

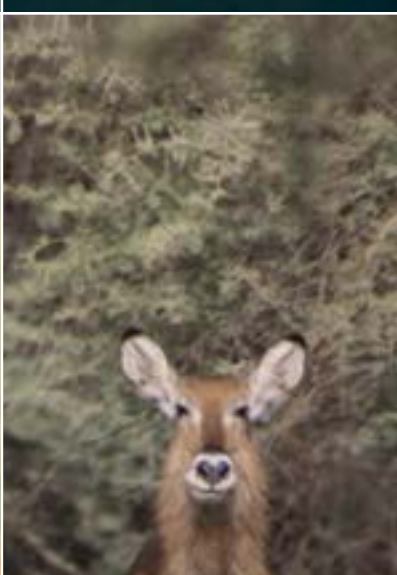


# Sudan

## First State of Environment and Outlook Report 2020

*Environment for Peace and Sustainable Development*

### Executive Summary





Republic of Sudan



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Sudan is a land of diverse ethnic groups and cultures. Photo Credit © UNAMID



# Executive Summary

## INTRODUCTION

The Sudan State of Environment and Outlook Report (2020) is the first of its kind to comprehensively take stock of the condition of the country's environment and the trends affecting it. The report follows an earlier issue-based environmental report, the Sudan Post-Conflict Environmental Assessment (UNEP 2007), which compiled field studies on the environmental impacts of the conflict in Sudan that ended with the 2005 Comprehensive Peace Agreement.

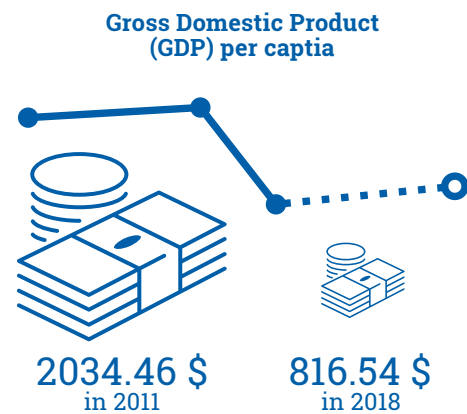
The State of Environment and Outlook Report (SoE) assesses the biophysical, social and economic conditions in the country and presents them in an integrated way, ultimately pointing to pathways that will lead the country towards a future based on sustainable development.

Through the use of the Drivers-Pressure-State-Impact-Response (DPSIR) analytical framework, the report not only establishes the causes and effects of environmental trends, but also addresses the country's policy and institutional response mechanisms. It starts with an overview of the country's geography and socio-economy and an explanation of its environmental governance system. It then discusses aspects of the environment under

the themes of Atmosphere, Land Resources, Water Resources, Biodiversity, Persistent Environmental Issues and Emerging Environmental Issues. These are followed by a detailed analysis of the country's policy and institutional arrangements, before the report concludes with a Future Outlook.

## SOCIO-ECONOMIC OVERVIEW

Located in northeast Africa (Figure 1), Sudan is the third largest African country by area after Algeria and the Democratic Republic of the Congo, covering 1.88 million km<sup>2</sup>. The secession of South Sudan in 2011 reduced its size by 24.7 per cent (Sudan National Survey Authority 2017).

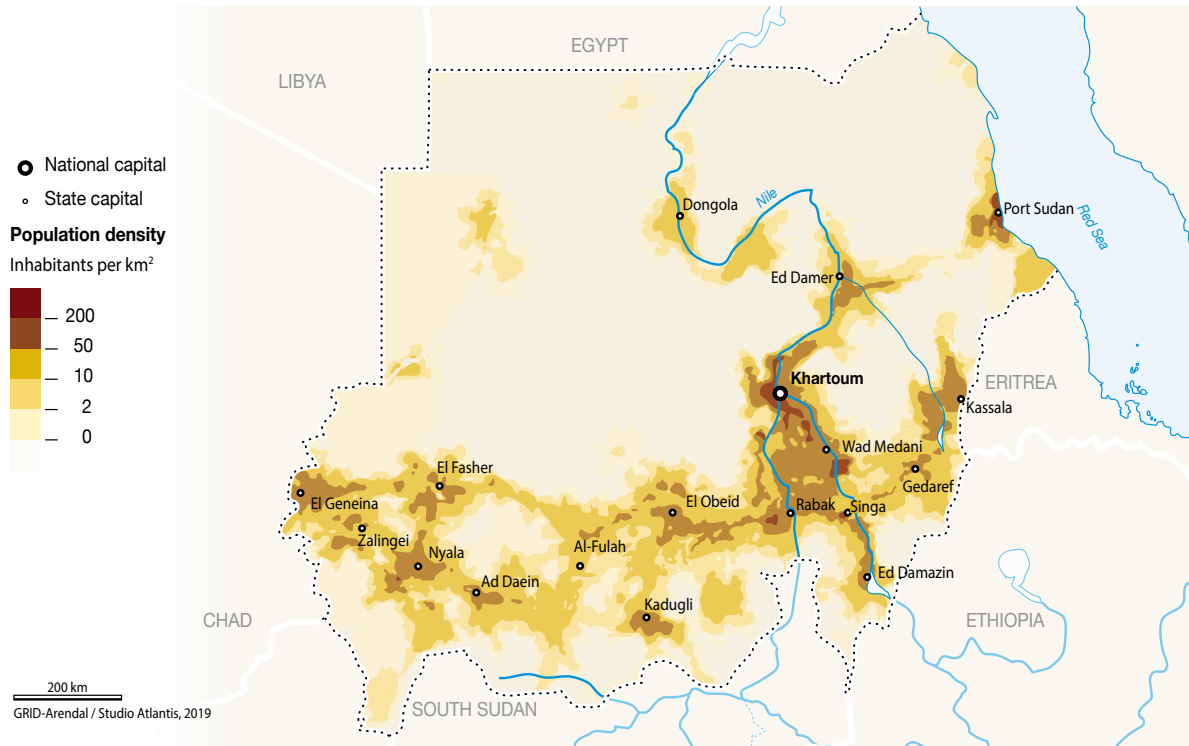


**Figure 1** Sudan on the map of Africa (GRID-Arendal)





**Figure 2** Population distribution in Sudan (GRID-Arendal)



The secession, compounded by economic sanctions imposed on the country by the United States of America, led to a significant decline in the country's Gross Domestic Product (GDP) per capita from 2034.46 USD in 2011 to 1698.08 and 816.54 USD in 2015 and 2018, respectively (Statista 2019).

The secession also led to Sudan losing 75 per cent of its oil reserves to South Sudan and consequently its crude production dropped by the same proportion (International Monetary Fund 2020).

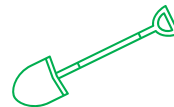
The country's population is estimated at 44.43 million, based on a projection from the 2008 census, and is predicted to increase to 57.3 million by 2030 (Central Bureau of Statistics 2018). 64 per cent of the country's population lives in rural areas (Ministry of Finance and Economic Planning 2016). Despite being a largely desert and semi-desert country, natural resources are the backbone of the economy. The agricultural sector contributes around 30-35 per cent to the nation's GDP, constitutes a source of livelihood for about 65 per cent of the population (World Bank and Ministry of Agriculture 2016) and employs about 50 per cent of the labour force (FAO 2018).

