN, ADILM. ALI

Contacts: arkosman@hotmail.com, sanjak1956@gmail.com

Photo: Marwa Shumo

Published by:
Zentrum für Entwicklungsforschung (ZEF)
Center for Development Research
Genscherallee 3
D – 53113 Bonn
Germany

Phone: +49-228-73-1861
Fax: +49-228-73-1869
E-Mail: presse.zef@uni-bonn.de

www.zef.de