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Country profile – Sudan

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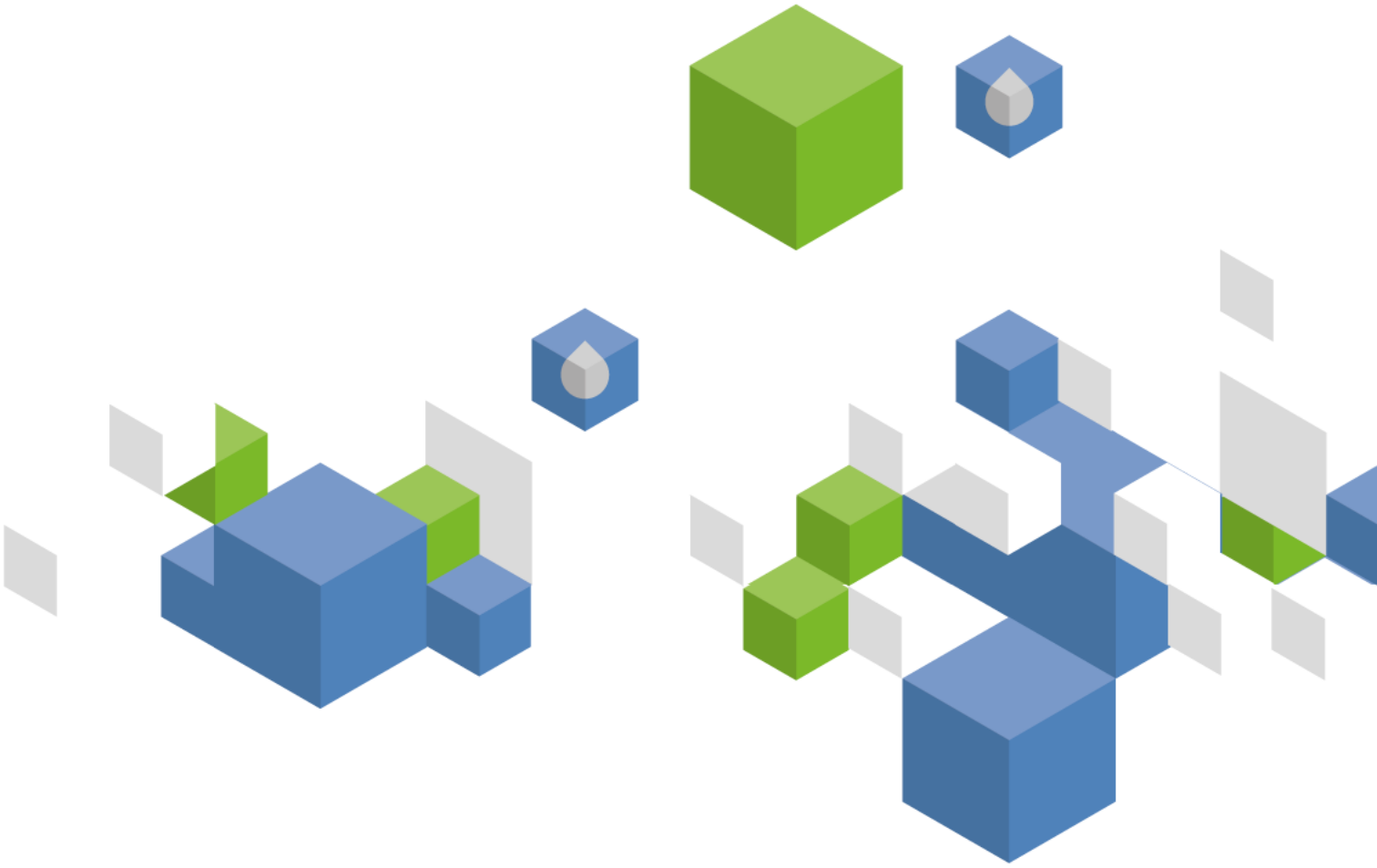

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Sudan

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Sudan has a special geopolitical location bonding the Arab world in Northern Africa to Africa south of the Sahara. It has an area of about 1.88 million km^2 (the exact area still needs to be confirmed, Table 1) and is the third largest country in Africa, after Algeria and the Democratic Republic of the Congo. Before the independence of South Sudan in 2011, it was the largest country in Africa. On the north-east Sudan is bordered by the Red Sea and it shares common borders with seven countries: Eritrea and Ethiopia in the east, South Sudan in the south, Central African Republic and Chad in the west, Libya in the northwest, and Egypt in the north.

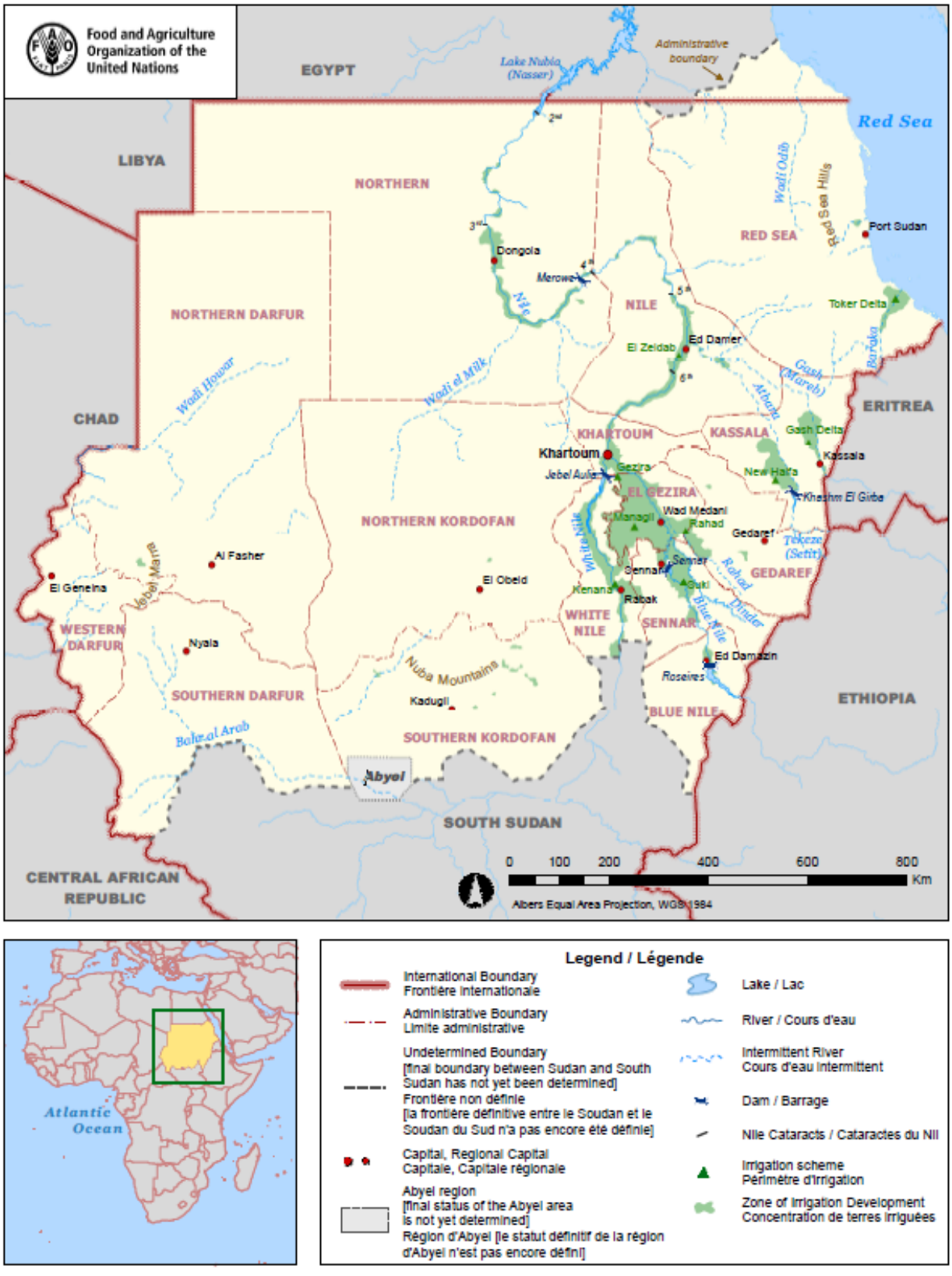
Sudan is under federal rule with 15 States. Each State is governed by a Wali (Governor) with 7 to 10 State Ministers, 4 to 5 Commissioners for the different provinces and a number of localities. Each State has complete administrative and fiscal autonomy and its own State Legislative Assembly for legislative matters of the State.