### Agricultural sector



**35–30%**  
of the nation's  
GDP

Source of livelihood  
for about **65%**  
of the population



Employs about **50%**  
of the labour force

Though most of Sudan's residents currently live in rural areas, the country is rapidly urbanizing. The capital city, Khartoum, grew at an annual rate of 5 per cent between 1973 and 1993, and at an even higher rate from 1993 to 2006. Many Sudanese have moved to urban areas in search of employment opportunities and better lives, while others have been driven there by drought and famine in Kordofan and Darfur. The conflict in the Darfur region resulted in 1.86 million internally displaced persons (UNHCR 2018), many of whom ended up living in towns.



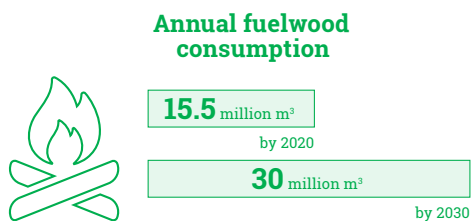


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As Figure 2 shows, the population is unevenly distributed across the country, with Khartoum, Gezira and South Darfur the most densely populated states.

Sudan's Interim National Constitution of 2005 acknowledged the roles played by women in agriculture and pastoralism. The country's supreme law also recognises the direct interaction that women have with the environment through the collection of firewood and water, as well as how women are impacted by environmental degradation and climate change. The Interim National Constitution also acknowledges the rights of other groups, including youth, farmers and pastoralists.

Given Sudan's location, which predisposes it to desert creep and drought, the country is vulnerable to poverty. According to the governmental data, 46.5 per cent of Sudan's population is living in poverty (Ministry of Finance and Economic Planning 2016). Poverty results in a higher dependence on the natural environment for livelihoods and resources, including forests for energy. Between 1993 and 1994, 81 per cent of Sudan's energy supplies came from fuelwood (UNEP 2013a). A 2010 report estimated that annual fuelwood consumption in Sudan would be 15.5 million m<sup>3</sup> by 2020 and 30 million m<sup>3</sup> by 2030 (FAO 2010).



The fourth constitutional decree of 1991 established Sudan as a federal country and this was reinforced by the Interim National Constitution of 2005 and later by the 2015 amendment to the constitution (National Assembly of Sudan 2015). Through the federal system, the country's governance is devolved to three levels: national, state and local (Figure 3). The country derives much of its environmental law from the Interim National Constitution, as well as from the Islamic law whose principles and values are mainly applied in the administration of traditional and customary values by community leaders.

The Interim National Constitution is explicit on tenure rights for land and other natural resources. Before the recent political change, the issue of land was centralized in the office of the president, a situation that did not align with the principles of devolution from federal to state and local levels.

Customary laws are central to Sudan's governance system. Customary laws prescribe access to land through membership in a community, while also allowing free passage, grazing and watering rights to pastoralist groups.

Sudan's environmental governance is also shaped by its national and international development goals. The country's Zero Thirst target aims to ensure that everyone in rural areas is within 500 metres of a reliable water supply by 2020. The Zero Hunger target involves tackling land degradation, land tenure issues and the impacts of climate change, as these factors hamper the country's food security. Sudan is also pursuing targets under the United Nations Sustainable Development Goals (SDGs), and has launched its National Programme for Sustainable Development (2016–2030) to ensure that the targets are met.

Sudan is party to many multilateral environmental agreements, which are key to the formulation of the country's laws. These include the United Nations Framework Convention on Climate Change, the United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification particularly in Africa, and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal.

Some of Sudan's environmental laws are derived from its membership of regional bodies such as the Inter-Governmental Authority on Development (IGAD) and the Nile Basin Initiative. The Nile Basin Initiative is important to Sudan given the country's dependence on the Nile River for much of its surface water. Under IGAD, which recognises drought as one of the most pressing needs for the region, Sudan has adopted the IGAD Drought Disaster Resilience and Sustainability Initiative Framework and established the Regional Platform for Drought Resilience and Sustainability.

The country has the institutions to ensure that environmental legislation is enforced, including traditional leadership, commissions and government bodies. The Higher Council for Environment and Natural Resources, established in 1991, was the most prominent, stable and recognisable environmental body in Sudan, as there was no government ministry solely dealing with



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the environment. On April 30 2020, the Transitional Supreme Council established a new Higher Council for Environment and Natural Resources (HCENR). On May 21, a Secretary-General was appointed to the HCENR, who reports directly to the Prime Minister of the Transitional Government.

Several other government ministries have mandates that cover the environment, including ministries with oversight on agriculture and water resources. At the state level and prior to the current government, the environment and natural resources were dealt with through the State Ministry of Production and Economic Resources.