The country is generally flat with the exception of the Jebel Marra, the Red Sea Hills and the Nuba Mountains. There are three ecological zones in Sudan from north to south: the desert, the semi-desert and the low rainfall savannah. Its soils feature mainly the clay deposits in the central and eastern part, the stabilized sand dunes in the western and northern part, the red ironstone soils in the south, and alluvial soils along the Nile and other rivers and deltas.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	2012	187 935 750	ha
Agricultural land (permanent meadows and pasture + cultivated land)	2012	112 702 000	ha
• As % of the total area of the country	2012	60	%
• Permanent meadows and pasture	2012	91 450 000	ha
• Cultivated area (arable land + area under permanent crops)	2012	21 252 000	ha
- As % of the total area of the country	2012	11	%
- Arable land (temp. crops + temp. fallow + temp. meadows)	2012	21 045 000	ha
- Area under permanent crops	2012	207 000	ha
Population:			
Total population	2013	37 964 000	inhabitants
- Of which rural	2013	70	%
Population density	2013	20	inhabitants/km^2
Economy and development:			
Gross Domestic Product (GDP) (current US$)	2013	66 569	million US$/year
• Value added in agriculture (% of GDP)	2012	27.6	%
• GDP per capita	2013	1 753	US$/year
Human Development Index (highest = 1)	2013	0.473	-
Gender Inequality Index (equality = 0, inequality = 1)	2013	0.628	-
Access to improved drinking water sources:			
Total population	2012	55	%
Urban population	2012	66	%
Rural population	2012	50	%

FIGURE 1
Map of Sudan



SUDAN

FAO - AQUASTAT, 2015

Half of the country area (50.7 percent) is bare rocks and soil, such as wind-blown sands free of vegetation in hyper-arid areas. Trees cover 10 percent, shrubby vegetation 11.8 percent and herbaceous vegetation 13.8 percent. In 2012, the cultivated land was 21.25 million ha (9 percent of the total land area), comprising 21.05 million ha arable land and 0.2 million ha under permanent crops (Table 1). The permanent meadows and pastures extend over 91.5 million ha and over most ecological zones: annual herbaceous plants with scattered trees and bushes dominate in the north, while perennial herbaceous plants increase southward with dense stands of woody cover. Livestock includes camels, sheep and goats, which are raised in the desert and semi-desert, and cattle that is raised in the low rainfall savannah. Almost all livestock, estimated at 107 million heads in 2009 (for the 15 northern Sudan states only; FAO and WFP, 2011), is raised under nomadic and semi-nomadic systems. The country has still a diverse and fairly rich wildlife, despite losses in biodiversity (plants and fauna) since the 1970s.

Climate

Sudan has a tropical sub-continental climate, extending from desert climate in the north through a belt of summer-rain climate to semi-dry climate. The average annual rainfall is 250 mm, but ranges from 25 mm in the dry north up to 700 mm in the south. The country can be divided into two zones according to the rainfall regime:

- The annual rainfall in the northern half of Sudan varies from 200 mm in the centre of the country to 25 mm northwards towards the border with Egypt. Where it rains, the rainy season is limited to 2-3 months with the rest of the year virtually dry. Rainfall usually occurs in isolated showers, which vary considerably in duration, location, and from year to year. The coefficient of variation of the annual rainfall in this northern half of the country could be as high as 100 percent.

- In the south of the country, the annual rainfall barely exceeds 700 mm and is concentrated in only four months, from July to October. The average annual rainfall of that region is between 300-500 mm. Rainfed agriculture in Sudan is mainly practised in this area. As the coefficient of variation in annual rainfall in this region is around 30 percent and the dry season extends for about eight months, the area cultivated and the productivity vary widely from one year to another.

The mean temperature ranges from 30ºC to 40ºC in summer and from 10ºC to 25ºC in winter. The isohyets show that in most years agricultural production is only possible where there are irrigation systems or where there is natural and/or human-made harvesting of runoff water above the 15th parallel (FAO and WFP, 2011).

Most of the agricultural activities are concentrated in the southwest of the country, in the generally semi-arid dry savannah zone, through which the Blue Nile and the Atbara river flow. The growing season in the region is around four months. The major limiting factor is not the agricultural potential, but the short duration of the rainy season and the erratic distribution of rainfall during the growing period.

Climate in Sudan is highly variable and prone to erratic rainy seasons. This may result both in droughts, such as during 1967-1973 and even more severe in 1980-1984, and in floods, either localized due to torrential rainfall and runoff or widespread caused by overflow of the Nile river and its tributaries (ARC, 2007), such as happened in 2013 affecting over 300 000 people. In addition, climate change is already evidenced with reduced rainfall in the last 40 years and desertification–the Sahara desert is advancing at a rate of about 1.5 km/year (WB, 2013).

Population

Sudan's population is almost 38 million (2013) with an annual growth rate of 2 percent (over the 2012-2013 period). Population density is 20 inhabitants/km^2 and 70 percent of the total population is rural (Table 1). Most of the population lives along the Nile and its tributaries, and some live around water points scattered around the country. At national level, 55 percent of the population had access to

improved drinking water sources in the year 2012 (Table 1). In urban areas this coverage was 66 percent, while in rural regions it was 50 percent (JMP, 2014). The Human Development Index ranks Sudan in 166th place among 177 countries. Poverty is massive, deeply entrenched and predominantly a rural phenomenon with an incidence of 46.5 percent in 2009 in the northern states of pre-2011 Sudan (SCBS, 2010). Displaced families, both refugees from South Sudan and internally displaced, especially due to insecurity in Darfur, contribute to persistent poverty and food insecurity (FAO, 2013b) and place pressure on potable water resources. In 2013, the life expectancy in Sudan was 62.1 years and the under-five mortality was 73 per 1000 births. Primary education was attended by 67 percent of the children in 2009 in the northern states of pre-2011 Sudan with a ratio of girls to boys of 0.82. Attendance dropped to 22 percent for secondary education, but with more females than males attending secondary school in 2009 (SCBS, 2010). The adult literacy is 72 percent in 2012, but only 63 percent of women are literate. The Gender Inequality Index is 0.628 in 2013.

ECONOMY, AGRICULTURE AND FOOD SECURITY

Although endowed with rich natural resources, Sudan is an extremely poor country amongst others as a result of social conflict and civil war. In 2012 Sudan's economy has been affected by falling oil revenues due to the secession of South Sudan in July 2011 and the resultant loss of about 75 percent of the country's oil resources. As a result, inflation rose–36 percent in 2012–and the GDP contracted to equal US$66 569 million (current US$) in 2013. These factors, as well as a high fiscal deficit of 4.4 percent in 2012 due to sanctions by the United States of America and devaluation of the currency, could impair political stability and social development. However, its economy is expected to recover gradually based on renewed agriculture and natural resources (oil and gold mainly), depending on the evolution of civil wars in Darfur, South Kordofan and Blue Nile (AfDB, 2014).

The agricultural sector was the most dominant in pre-2011 Sudan until 2003, but then its share has declined to the benefit of both services and industries related to the exploitation and export of mineral oil, which boomed for a decade. In 2012, the agricultural sector contributed 27.6 percent to the GDP and employed 49 percent of the total economically active population in 2013. Almost half of the households in the northern states of pre-2011 Sudan were mostly agricultural, and up to 82 percent in Kordofan and Darfur states (SCBS, 2010)

Sudan's agro-ecological zones support a variety of food, cash and industrial crops. Vast natural pastures and forests support large herds of livestock including cattle, sheep and goats. The main exported crops are sorghum, cotton, groundnuts, sesame, sugarcane, Arabic gum, fruits and vegetables. Livestock is also important for exports.

Rainfed agriculture covers by far the largest area in Sudan. The area actually cultivated and total production may, however, vary considerably from year to year depending on variability of rainfall. The rainfed farming system is characterized by a small farm size, labour-intensive cultivation techniques employing hand tools, low input level and poor yields. Crops grown in the rainfed sector include sorghum, millet, sesame, sunflower and groundnuts.

Sudan has the largest irrigated area in sub-Saharan Africa and the second largest in the whole of Africa, after Egypt. The irrigated sub-sector plays a very important role in the country's agricultural production. Irrigated agriculture has become more and more important over the past few decades as a result of drought and rainfall variability and uncertainty. It remains a central option to boost the economy in general and increase the living standard of the majority of the population.

Pre-2011 Sudan was traditionally seen as the African 'bread basket'with a positive cereal balance. In 2014-2015, despite a record production of over 7.84 million tons of cereals, 20 percent of the cereals balance relied on imports, mostly for wheat.

Sudan's prevalence of undernourishment is as high as 38.9 percent in 2013 (FAO, 2013). An estimated 4.6 million people are food insecure in Sudan in 2014 despite above-average harvest by the end of 2014 (FAO, 2015). Food security deteriorated in the last years due to multiple reasons: influx of refugees,

poor harvests, restrictions on trade and assistance, conflicts and increased prices. While frequent droughts led to famine, regular variable rainfall patterns, recurrent conflicts and high food prices result in the most vulnerable people struggling to access enough food (FAO, 2013b).

WATER RESOURCES

Internal renewable water resources (IRWR) in Sudan are rather limited. The erratic nature of the rainfall and its concentration in a short season places Sudan in a vulnerable situation, especially in rainfed areas. Surface water in Sudan mainly comprises the Nile river system (nilotic water) and a few other, non-nilotic streams. About 43 percent of the Nile basin lies within Sudan, while 72 percent of Sudan lies in the Nile basin.

Sudan shares parts of the following basins with neighbouring countries:

- Nile basin, covering 1 350 616 km^2 of the country (72 percent of the area of the country)
- Northern Interior basins, covering 310 888 km^2 in the northwest part of the country (16.5 percent)
- Lake Chad basin, in the west of the country along the border with Chad and the Central African Republic, covering 101 048 km^2 (5.4 percent)
- Northeast Coast basins, representing a strip along the Red Sea coast of the country, covering 83 840 km^2 (4.5 percent)
- Baraka basin, along the Eritrean border, covering 24 141 km^2 (1.3 percent)
- Mareb-Gash basin, also along the Eritrean border, covering 8 825 km^2 (0.5 percent) (FAO, 1997; UNEP, 2007)

The last two, Mareb-Gash and Baraka, are seasonal streams, also named *khors*.

The Nile system within Sudan comprises:

- The Blue Nile and Atbara rivers originating in the Ethiopian highlands
- The White Nile system, downstream of Malakal, originating on the Great Lakes Plateau
- A small part of the Bahr El Ghazal basin, an internal basin in southwest Sudan and mainly located in South Sudan

The characteristics of the Nile system tributaries are the following:

- *The Blue Nile*: The flow of the Blue Nile reflects the seasonality of rainfall over the Ethiopian highlands where the two flow periods are distinct. The flood period or wet season extends from July to October, with the maximum in August-September, and low flow or dry season from November to June. Therefore the annual Blue Nile hydrograph has a constant bell-shaped pattern, regardless of variation in the annual flow volumes. The average annual inflow flow of the Blue Nile and its tributaries from Ethiopia to Sudan is estimated at 52 600 million m^3. The daily flow fluctuates between 10 million m^3 in April to 500 million m^3 in August (ratio of 1:50).
- *The White Nile*: The average annual flow of the White Nile System entering Sudan from South Sudan is about 34 000 million m^3. During the flood period the Blue Nile forms a natural dam that obstructs the flow of the White Nile and consequently floods the area upstream of the confluence.
- *The Atbara river*: This is a highly seasonal river, with an annual flow entering Sudan from Ethiopia of 4 370 million m^3 restricted to the flood period of July-October, the maximum occurring between August-September. The river has a steep slope and small catchments, and reflects the rainfall over the upper catchments as runoff at Sudan border within one to two days.
- *The Setit-Tekeze river*: This also is a highly seasonal river, with an annual flow crossing the border from Ethiopia to Sudan of 7 630 million m^3/year, restricted to the flood period of July-

October with the maximum occurring between August-September. Originating in Ethiopia, the river becomes the border between Ethiopia and Eritrea before entering Sudan.

- *The Main Nile*: The reach of the Nile downstream of the confluence of the Blue Nile and the White Nile rivers is known as the Main Nile. The Atbara river is regarded as the only and last tributary joining the Main Nile. The average annual flow of the Main Nile at the Sudan-Egypt border at Aswan (leaving Sudan), upstream of the reservoir is estimated at 84 000 million m^3. This is less than the sum of IRWR and the above water resources flowing into Sudan due to evaporation (see below).

The major non-nilotic streams are the Mareb-Gash and Baraka in the east of the country, coming from Eritrea, both of which are characterized by large variations in annual flow and heavy silt loads. Average annual flow is estimated at 700 million m^3. The major groundwater formation and basin is the Nubian Sandstone Basin covering a total area of 2.2 million km^2. It is the largest volume of freshwater in the world with an estimated 150 000 000 million m^3, mostly non-renewable (fossil water), except for the Nubian Nile aquifer recharging from the Nile river. This deep artesian aquifer underlies approximately 376 000 km^2 of Sudan, where it is almost untapped as in Chad, but contrarily to Libya and Egypt where it is tapped (UNEP, 2007). The groundwater outflow from Sudan to the Nubian aquifer in Egypt is estimated at 1 000 million m^3/year. A small portion of the Umm Rwaba aquifer lies also in Sudan.

In 2013, three wetlands are Ramsar listed, covering around 2.5 million ha: the Dinder National Park in Sennar State, and the Dongonab Bay (Marsa Waiai) and the Suakin (Gulf of Agig) in the Red Sea State.

Sudan's IRWR are estimated at 4 000 million m^3/year (Table 2). Total inflow is estimated at 99 300 million m^3/year, of which 98 600 million m^3/year through the Nile system (see bullet points a-d above) and 700 million m^3/year from Eritrea. Therefore total natural renewable water resources are equal to 103 300 million m^3/year. Natural surface water outflow to Egypt is 84 000 million m^3/year. This is less than the IRWR plus inflow, since 19 300 million m^3/year is estimated to evaporate in the swamps in the south of the country. Accounted water resources are less due to an agreement between pre-2011 Sudan and Egypt that 65 500 million m^3/year should enter Egypt from Sudan, leaving 18 500 million m^3/year for pre-2011 Sudan (=84 000-65 500). While it is not known yet what the treaty will be after the splitting of Sudan into South Sudan and Sudan, this will have consequences for both South Sudan and Sudan. For now AQUASTAT has considered that the outflow secured through treaties to Egypt is still 65 500 million m^3/year and that 26 500 million m^3/year of the total flow of 34 000 million m^3/year flowing from South Sudan to Sudan is submitted and secured through the agreement (from South Sudan to Sudan and then from Sudan to Egypt). These 26 500 million m^3/year are equal to 34 000x(65 500/84 000), whereby 65 500 million m^3/year is the inflow into Egypt according to the agreement and 84 000 million m^3/year is the flow to Egypt (see above). Considering the outflow of 65 500 million m^3/year as per the agreement, total (accounted) renewable water resources are equal to 37 800 million m^3/year (103 300-65 500). It should be mentioned that this calculation done by AQUASTAT is an interim calculation that neither represents AQUASTAT's position or recommendation, nor should it carry any political significance. Information will be updated as soon as information on a new or updated treaty will become available.

TABLE 2
Water resources

Renewable freshwater resources:			
Precipitation (long-term average)	-	250	mm/yr
	-	469 800	million m^3/yr
Internal renewable water resources (Long-term average)	-	4 000	million m^3/yr
Total renewable water resources	-	37 800	million m^3/yr
Dependency ratio	-	96	%
Total renewable water resources per inhabitant	2013	996	m^3/yr
Total dam capacity	2011	21 230	million m^3

The high variability of river flows necessitates storage facilities. The total storage capacity of the following five main dams is estimated at 21 230 million m^3, reduced to about 19 170 million m^3 owing to sedimentation and debris:

- The Sennar dam on the Blue Nile (design capacity 930 million m^3, present capacity 370 million m^3) is for the flood control and irrigation of the Gezira Scheme.
- The Roseires dam on the Blue Nile (design capacity 3 000 million m^3, present capacity 2 200 million m^3; there are plans to increase the present dam height of 60 m to provide an extra capacity of 4 000 million m^3) is for flood control and utilizes part of the country's share of the Nile waters for irrigation.
- The Jebel Aulia dam on the White Nile (design capacity 3 500 million m^3, present capacity is similar) was originally designed to benefit Egypt by augmenting the supply of summer flow to the Aswan dam. After the construction of the High Aswan dam it was no longer needed by Egypt and was officially handed over to the Sudan in 1977.
- The El Girba dam on the Atbara River (design capacity 1 300 million m^3, present capacity 600 million m^3) is for flood control, irrigation of New Halfa Scheme for the benefit of the people displaced by the High Aswan dam, and hydropower.
- The Merowe dam on the 4th cataract of the Nile, completed in 2009, created a reservoir of 12 500 million m^3 and 174 km long and has a hydropower capacity of 1 250 MW.