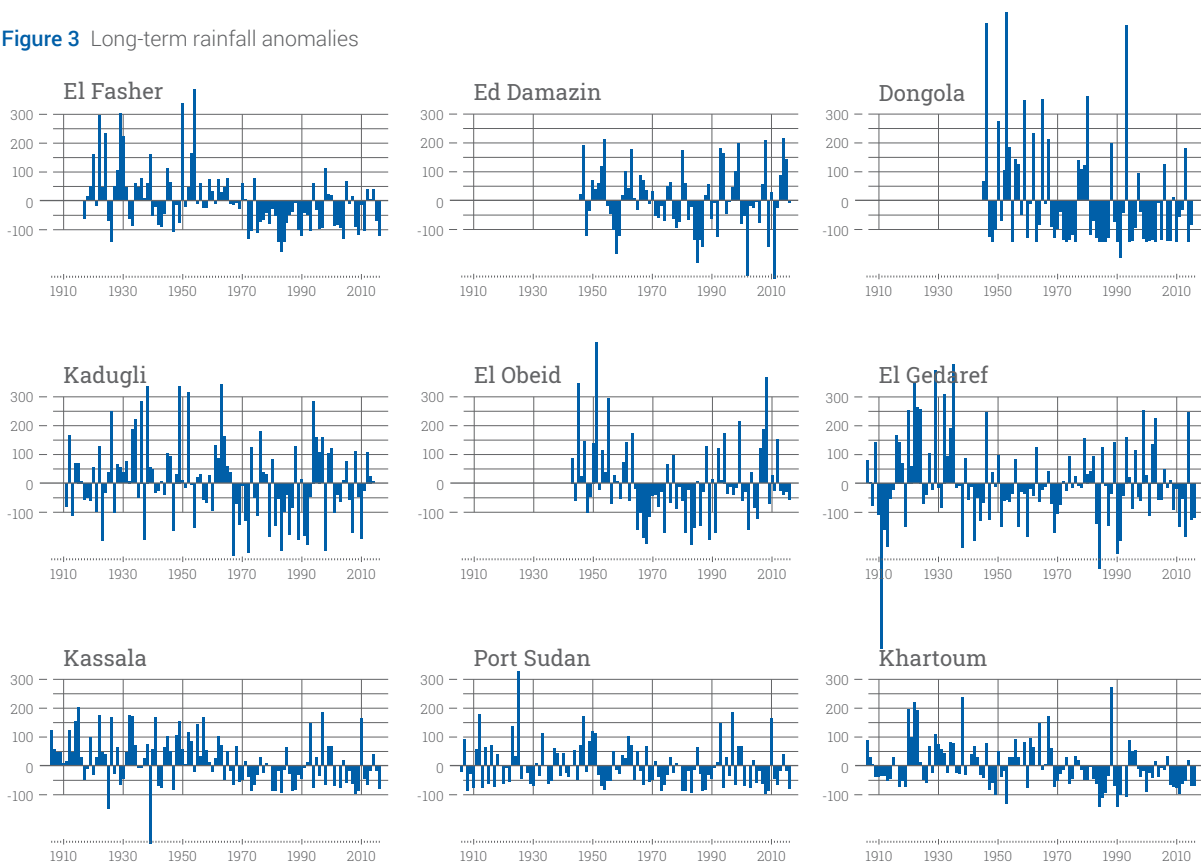
## ATMOSPHERE

Sudan's climate is generally hot for most of the year, with seasonal rainfall that decreases the further north you go. The movement of the Inter-Tropical Convergence Zone is the most important factor in determining the amount of rainfall received by the country. Humid maritime winds from the Atlantic and Indian Oceans have much less effect on the rainfall season.

Southern Sudan receives the highest amount of rainfall. Ed Damazin, near the border with Ethiopia, has an eight-month rainfall season that extends from April to November and receives an average of 692 mm of rainfall per year (Sudan Meteorological Authority 2019). Khartoum has a three-month rainfall season extending from July to September, with rainfall averaging 120 mm per year (Khyar and Fota 2001). In the areas closer to the border with Egypt, no rain falls at all in some years. The Sudan Meteorological Authority's data for the period 1981-2016 shows that the rainfall season is starting later and drought conditions are becoming more frequent.

Average temperatures are generally very high in Sudan, which together with the low rainfall make the country arid and dry. May and June are the hottest months, with temperatures averaging 41°C, but they can reach 47°C (Sudan Meteorological Authority 2019). High altitude areas and the coastal regions are generally cooler. The aridity and the desert environment create ideal conditions for dust storms, locally known as simoom and haboob.

Figure 3 Long-term rainfall anomalies



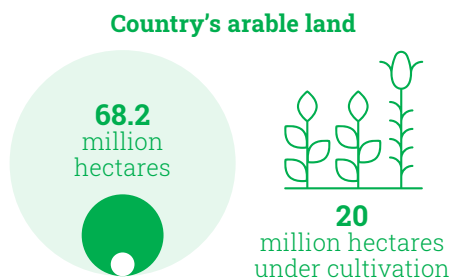
(Source: Sudan Meteorological Authority 2019, redesigned by GRID-Arendal)

Sudan's climate is changing, as demonstrated by a general rise in temperature, reduction and variability of rainfall (Figure 3), increased frequencies of droughts and floods, and sea level rise (Zakieldeen and Elhassan 2015). The biggest impact of the changing climate on Sudan is decreased food production. Climate change adaptation and mitigation efforts in the country include a switch to improved drought-resistant crop cultivars and animal breeds, the creation of green belts of gum arabic, and a shift to renewable forms of energy.

Despite having long hours of sunshine that could be tapped for solar power, Sudan largely depends on fossil fuels for energy, and this exposes people to various forms of pollution, including indoor household pollution. Most air pollution is caused by energy consumption. 56 per cent of Sudan's energy supply comes from biomass (wood, charcoal, agricultural residues and animal waste), 39 per cent from petroleum (gasoline, diesel and heavy oils) and 5 per cent from hydropower (Rabah et al. 2016). Dust storms constitute a natural form of air pollution.

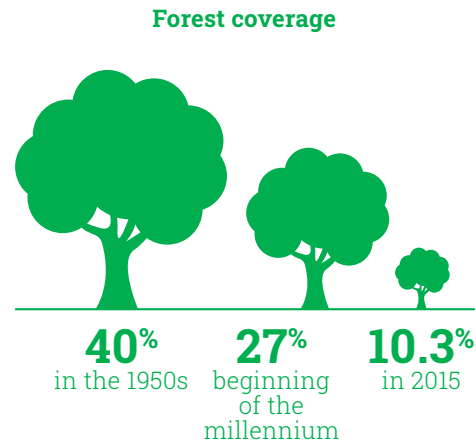
## LAND RESOURCES

About 72 per cent of Sudan is desert and sparsely populated. The land supports an agrarian economy and pockets of mining. The country's arable land extends to 90.7 million hectares (216 million feddan) of which only 23.5 million hectares (56 million feddan\*) is under cultivation (Ministry of Agriculture and Forest 2018).



The largest portion of arable land, making up 35.6 per cent of the total, is located in Kordofan region. Rain-fed agriculture is practised on 12.4 million hectares (29.5 million feddan), while the area under irrigation makes up only 3.9 per cent of the country's total land area (Ministry of Agriculture and Forests 2018). Sorghum and millet are the major staple crops,

while sugarcane, sesame, groundnut and watermelon are among the cash crops. Some of the arable land was formerly forest, rangeland or pasture. About 25.6 per cent of Sudan's total land area is considered rangeland, with over 60 per cent of South Darfur classified as rangeland.



The Food and Agriculture Organization of the United Nations (FAO) Global Forest Resources Inventory (1990-2015) indicates that Sudan's forest coverage declined from more than 40 per cent of the country's land area in the 1950s to 27 per cent at the beginning of the millennium before declining further to 10.3 per cent in 2015 in the post-secession era.