A small barrage was constructed on the Rahad river to divert floodwater to the Rahad Agricultural Scheme and to siphon underneath the Dinder river to augment the water supply during the dry season from the Meina Pump Station on the Blue Nile.

Four additional dams are proposed in Sudan at different proposal stages:

- The Kajbar dam planned upstream Lake Nubia, also called Lake Nasser on the Egyptian side, on the 3rd cataract of the Nile, close to the Egyptian border, was granted US$705 million and 5-years contract in 2010 by the government for its construction: it will generate 360 MW for a reservoir with a surface area of 110 km^2.
- The Dal dam on the 2nd cataract would have a height of 25-45 m and a capacity of 340-450 MW.
- The Shereik dam on the 5th cataract of the Nile.
- The Upper Atbara Project, an irrigation and hydropower complex in eastern Sudan, was awarded a US$838 million contract in 2010.

Non-conventional sources of water are limited in Sudan. However, the desalination of seawater was introduced recently in Port Sudan town. Fossil groundwater resources are estimated to be 16 000 000 million m^3.

INTERNATIONAL WATER ISSUES

Surface water and groundwater resources are mostly shared with neighbouring countries. The Nile river, which is shared between 11 countries, is the primary source of Sudan's water.

The first Nile Waters Agreement between Egypt and (pre-2011) Sudan was signed in 1929. It allocated to Egypt the right to use 48 000 million m^3/year, while it gave Sudan the right to tap only about 4 000 million m^3/year. The agreement does not allocate to Ethiopia any rights to use the Nile waters and also still binds Uganda, the United Republic of Tanzania and Kenya and bars them from using the Lake Victoria waters. In 1959, the Nile Waters Agreement between Egypt and Sudan assigned to Sudan 18 500 million m^3/year, measured at Aswan at the border with Egypt. The other riparian countries are still not included in this agreement.

In the beginning of the 21st Century the Nile Basin Initiative (NBI) created and prepared a Strategic Action Programme, which consists of two sub-programmes: the Shared Vision Programme (SVP) and the Subsidiary Action Programme (SAP). The SVP is to help create an enabling environment for action on the ground through building trust and skill, while the SAP is aimed at the delivery of actual development projects involving two or more countries. Projects are selected by individual riparian countries for implementation and submitted to the Council of Ministers of the NBI for approval. Pre-2011 Sudan, Ethiopia and Egypt also adopted a strategy of cooperation in which all projects to be

launched on the river should seek the common benefit of all member states and this should be included in accompanying feasibility studies.

However, the NBI is intended to be a transitional institution until the Cooperative Framework Agreement (CFA) negotiations are finalized and a permanent institution created. This new Nile CFA was signed in 2010 by five countries–Ethiopia, Kenya, Uganda, Rwanda and United Republic of Tanzania–and in 2011 by Burundi. Egypt strongly opposed this agreement which gives deciding power over large-scale hydraulic projects to a commission representing all the signatories, hence cancelling Egypt's historical right of veto. Pre-2011 Sudan, a traditional ally of Egypt, initially also rejected the agreement, but the new Sudan is now considering its signature due to increasing awareness of the unequal sharing and also hoping for benefits, in particular from the Ethiopian Renaissance dam, expected to be completed in 2017. Due to its proximity to the Sudanese's border, the dam could provide water for vast areas of irrigable land in Sudan, as well as mitigate floods in the agricultural El-Gezira region and greater Khartoum. The Democratic Republic of the Congo is also still to decide upon the CFA signature, as well as South Sudan, moreover so since the water contribution of the latter is considerable. The CFA was put on hold due to the Egyptian revolution of 2011. As mentioned in the previous section, for now AQUASTAT has considered that 26 500 million m^3/year flowing from South Sudan to Sudan is submitted to and secured by the agreement (to contribute to the 65 500 million m^3/year to flow to Egypt as per the agreement between Egypt and pre-2011 Sudan). However, it should clearly be mentioned that this is an interim calculation that neither represents AQUASTAT's position or recommendation, nor should it carry any political significance. Information will be updated as soon as information on a new or updated treaty will become available.

The main non-nilotic streams are also shared with neighbouring countries. A small part of Sudan, just over 5 percent, is located in the Lake Chad basin together with Algeria, Cameroon, the Central African Republic, Chad, Niger and Nigeria. For more information on the Lake Chad basin see the Chad and Niger country profiles, and the 2005 regional overview for Africa, in particular its Box 2.

In addition, Sudan shares also seven transboundary aquifers with neighbouring countries (Table 3) for which there is no sharing agreement. The largest groundwater aquifer is the Nubian sandstone aquifer system.

TABLE 3
Transboundary aquifers (Source: IGRAC, 2014)

Aquifer name	Total aquifer area (km^2)	Sharing countries
Gedaref	36 491	Ethiopia
Disa	38 675	Chad
South-West (IGRAC code AF50)	155 442	Cameroon, Central African Republic, Chad,
Baggara Basin	239 411	Central African Republic, South Sudan
West (IGRAC coed AF87)	540 224	Chad, Niger
Lake Chad Basin	1 425 319	Cameroon, Central African Republic, Chad, Niger, Nigeria
Nubian Sandstone Aquifer System (NSAS)	2 607 985	Chad, Egypt, Libya

WATER USE

Total water withdrawal in pre-2011 Sudan was estimated at 27 590 million m^3 for the year 2005. The largest water user by far was agriculture with 26 150 million m^3. Municipalities and industry accounted for withdrawals of 1 140 million m^3 and 300 million m^3 respectively. Figures for 2011 for Sudan have been estimated based on the above figures for pre-2011 Sudan, keeping the same total for South Sudan and Sudan together and considering that no essential changes have taken place, that almost all irrigation is located in Sudan (Figure 2), that the population of Sudan is 83 percent of the total population of pre-2011 Sudan and that most (75 percent) of the industries are located in South Sudan (petrol area) (Table 4).

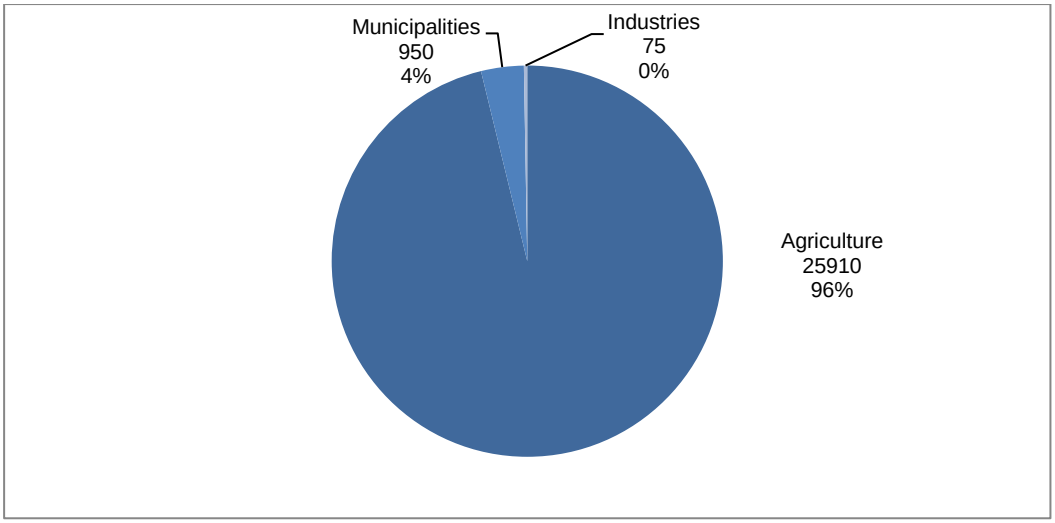
Water used in Sudan derives almost exclusively from surface water resources. Groundwater is used only in very limited areas, and mainly for municipal water supply, but is of critical importance locally.

However, extraction data is inexistent. Small water reservoirs fed by rainfall and runoff, also called *hafirs*, had a crucial role in supplying water for domestic use in villages and to pastoralists in remote areas, in particular in Darfur and Kordofan (UNEP, 2007; WB, 2011). Rehabilitation of these structures is currently taking place to provide a safe source of water for herds during dry season (FAO, 2013b).

TABLE 4
Water use

Water withdrawal:			
Total water withdrawal	2011	26 935	million m^3/year
- Agriculture (Irrigation + Livestock + Aquaculture)	2011	25 910	million m^3/year
- Municipalities	2011	950	million m^3/year
- Industry	2011	75	million m^3/year
• Per inhabitant	2011	739	m^3/year
Surface water and groundwater withdrawal (primary and secondary)	2011	26 935	million m^3/year
• As % of total renewable water resources	2011	71	%
Non-conventional sources of water:			
Produced municipal wastewater		-	million m^3/year
Treated municipal wastewater		-	million m^3/year
Direct use of treated municipal wastewater		-	million m^3/year
Direct use of agricultural drainage water		-	million m^3/year
Desalinated water produced		-	million m^3/year

FIGURE 2
Water withdrawal
Total 26 935 million m^3 in 2011



Domestic and industrial wastewater is disposed in open pit latrines or ponds. Collective sewage systems exist only in Khartoum (HCENR, 2008).

Disputes over water use, particularly between nomadic pastoralists and settled populations, have become inextricably linked to a wider regional conflict.

IRRIGATION AND DRAINAGE

Evolution of irrigation development

Irrigation potential was estimated at about 2.5 million ha based on soil and water resources criteria.

Large-scale gravity irrigation started during the British colonial period (1898-1956) and the colonial agricultural policy was characterized by the promotion of cotton production in the Nile basin. Irrigation by pumping water began at the beginning of the 20th Century, substituting traditional flood irrigation and water wheel techniques.

The Gezira Scheme is Sudan's oldest and largest gravity irrigation system, located between the Blue Nile and the White Nile. Started in 1925 and progressively expanded thereafter, in particular with its Managil expansion. It covers about 870 000 ha–one of the largest continuous irrigation schemes under a single administration in the world (UNEP, 2007)–and is divided into some 138 000 tenancies with an average size of about 8 ha (NBI, 2008). It receives water from the Sennar Dam on the Blue Nile and withdraws over a third of Sudan's share of Nile water under the 1959 Agreement (UNEP, 2007)–from 2 km^3 in 1958 to 7.1 km^3 in 1998 (NBI, 2008). The scheme has played an important role in the economic development of Sudan, serving as a major source of foreign exchange earnings and of Government revenue. It has also contributed to national food security and in generating a livelihood for the estimated 2.7 million people who live in the command area of the scheme.

In the post-colonial period, it was assumed that the only sound way to bring about development would still be through large irrigation developments. The increase in Nile water allocation through the 1959 Nile Waters Agreement with Egypt led for example to the construction of the Managil extension of the Gezira scheme and of the New Halfa scheme. The New Halfa scheme is located on the upper Atbara river in the east of the country. It was partly financed by Egypt after the construction of the Aswan High Dam that created Lake Nubia, which flooded the Sudanese town of Wadi Halfa in 1964.

In the 1970s, Sudan was expected to become the "bread basket" of the Arab world, and with large investments from oil-rich Gulf nations, irrigation schemes such as the Rahad scheme, which receives its water from the Rahad river and the Blue Nile, were established on the bank opposite Gezira. Large-scale irrigated agriculture expanded from 1.17 million ha in 1956 to more than 1.68 million ha by 1977. The 1980s were a period of rehabilitation, with efforts to improve the performance of the irrigation sub-sector. In the 1990s, some small schemes were licensed to the private sector, while the four main schemes of Gezira/Managil, New Halfa, Rahad and Suki–totalling almost 1.2 million ha–remained under government control because they were considered strategic schemes, and managed by parastatal organizations known as Agricultural Corporations. In addition, there were also four major government-run sugarcane schemes. Only the fifth and largest sugarcane plantation, the Kenana Sugar Company (White Nile State), is an international public-private joint venture (with the Kuwait Investment Authority and the Saudi Arabian government). Transfer of the irrigation management of the main schemes to water user associations started in 2009.

Out of the 1 890 000 ha equipped for irrigation in pre-2011 Sudan, almost all is located in Sudan. In 2011, the total area equipped for irrigation in Sudan was 1 851 900 ha, comprising 1 725 870 ha equipped for full control irrigation (modern and traditional irrigation) and 126 030 ha equipped for spate irrigation (Table 5, Table 6 and Figure 3).

Crops were previously irrigated by *shadufs* (hand-operated water pump) and *sequia* (animal-driven water-wheel), which are now almost entirely replaced by small irrigation pumps (UNEP, 2007). Traditional irrigation is still practiced on the floodplains of the main Nile downstream of Khartoum, as well as over substantial areas along the White and Blue Nile and the Atbara river. Irrigation systems in modern irrigation include surface, sprinkler and localized irrigation systems. Spate irrigation is practiced in the Gash Delta (Kassala State) with water from the Mareb-Gash river, in the Toker Delta (Red Sea State) with water from the Baraka river, and to a lesser extent, in Abu Habil (North Kordofan state) (NBI, 2008). In spate irrigation, water from the seasonal streams is captured and redirected by diverting structures and canals to flood wide areas of arable land. Actually irrigated area depends on the volume of water carried by the river each year. The crop grows on residual moisture in the soil and no irrigation is needed. Sometimes two crops are grown in one season.