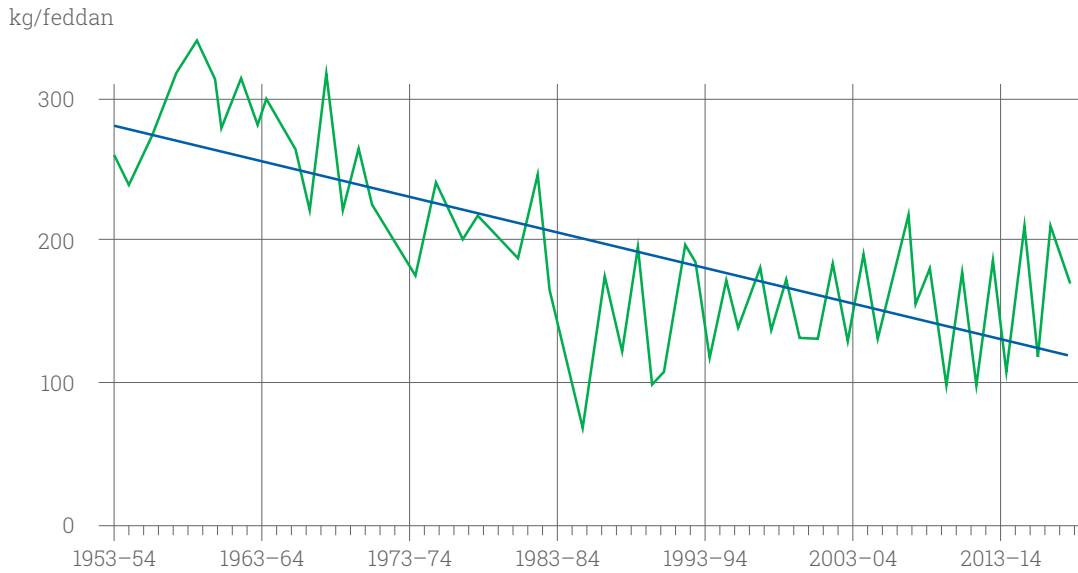
About 8.1 per cent of Sudan is set aside as protected areas, with Wadi Hawar, Radom and Dinder some of the largest reserves in the country. A small portion of Sudan's land constitutes oil fields. Organized and artisanal gold mining takes up small areas of land, especially in the northern desert regions of Northern, River Nile and North Darfur states.

Most rain-fed agriculture is village-based, and while the practice constitutes the main source of income for the majority of Sudanese, average yields over the years have been decreasing. As Figure 4 shows, average cereal yields are declining, with sorghum and millet yields having dropped from 350 kg/feddan in the late 1950s to under 200 kg/feddan in 2016/17 (Sudan National Survey Authority 2017). To compensate for the falling yields, farmers have been expanding the land under cultivation at a rate of 3.71 per cent per year (Ijaimi 2016).

\* Hectare = 10,000 m<sup>2</sup> = 2.38 feddan



**Figure 4** Declining yields of cereals (redesigned by GRID)



Mechanised farming is practiced on around 6.7 million hectares (16 million feddan). Some of this land has over-worked soils.

### Agricultural areas in million hectares



Irrigated

**3.5**



Mechanized

**6.7**



Rainfed

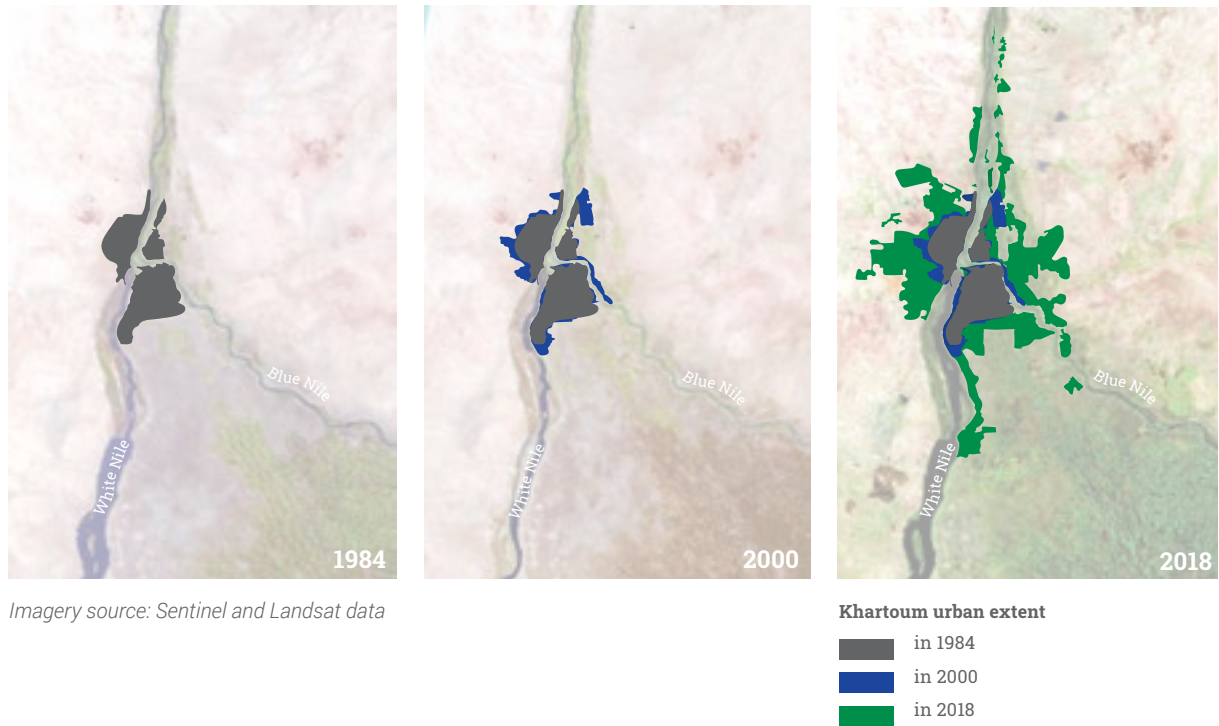
**12.4**

About 3.5 million hectares (8.3 million feddan) of land is used for irrigated farming growing mainly sugarcane, cotton, wheat and alfalfa.

Nomadic pastoralism is practiced by 13 per cent of Sudan's population (UNEP 2013b). The total livestock population in the country is estimated at 108.6 million, with sheep and cattle numbering 40.8 million and 31.2 million, respectively (FAO 2018). The migration patterns of the pastoralists involve wet season grazing towards the north and dry season grazing towards the south. Major rivers such as the White Nile, Blue Nile and Atbara constitute important dry season refuges for the pastoralists.

Major land-related issues in Sudan include conflicts, land degradation and urban encroachment, such as the dramatic expansion of the city of Khartoum since 1984 (as shown in Figure 5). Major recent conflicts in Sudan have occurred in Darfur and Kordofan. Some of the local conflicts have been between pastoralists and sedentary farmers over livestock routes, while other conflicts have been over mining rights and mining allotment boundaries. Land degradation, mainly in the form of soil erosion, is rife, causing siltation of water resources.

**Figure 5** Expansion of Khartoum City between 1984 and 2018 (redesigned by GRID-Arendal)

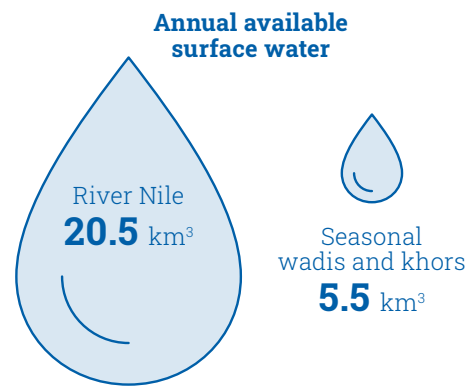


**WATER RESOURCES**

Sudan’s annual per capita water availability is about 700 m<sup>3</sup> based on the Falkenmark Water Stress Indicator, significantly below the “water scarcity margin” of 1000 m<sup>3</sup> per capita (White 2012). The country’s major surface freshwater sources are transboundary and include 44 per cent of the Nile River Basin, which Sudan shares with 10 other countries (FAO 2017). Many of its groundwater sources are also shared with neighbouring countries. For example, the Nubian Sandstone Aquifer is shared by Sudan has a significant share of the Red Sea with a coastline that extends for 853 km, including embayments and inlets (FAO 2019).

The Nile River system provides 73 per cent of Sudan’s annual freshwater supplies (Hamad 2015). Based on the 1959 agreement with Egypt, Sudan receives 18.5 km<sup>3</sup> of water per year from the Nile River as measured at Aswan in southern Egypt, and this translates to 20.5 km<sup>3</sup> per year in the centre of Sudan. A lot of surface water is lost to evaporation: the Nile River system loses 13 per cent of its flow as it passes through Sudan and the Sahara Desert (Governments of Sudan and Egypt 1959).

\* Wadi or khor: Seasonal water course  
 \*\*Hafir: Rainwater and runoff harvesting reservoir

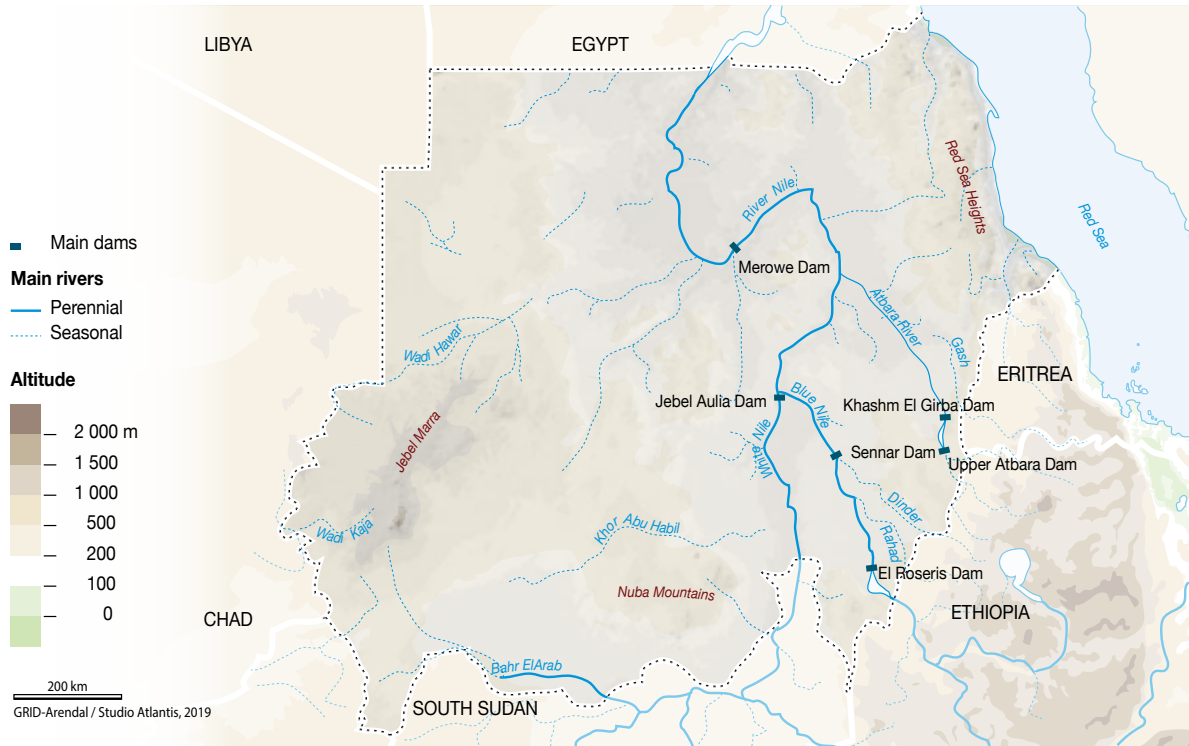


As Figure 6 shows, seasonal *wadis*\* and *khors* are also critical freshwater sources for Sudan. They contribute an additional 5.5 km<sup>3</sup> of water per year (Government of Sudan 2000), but the amount may vary between years depending on the rainfall received. The *wadis* and *khors* usually flow for a few days or even hours during the period July to October. Natural lakes, wetlands and *hafirs*\*\* are also valued as important sources of freshwater.

Groundwater sources contribute about 4.5 km<sup>3</sup> per year (Hamad 2015). The Nubian aquifer and the Umm Ruwaba formation are the major groundwater sources for Sudan.



Figure 6 Perennial and seasonal rivers (redesigned by GRID-Arendal)



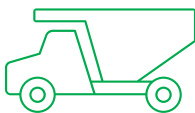
### Access to drinking water



70% of the urban population

63.5% of the rural population

### Access to sanitation services



57% in urban areas

22% in rural areas

Sudan uses its water for domestic purposes, irrigation, hydropower generation, navigation and recreation. The municipal domestic sector uses about 3.5 per cent of the water available to Sudan (FAO 2015), mainly for household use. Access to safe drinking water and sanitation services is generally low. 70 per cent of the population in urban areas and 63.5 per cent in rural areas have access to safe drinking water; while access to sanitation services averages 39.5 per cent (57 per cent in urban areas and 22 per cent in rural areas) (Central Bureau of Statistics and UNICEF 2016).

Hydropower is an important part of Sudan's electricity mix. The Merowe dam has the largest hydropower capacity at 1,250 MW, while the Upper Atbara dam complex is capable of producing 320 MW (Dams Implementation Unit 2018). The Roseires, Sennar and Khashm El-Girba dams can generate 280 MW, 15 MW and 10 MW respectively (Dams Implementation Unit 2018).

An estimated 0.02 million m<sup>3</sup> of water per day is produced from non-conventional sources, including the desalination of sea water from Sudan's portion of the Red Sea (Adam and Abdo 2017). These non-conventional sources also include wastewater.

Sudan's coastal and marine resources are largely dedicated to biodiversity conservation. The Sanganeb and Dungenab Bay–Mukkawar Marine Protected Areas are important eco-tourism bases (Ali 2016), with scuba diving, snorkelling and fishing as the major attractions.



Sudan's limited water resources face several threats that include siltation and pollution of major water bodies. The reservoirs of Roseires dam, Khashm El-Girba dam and Sennar dam have lost more than half of their design capacity (Ahmed 2017). However, the heightening of the Roseires dam in 2013 has raised its storage capacity from 3.35 to 5.8 km<sup>3</sup>. Water withdrawals also continue to increase due to growing population, changing consumption patterns and climate change. The fact that Sudan's freshwater sources are transboundary means that water availability will be affected by the demands and uses in neighbouring countries, especially the upstream countries. The expected impact of the Grand Ethiopian Renaissance Dam on Sudan's water resources must be considered within the context of climate change and rainfall variability.

### BIODIVERSITY

Sudan is home to a variety of ecosystems and habitats. Harrison and Jackson (1958) identified five major ecological zones in the country, namely Desert, Semi-desert, Woodland Savanna, Flood region and Mountain vegetation. Also important to Sudan are the agro-regions and the freshwater and marine ecosystems.