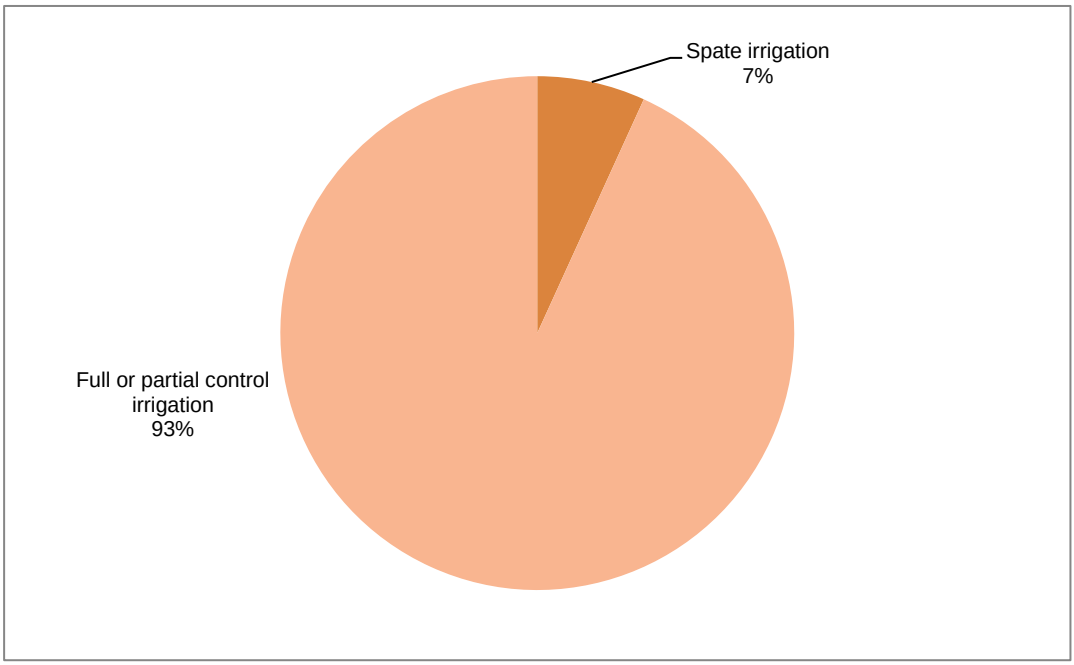
TABLE 5
Irrigation and drainage

Irrigation potential		-	2 500 000	ha
Irrigation:				
1. Full control irrigation: equipped area		2011	1 725 870	ha
- Surface irrigation			-	ha
- Sprinkler irrigation			-	ha
- Localized irrigation			-	ha
• Area equipped for full control irrigation actually irrigated		2011	993 520	ha
- As % of area equipped for full control irrigation		2011	58	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation		2011	126 030	ha
Total area equipped for irrigation (1+2+3)		**2011**	**1 851 900**	**ha**
• As % of cultivated area		2011	10	%
• % of area irrigated from surface water		2011	96	%
• % of area irrigated from groundwater		2011	4	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from non-conventional sources of water			-	%
• Area equipped for irrigation actually irrigated			-	ha
- As % of total area equipped for irrigation		2011	53.6	%
• Average increase per year		-	-	%
• Power irrigated area as % of total area equipped for irrigation		2011	19	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2011**	**1 851 900**	**ha**
• As % of cultivated area		2011	10	%
Size of full control irrigation schemes:	**Criteria**:			
Small schemes	< 100 000 ha	2011	437 970	ha
Medium schemes	> 100 000 ha and < 500 000- ha	2011	417 150	ha
large schemes	> 500 000 ha	2011	870 750	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes:				
Total irrigated grain production		2011	1 457 000	metric tons
• As % of total grain production			25.5	%
Harvested crops:				
Total harvested irrigated cropped area		2011	1 562 930	ha
• Temporary crops: total		2011	1 562 930	ha
- Sorghum		2011	678 700	ha
- Wheat		2011	254 600	ha
- Millet		2011	8 200	ha
- Other cereals		2011	61 700	ha
- Cotton		2011	157 300	ha
- Groundnuts		2011	45 000	ha
- Vegetable		2011	95 000	ha
- Sugarcane		2011	70 700	ha
- Sunflower		2011	20 900	ha
- Potatoes		2011	15 900	ha
- Other roots and tubers		2011	15 900	ha
- Fodder		2011	139 030	ha
• Permanent crops: total		2011	0	ha
Irrigated cropping intensity (on full control area actually irrigated)		2011	157	%
Drainage - Environment:				
Total cultivated area drained		2011	560 000	ha
• Non-irrigated cultivated area drained			-	ha
• Area equipped for irrigation drained			-	ha
- As % of total area equipped for irrigation			-	%
Area salinized by irrigation		2011	500 000	ha
Area waterlogged by irrigation			-	ha

TABLE 6
Government irrigation schemes in Sudan

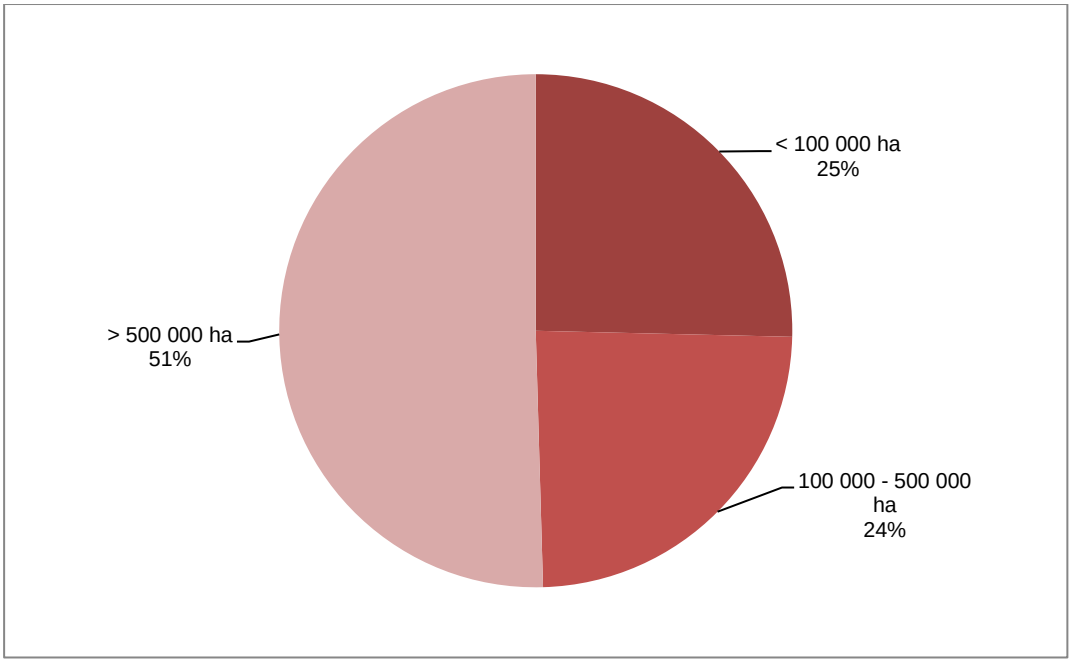
Schemes	Equipped area (ha)
Gezira and Managil	870 750
White Nile pump schemes	192 375
New Halfa	152 280
Rahad	121 500
Blue Nile pump schemes	112 590
Gash Delta (spate irrigation)	101 250
Northern pump scheme	41 715
Suki	35 235
Tokar Delta (spate irrigation)	30 750
Guneid Sugar	15 795
Assalaya Sugar	14 175
Sennar Sugar	12 960
Khashm El Girba	18 225
Other areas	132 300
TOTAL	**1 851 900**

FIGURE 3
Distribution of the irrigation area
Total 1 851 900 ha in 2011



In pre-2011 Sudan, in 2000 only about 800 000 ha, or 43 percent of the total area equipped for irrigation, were actually irrigated owing to deterioration of the irrigation and drainage infrastructures. Based on the irrigated cropping calendar, it was estimated that around 993 520 ha were actually irrigated in 2011. In 1995, surface water was the water source for 96 percent of the total irrigated area land, and the remaining 4 percent were irrigated from groundwater (small tubewells). The irrigated area where pumps are used to lift water was 346 680 ha in 2000. Most irrigation schemes are large-scale and were up to recently managed by parastatal organizations known as Agricultural Corporations. They have now been transferred to water users, while small-scale schemes are owned and operated by individuals or cooperatives (Figure 4).

FIGURE 4
Irrigation scheme size
Total area equipped for full control irrigation 1 725 870 ha in 2011



Traditional water harvesting practices are found in all the states of Sudan. Projects in the western part of Sudan were implemented during the 1970s, 1980s and late 1990s to combat the effects of drought by improving crop production and increasing municipal water use. However, few of those projects have succeeded in combining technical efficiency with low cost and acceptability to the local agro-pastoralist farmers. This is partially due to the lack of technical know-how, but also due to the selection of inappropriate approaches with regard to the prevailing socio-economic conditions.

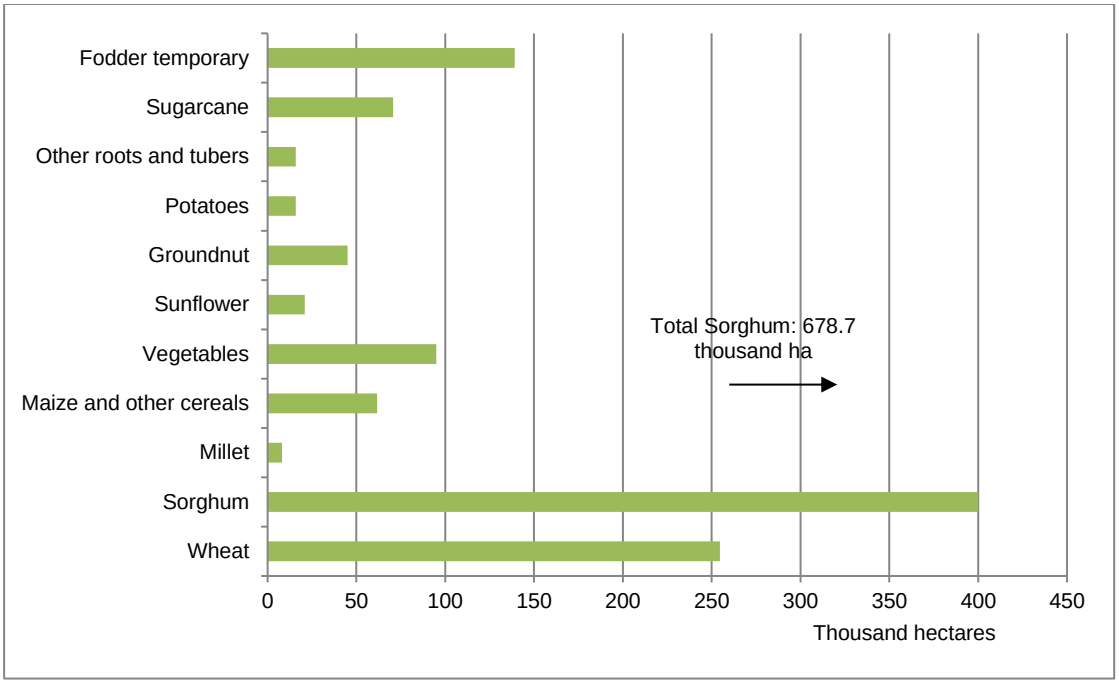
Role of irrigation in agricultural production, the economy and society

The importance of the irrigated agriculture is evidenced in 2011, when it corresponded to 11 percent of the cultivated area but produced over 25 percent of the total cereals production of Sudan with almost 1.5 million tons of irrigated cereals. In addition to cereals (mainly sorghum, wheat and millet, and to a lesser extent maize and rice), the main irrigated crops are cotton, fodder, groundnuts, vegetables, sugarcane and in a lesser extent sunflower, roots and tubers (Table 5 and Figure 5). In spate irrigation, the same crops are grown except for the cash crops (cotton, groundnuts, sugarcane). The irrigation sector is of crucial importance for the country due to its reliable production, contrarily to rainfed agriculture, in particular in drought years.

In recent years, sorghum has become the main crop in terms of area in the Gezira scheme with an average of 35 percent of total area planted, followed by wheat (25-30 percent) but with a downward trend, cotton (less than 25 percent) and groundnuts (about 20 percent). Sorghum has occupied the largest area because it is both a fodder and a subsistence grain crop. However, cotton is an important crop due to its high value, as well as its importance to farmers for cash income and to the national economy for the foreign exchange it generates (FAO, 2011). The irrigated subsector contributes to almost all sugar and cotton produced in the country (NBI, 2008).

Yields in Gezira for both sorghum and wheat (2.2 and 1.7 tons/ha respectively) are above the national average yields for irrigated crops (1.5 and 1.6 tons/ha respectively), but they are well below their potential yields (3.8-5.7 tons/ ha for sorghum and 3.3-4.1 tons/ha for wheat). Sugar is well-suited to Sudan because of the abundance of fertile delta lands between the Blue and White Niles and the intense sun and availability of water. This results in some of the highest sugarcane yields in the world: 92.7 tons/ha per year in average over the 1998-2007 period.

FIGURE 5
Main irrigated crops in 2011
Total 1 562 930 ha harvested irrigated crop in 2011 (cropping intensity on actually irrigated area: 157 percent)



A study at Nile basin level in 2009 evidenced that the irrigation performance and water productivity vary widely over the different irrigation schemes in pre-2011 Sudan, but the irrigation practices seem to be sustainable with irrigated land becoming greener over the previous years and the irrigation systems healthy and continuous with large water resources available. At scheme level, the modern and privately-managed West Sennar and new Kenana schemes have good irrigation results but do not seem to be sustainable in the long-term, while the El Gezira and Kassala schemes have low irrigation performances. The study also confirms that yields of irrigated agriculture in the country are generally poor with low biomass water productivity (Perry *et al.*, 2009).

Finally, it is worth noting that large areas have been sold or leased to foreign countries or companies, in particular on the banks of the Blue Nile, thus with access to irrigation water (Rulli *et al.*, 2013).

Women and irrigation

Women carry out a major portion of agricultural activities and bear almost the entire burden of household work, including water and fuelwood collection and food processing and preparation. Depending on the States, women are active in agriculture either only within their households (in Northern and Eastern states) or within and outside their households (in Western and Central states). Although women have equal access to land use, very few have land ownership rights, and thus can't access credit, membership in cooperatives or extension. Fewer women than men work in the irrigated agricultural sector, however they represent 49 percent of the farmers in the irrigated sector–against 57 percent in the rainfed traditional sector. Women in the rainfed sector are primarily subsistence farmers but they also work as seasonal wage labourers in the rainfed mechanized sector, and as hired or unpaid family labourers in the irrigated sector. At the household level, women are responsible for a wide range of decision making in farming activities, even when the husband is present (UNEP, 1994).

Status and evolution of drainage systems

Due to excess rainfall and sometimes to misuse of irrigation water all irrigation schemes need drainage networks to remove any excess water from the cultivated areas. In low areas, minor drains and collector drains are constructed to remove this excess water by gravity into low areas or natural drains. Sometimes, pumps are used to take water from low lands into areas outside the scheme. Also escape

drains are constructed along the main canal to carry any excess water to the nearest river or natural drain. In pre-2011 Sudan, it was estimated that about 500 000 ha were drained.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

Sudan has kept most institutions of pre-2011 Sudan, including the water related institutional structure.

The main ministry involved in water management and irrigation development at federal level is the Ministry of Water Resources and Electricity, resulting from the merge in 2012 of the Ministry of Irrigation and Water Resources and the Ministry of Electricity and Dams. It sets the national water resources policies, develops and monitors water resources, and promotes water management including irrigation and drainage. The National Water Resources Council is its advisory body at national level.

In a lesser extent, two others ministries are also involved in water management:

- The Ministry of Agriculture
- The Ministry of Environment, Forestry and Physical Development, and in particular its Higher Council for Environment and Natural Resources (HCENR), the coordination body for all environmental and natural resource management related matters in the Sudan, established in 1992 (HCENR, 2008).

Research on the various aspects of water use and management is carried out at federal level by a number of research institutions:

- Land and water research centre
- Water harvesting research institute
- Hydraulic research station
- National corporation for rural water
- Soil and water studies centre
- Agricultural research corporation centres
- Desertification and water research centre

The Public Water Corporation in Khartoum is responsible for the entire country water supply policy and development and for the 15 State Water corporations.

Finally, UNESCO Chair in water resources (UWCR-SD) was founded in 1994 in Sudan to serve the Nile basin and Shared Aquifer countries in the region, but contribute also to international debates on water resources.

At state level, institutions dealing with water are weak, due to the management of all natural resources according to state boundaries, thus not adequate for management at basin river or aquifer scale (HCENR, 2008).

Water management

Water management is completely separated from other natural resources (UNEP, 2012) and is made based on administrative rather than environment units, preventing comprehensive approach for natural resources management and conservation (HCENR, 2008).

In Darfur, water management is even more laborious due to lack of comprehensive knowledge of the resources, especially groundwater, as data is spread among many institutions. In addition, there is a lack of skilled staff for operation and management of both urban and rural water infrastructures, due to weak institutions and resources. A high level International Darfur Water Conference to address water issues and mobilize funds for the sector was held in Khartoum in June 2011 (AWF, 2011).

The Gezira scheme was government-owned and managed until 2009/2010. By 2001, participation of the water users was introduced in the management through Minor Canal Committee, but the Ministry was responsible for managing the Sennar Dam on the Blue Nile and the upper reaches of the irrigation system, and the semi-autonomous Sudan Gezira board (SGB) was entrusted with a vertically integrated management of lower reaches of the irrigation system, including prescribed rotations of cotton. Each tenant had plots in five tertiary units and had to plant according to the approved rotation so that all fields of a same crop were grouped together. The *2005 Gezira act* introduced a complete change in management from 2009/2010, effectively transferring the responsibilities for irrigation to land-owner and to water user associations and thus devolving planting decision-making to the farmers, thereby allowing planting flexibility within the water delivery regimes. The Rahad and Suki schemes are also under new management, while the New Halfa scheme was expected to follow (FAO and WFP, 2011).

Finances

Financing irrigation operation and maintenance through fees collected from the beneficiaries of the irrigation system was first introduced in Sudan with the introduction of the modern irrigation system at the El Zeidab scheme in 1909 when a private foreign company erected a pump station to irrigate local farmers' land for an agreed irrigation fee. After the success of the experiment for the first two seasons, a bad crop yield in 1911/12 meant that the farmers were unable to pay their irrigation fees. The company experienced heavy losses and decided to pull out of the scheme.

Experience from El Zeidab scheme was used in selecting the form of production relationship between the government, the Sudan Plantation Syndicate and the farmers when the Gezira scheme was commissioned. To avoid the inability of some farmers to pay irrigation fees in the case of bad crop yields, a "sharing system" between the three parties was adopted. This system continued until 1981 when it was replaced by what is known as the "individual account system" in which each individual farmer is treated separately in terms of cost and profit. The objective was to create some incentive for the individual farmers to increase their productivity. The new account system failed to achieve break-even productivity. The individual account system was also applied in all the irrigation schemes run by the government at that time. Payment of irrigation fees by the farmers continued in all government schemes from 1981 to 1995. During this period irrigation fees collected were very low, averaging about 50 percent only. The non-recovered part of the water supply costs is borne by the government.

Starting from 1995, and as part of the liberalization of the economy, the government withdrew from financing the cost of irrigation services, among other things. Farmers were left to pay irrigation fees to the newly established Irrigation Water Corporation (IWC), which uses these fees directly to provide water supply services to the farmers. Instead of the IWC setting up its own mechanism for collecting the fees directly from the farmers, it relies on the Agricultural corporations (AC) managing the scheme to collect the fees from the farmers. Because these ACs were also facing considerable financial difficulties, part of the water fees collected may not reach the IWC and part of the collected fees paid to IWC is delayed for some time as it is used for financing other urgent activities. The result of this is the inability of IWC to have the required budget that enables it to provide its services in a sustainable manner. This led to the accumulation of sediment in the irrigation canals, deterioration of the water regulation structures, machinery and pumps.