The desert is often barren, with quick-maturing vegetation sprouting only with the rare rains. Desert areas are found in Northern, River Nile, Red Sea, Kassala and North Kordofan states. Sparse woody trees grow in the wadis, such as the endemic, critically endangered Argun Palm (*Medemia argun*) in the Eastern Nubian desert (Ali 2016). In the semi-desert region, natural vegetation includes grass and shrubs interspaced with trees. *Acacia tortillis*, *Maerua crassifolia*, *A. mellifera* and *Commiphora africana* are some of the dominant tree species. The savanna grasslands have more trees, shrubs and woodlands than the semi-desert areas. The savannas cover most of eastern and central Sudan. The indicator species for the savanna grasslands is *Combretum hartmannianum*. Savannas are home to many birds, reptiles and mammals such as antelopes and gazelles. The mountains are rich in species such as the gazelle *Dorcas gazelle* and the lizard *Uromastyx ocellata* (Abdelhameed et al. 2013).

Sudan is home to an estimated 653 species of birds (Avibase 2020), and it ranks third among African countries used as flyways by migratory birds. The marine and coastal ecosystems have a variety of species, including sharks, fish, oysters, sea weeds, sea cucumber and turtles (Antonio 2017). As an agro-based

economy, Sudan has many local cultivars of sorghum and millet, as well as several breeds of sheep, cattle, goats and camels. Agro-forestry is practised widely through the introduction of *Acacia senegal* (the gum arabic tree) (Ballal 2002).

Sudan's biodiversity is threatened by various factors, including loss of habitat through deforestation and mechanised farming. Sudan has reserved forests that cover 6.6 million hectares (0.03 per cent of the country's land area), as well as irrigated forests of mainly *Eucalyptus microtheca* covering more than 3,360 hectares (8,000 feddans) (Badi and Abdel Magid 2017). In 1990, the annual forest loss due to the expansion of agriculture and the growing demand for energy was estimated at 855,000 feddans (35.91 km<sup>2</sup>) (Ministry of Agriculture and Forests 1995), and this rate of loss has not changed much.

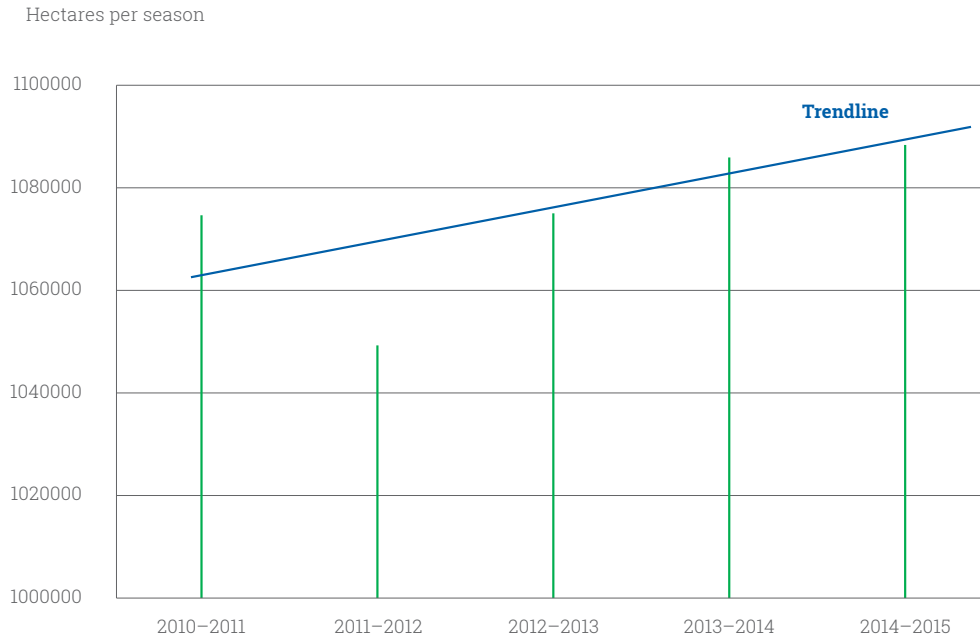
Fire is another factor contributing to biodiversity loss in Sudan, especially on *Acacia senegal* (gum arabic) plantations, which is an important export commodity (Badi and Abdel Magid 2017). As Figure 7 shows, forest fires are increasing and burning more woodlands, and this is affecting biodiversity. During the 2014/15 fire season, more than 1 million hectares of forest were burned (Hassan and Tag 2018). Forests are also lost during exploration for oil and the construction of pipelines. For example, in West Kordofan over 540,000 hectares of forests were cut down to make way for an oil pipeline (Badi and Abdel Magid 2017).

To address the loss of forests, Sudan has over the years significantly expanded its afforestation activities. For example, in 2016 the country planted 210,000 hectares of trees (0.5 million feddans) (Hassan and Tag 2018).

Biodiversity loss is pronounced, especially among wild animals. Species such as white antelope (*Addax nasomaculatus*), East African oryx (*Oryx beisa*), Common eland (*Taurotragus oryx*), African wild ass (*Equus africanus*) and Rim gazelle (*Gazella leptoceros*) have become locally extinct, while the Northern giraffe (*Giraffa Camelopardalis*) and the African wild dog (*Lycaon pictus*) are endangered. The Nubian ibex (*Capra ibex nubiana*) and Mangalla gazelle (*Gazella albenetata*) are rarely seen (Abdelhameed et al. 2013). The most significant effort to guard against biodiversity loss has been through protected areas, but the number of protected areas has not been increasing. Terrestrial and marine protected areas covered 1.3 per cent of Sudan in 2010 and 1.7 per cent in 2016 (World Bank 2017), but this percentage increase was due to the reduction in the country's overall land area following South Sudan's secession.



**Figure 7** Forest fire losses (redesigned by GRID-Arendal)



Source: Hassan and Tag, 2018

Sudan also has problems with invasive species, which replace local species by outcompeting them through predation or via the spread of pests and diseases. Invasive alien species in Sudan include *Orobanche crenata*, a parasitic weed found in the Nile River Basin, and *Prosopis juliflora* (Mesquite) is invading many areas including agricultural farms. There are also invasive insects, including *Parlatoria blanchardii*, a major pest of date palms.

### PERSISTENT ENVIRONMENTAL ISSUES

Sudan has a number of environmental problems that have afflicted the country over many years. While some of them appear manageable, others have become systemic. Desertification, old and banned pesticides, and solid waste problems have become chronic issues and less responsive to current policy and institutional measures.

It is not clear how much of Sudan is desert, with Salih (2007) estimating 50.4 per cent, the FAO (2012) 60.4 per cent and the Ministry of Agriculture and Forests (2006) 72 per cent. Similarly, there is no consensus

on the southwards advancement of the Sahara. The United Nations Environment Programme (2007) reported that the Sahara had advanced southward by 200 km from 1935 to 2000. Klemas (2011) and Lamprey (1975) reported that the Sahara's southerly expansion was between 5 and 40 km, while English et al. (1997) reported that desert conditions oscillate back and forth depending on the quality of the rainy season.

Around half of Sudan's population lives in desert areas, where overgrazing is a significant problem. The country's livestock population exceeds the national carrying capacity. At the turn of the millennium, the national herd needed 95 million hectares of rangeland, while only 36.4 million hectares were available. Earlier studies by Ayoub (1998) had shown that overgrazing was responsible for the damage on 74 per cent of Sudan's degraded land. Deforestation and poor methods of crop cultivation are also to blame for the expansion and persistence of desertification. The greatest socio-economic impacts of desertification are on livelihoods and food security. Efforts to restore grazing land and to harvest rainwater have not been very effective.



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Old and persistent pesticides have over the years been a big challenge for Sudan. This stems from the country's long history in commercial farming, including cotton farming in Gezira dating back to the 1940s. At the time, the pesticides had the positive effect of increasing yields, but they later became a problem due to their long life and the tendency of some to bio-accumulate in the food chain.

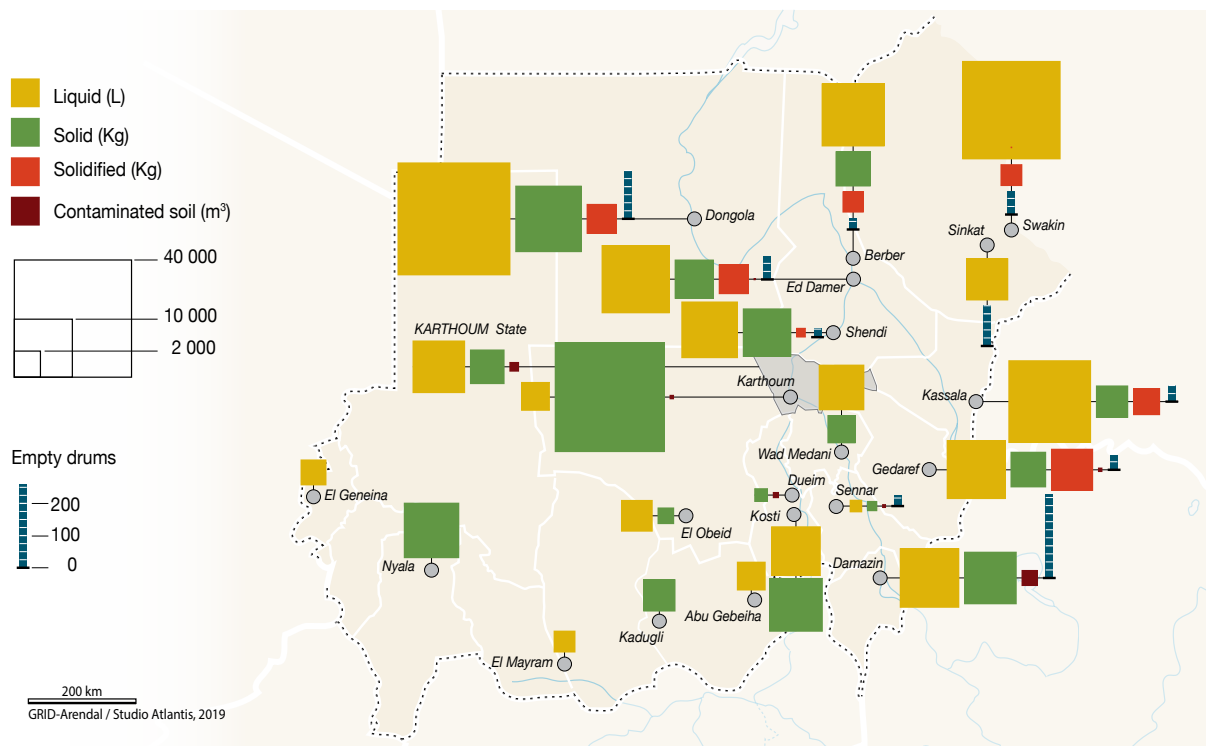
The use of pesticides to create higher yields was partly in response to food demands for a growing population as well as the southwards advancement of the Sahara Desert. Sudan imports most of its pesticides; a study by Omer (2015) found that the country's pesticide imports made up 5 per cent of Africa's total.

Long-life pesticides used in Sudan include DDT (Dichlorodiphenyltrichloroethane), which was first used in the country in 1945 and banned in 1981 (El Hindi 1994); aldrin, dieldrin, heptachlor and chlordane, mainly used in sugarcane plantations to control termites; and persistent organic pollutants (POPs), which are known to cause cancer and disruption of the endocrine and immune systems. As shown in Figure 8, large areas of Sudan have been contaminated with long-life pesticides, while obsolete pesticides are found across much of the country.

Soil samples collected from inside and outside pesticide dumping sites in Gezira state revealed residues of endosulfan ( $\alpha$  and  $\beta$ ), DDT, nitrogen and 2,4-dichlorophenol (Republic of Sudan 2014). DDT, heptachlor and dieldrin were found in irrigated cotton soils – levels of contamination were higher in Gezira than in other irrigated cotton and sugar schemes. Similar levels of aldrin, dieldrin and heptachlor were detected in the riverine soil of northern Sudan. These studies indicate that some of the contamination is caused by poor storage and the exposure of obsolete pesticides and leaky containers to various climatic conditions. Organochlorine pesticides have even been detected in the blood of residents living in areas of limited pesticide use in northern Sudan (Abdelbagi et al. 2015).

Unused quantities of insecticides brought in through the migratory desert locust control campaigns have become obsolete while some are stored in poor stockpiles. The agricultural scheme stores all over Sudan contain about 600 tonnes of pesticides out of which 90 tonnes are POPs. In addition, 6,000 m<sup>3</sup> of soil was contaminated.

**Figure 8** Obsolete pesticides and soil contamination in Sudan (redesigned by GRID)

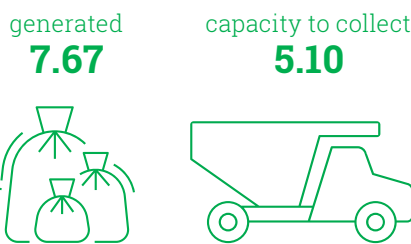




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Sudan is also facing a problem with solid waste, especially municipal solid waste. In 2016 Khartoum generated about 6,600 tonnes of waste per day, though the city only has a capacity to collect 4,200 tonnes per day (Azubair 2016). Khartoum also has the challenge of dealing with toxic waste that is dumped in landfills and ends up leaching into groundwater.

### Waste a year (in million tonnes)



There are also growing concerns in the country over the management of plastic waste, industrial waste, medical waste and wastewater.