By the year 2000 the IWC was dissolved and the Ministry of Irrigation and Water Resources was again responsible for the operation and maintenance (O&M) of the irrigation canals up to the minor off-takes.

It is unclear how payment of irrigation feed is made since the recent devolution to water users in the large irrigation schemes.

Policies and legislation

The legal basis for water management, as well as irrigation and drainage, in Sudan at federal level was directly inherited from pre-2011 Sudan and includes the following acts (UNEP, 2012):

- *Civil Transaction Act 1984* ties the rights to develop and access water resources with land rights, as long as permission is granted by the respective water authority;
- *Irrigation and Drainage Act 1990* states authority over Nile and surface waters, in particular to issue licenses especially for irrigation and discharge into surface waters;
- *Water Resources Act 1995* is a major institutional reform concerned with the Nile and Non-Nilotic surface waters as well as with groundwater, hence superseding the *1939 Nile pumps control act* that was limited to the Nile waters only. It also establishes the NWRC and the need of a license for any water use;
- *National Water Commission Act 1995*, which is responsible water planning, coordinate water use, protect the environment, and carry out research on water sources and their sustainable exploitation;
- *Groundwater Regulation Act 1998* mandates the Groundwater and Wadis Directorate as the sole government technical organ to develop and monitor wadis and groundwater, and to issue permits for constructing water points;
- *Public Water Corporation Act 2008* gives authority to central government for national planning, research, development and investment in the water supply sector, as well as the corresponding policies and legislations.

In addition to these legislations, a number of policies, programmes and strategies have been defined for practical water management at federal level (AWF, 2011; FAO and WFP, 2011; UNEP, 2012):

- *Draft National Water Policy 1999*, amended in 2006, to ensure "sustainable and integrated management of available water resources and recognition of water as an instrument for conflict resolution".
- An *Integrated Water Resources Management (IWRM) Strategy* from 2008, currently reworked (UNEP, 2012).
- *The National Adaptation Programme of Action* to address climate variability and climate change focusing agriculture, water resources and public health;
- *The National Water Supply and Sanitation Policy 2010*, still awaiting endorsement at the national level, to ensure equitable and sustainable utilisation and provision of safe water and sanitation, with a view to achieving the Millennium Development Goals (MDGs).
- *Water, Sanitation and Hygiene (WASH) strategic plans* for the 15 States, covering a period of five years from 2011- 2016, were completed in May 2011.
- *The National Agricultural Revival Programme 2007-2012*, to improve water control through rehabilitation of the large irrigation schemes, encouraging development of the agro-industry by establishing a number of sugar factories, and improving infrastructure. Construction of the Merowe Dam was part of this programme.

ENVIRONMENT AND HEALTH

Desertification in Sudan is due in particular to overgrazing, but also to climate variability and reduced rainfall. Overgrazing is especially important around water points (AWF, 2011; HCENR, 2008). As a result, groundwater yields have reduced and aquifer levels have lowered in Darfur and Kassala states, and intrusion of seawater appeared in the Red Sea coastal zone (UNEP, 2007).

Environmental pollution of water and soil resources results from uncontrolled use of chemicals (UNEP, 2012), in particular obsolete pesticide stocks, as well as water pollution from sugar factories and extensive aerial spraying. Water pollution is especially worrying when irrigation canals are the source of drinking water, such as in Managil extension (UNEP, 2007).

Siltation of irrigation canals and dams is also significant, with its subsequent built-up of aquatic weeds. It results not only in loss of hydropower potential, but also in loss of agricultural production. In addition, some 500 000 ha were salinized by irrigation in 2000, reducing agricultural yields too.

In Darfur, disputes over natural resources, particularly between pastoralist, nomadic and settled populations, have become inextricably linked to the wider regional conflict. The increasing water shortages resulting from changes in climatic conditions have added to the conflict existing in 3 states of the region for a decade (AWF, 2011).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The country has an agricultural potential of 105 million ha, of which only 16.7 million ha are cultivated and only about 1.9 million ha out of an irrigation potential of around 2.5 million ha are equipped for irrigation now. Although there are still large areas of suitable land for irrigation development, the available water resources have reduced considerably since the secession of South Sudan, corresponding to the states with higher rainfall. In addition, availability of water resources is also curtained by the current uncertainty regarding the future of the Nile agreement and therefore Sudan's share of the Nile water resources. However, the low efficiency of irrigation schemes allows further improvement in irrigated agriculture.

Apart from the Gezira scheme established in 1925, most of the irrigation schemes were developed in the 1960s and 1970s. Since then, there have been no significant irrigation developments, for two reasons: any possible remaining sites would be complex and expensive to develop, and the low levels of productivity of the irrigated crops in the country make it difficult to justify further investment. As a result, priority has been given to increasing productivity from the existing irrigation schemes. But the recent division of the country, the recurrent conflicts in the last decade–through disorganisation and displacement of skilled staff–as well as weak institutions and legislations, constrain irrigation management and improvement in Sudan.

Hopefully, the recent irrigation transfer management of the large irrigation schemes to water users might contribute to improve results of the irrigation sub-sector. In addition, the prospects for sugarcane production in Sudan are encouraging and there are plans for the expansion of areas controlled by the Kenana Sugar Company and the Sudanese Sugar Corporation, as well as for the construction of new estates on both the Blue and White Niles. This could enable Sudan to grow in importance as a sugar exporter and will have major benefits for populations around the sugar estates (FAO, 2011), if water resources are made available both in the country and in the Nile basin.

MAIN SOURCES OF INFORMATION

AfDB. 2013. Sudan Economic Outlook. *African Economic Outlook*. African Development Bank.

ARC. 2007. *Managing risk, reducing vulnerability and enhancing agricultural productivity under a changing climate. Country report: Sudan.* Agricultural Research Corporation (Land and Water Research Center and Sudan Meteorological Authority).

AWF. 2011. *Darfur water project for conflict resolution and peace-building*: Investment planning, priority rehabilitation works and capacity building to meet water and sanitation needs in 15 to 20 Towns. Appraisal report. Republic of Sudan. African Water Facility. Tunis.

FAO. 1997. Irrigation potential in Africa: A basin approach. *Land and Water Bulletin 4*. Food and Agriculture Organization of the United Nations. Rome.

FAO. 2011. *Farming Systems Report*. Project "Information products for Nile basin water resources management". Food and Agriculture Organization of the United Nations. Rome.

FAO. 2013. *The State of Food Insecurity in the World 2013*. Food and Agriculture Organization of the United Nations. Rome.

FAO. 2013b. *Sudan. FAO in emergencies.* Food and Agriculture Organization of the United Nations. Rome.

FAO. 2015. *Sudan. FAO in emergencies.* Food and Agriculture Organization of the United Nations. Rome.

FAO, WFP. 2011. *Crop and food security assessment mission: January 2011*. Food and Agriculture Organization of the United Nations and World Food Programme. Rome.

HCENR. 2008. *National capacity self-assessment: report and action plan*. Higher Council for Environment and Natural Resources. Khartoum.

IGRAC. 2014. *Transboundary Aquifers of the World Map –Update 2014*. 1:50 000 000. International Groundwater Resources Assessment Centre.

JMP. 2014. *Progress on drinking water and sanitation – 2014 update*. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation.

NBI. 2008. *Best practices for water harvesting and irrigation: Sudan.* Efficient Water Use for Agricultural Production (EWUAP) Project. Nile Basin Initiative.

NBI. 2012. *State of the River Nile Basin 2012*. Nile Basin Initiative.

Perry, C. and Bastiaansseen, W. 2009. *Agricultural water use and water productivity in the large-scale irrigation (LSI) schemes of the Nile Basin*. Efficient Water Use for Agricultural Production Project. Nile Basin Initiative.

Rulli, M.C., Savioria, A., and D'Odoricob, P. 2013. Global land and water grabbing. *Proceeding of the National Academy of Sciences of the United States of America*. Vol. 110 (3): 892–897.

SCBS. 2010. *Sudan national baseline household survey 2009. North Sudan - Tabulation Report*. Sudan Central Bureau of Statistics.

UNEP. 2007. *Sudan post-conflict environmental assessment*. United Nations Environment Programme. Nairobi.

UNEP. 2012. *Environmental governance in Sudan: An expert review*. United Nations Environment Programme. Nairobi.

UNDP. 2013. *Human Development Report Statistics*. United Nations Development Programme,

WB. 2011. *World Bank supports sustainable livelihoods and landscapes in Sudan.* Press Release 19 December 2013. Washington DC.