### EMERGING ENVIRONMENTAL ISSUES

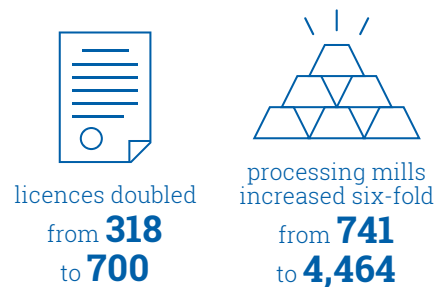
Sudan is facing new environmental challenges about which there is little local knowledge and data. Artisanal gold mining is growing as a means of generating foreign currency, but this comes at a cost to human life and the environment through the increased use of mercury. The country is also grappling with new forms of waste, including electronic. The growing demand for low-cost transport and the absence of reliable and stable electricity supplies have encouraged the use of rickshaws and diesel/petrol electric generators, both of which cause significant noise and air pollution.

Artisanal gold mining became widespread after the secession of South Sudan in 2011. This was partly in response to the decline in foreign currency revenues due to reduced oil exports. In addition, artisanal gold mining is an inexpensive activity that requires only simple and cheap tools such as hand-held metal detectors.

The biggest jump in artisanal gold mining came in 2012 when gold mining licences doubled from 318 to 700, and the number of processing mills increased six-fold from 714 to 4,464 (Ministry of Mineral Resources 2015). In 2014, artisanal gold miners produced 60 tonnes of gold, almost six times more than large-scale miners (Government of Sudan 2016b). The boom in artisanal

gold mining is partly a result of weak law enforcement: the miners often take advantage of non-enforcement of labour laws and environmental impact assessments. Onour (2018) estimated that as much as 34 per cent of mined gold may be smuggled out of the country. Quick returns have encouraged farmers to switch from farming to mining.

### Artisanal gold mining in 2014



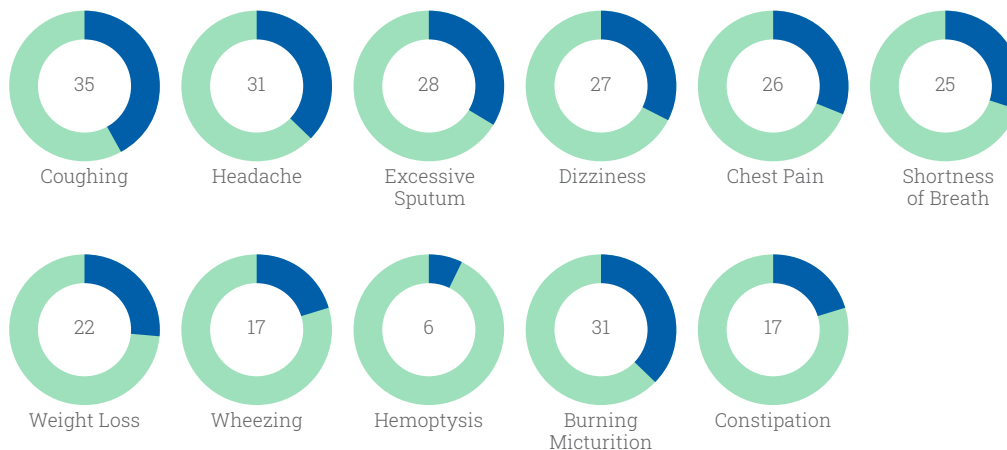
The use of mercury in gold extraction has negative effects on the environment and human health, causing a wide range of symptoms, as shown in Figure 9. One study has suggested that as much as two to three tonnes of mercury are needed to extract a tonne of gold; another estimated that 83 tonnes of mercury would be required to produce 64 tonnes of gold (Ibrahim 2015). In addition to the problem of mercury remaining in and polluting the tailings, vast tracts of land that would otherwise be used for farming are instead used for mining and degraded. Despite the fact that trade in mercury is banned by the Minamata Convention, the metal continues to be imported into Sudan (UNEP 2017).

Electronic waste is one of the fastest growing waste streams in the world. It is estimated that Sudan produces 3–6 kg per person per year of electronic waste (Baldé et al. 2017). The waste is often not properly disposed of. In some cases, electronic waste is just kept in homes and offices.

Due to their convenience and affordability, the use of three-wheel motorcycles, commonly called rickshaws, is increasing in Sudan, especially in towns and cities. In 2013, there were 69,000 registered rickshaws in Khartoum (Al Tayeb and Nimir 2017). The three-wheelers use blended petrol-oil, which is not sold at most fuel stations. Buyers often purchase the cheapest ratios of petrol-oil, which cause significant air pollution. The emissions from the three-wheelers reduce visibility, cause damage to vegetation and lead to respiratory illnesses in people.

**Figure 9** Common symptoms of mercury poisoning in Abu Hamad district

Case study with 83 participants from the artisanal mining community in Abu Hamad district



Source: Tyrab et al. 2016, redesigned by GRID-Arendal

As Sudan goes through a period of reduced electricity generation, diesel- and petrol-powered generators are increasingly being used more to power industry and homes. The generators emit significant amounts of pollution due to incomplete combustion. The generators also make a lot of noise.

## POLICY ANALYSIS

Sudan's environmental policies are based on the country's strategic and development plans, the constitution, and global targets such as the SDGs. The policies are meant to deter environmental crimes and act as incentives for good environmental practices. Sudan's economic and anti-poverty policies also have a bearing on the environment.

Key strategic plans that have informed Sudan's environmental policy landscape include the 10-Year Development Plan for 1960–1970, and several five-year development plans that followed. The country is currently in a 25-Year Development Strategy (2007–2031), which will conclude a year after the end date of the SDGs. Other framework policies that are key to the environment are the 2005 Comprehensive Peace Agreement and the Interim National Constitution. The constitution is clear on the need to provide a clean environment, protect biodiversity and better manage land resources.

The majority of Sudan's economic policies seek to deal with systemic issues affecting society, such as poverty and food security. For example, the country's livestock policies not only aim to grow the meat industry, but also to ensure that the quality of rangelands is improved and livestock drinking water facilities are protected. By contrast, some economic policies disregard their impact on the environment. For example, oil and gold mining policies have resulted in the contamination of water bodies in West Kordofan state (Pantuliano and Egemi 2009) and the destruction of pastures in eastern Sudan (FAO 2013), respectively. At the same time, some policies have in-built provisions for environmental protection but suffer from weak enforcement. Oil policies compel oil and gas companies to give 2 per cent of their revenues to the states in which they operate, and such funds can be used to protect the environment. However, it is questionable if such instructions are properly adhered to.

Sudan's environment policies include the forestry policy, which can be traced to 1932 and has been amended to reflect new forms of forest tenure that encourage afforestation and add economic value to forests (Government of Sudan 1992); the National Biodiversity Strategy and Action Plans that seek to protect and conserve the country's rich biological resources; and water policies that are designed to protect watersheds.



Some policy gaps exist. For example, there is no clear policy to deal with invasive alien plants such as mesquite shrubs (Government of Sudan 2015). The Wildlife Conservation and National Parks Act (1986) protects species and licenses hunting, but it does not protect habitats, including forests, and ignores community participation. The country's oil and gas policies are silent on the unintended consequences of exploration and drilling (Government of Sudan 2015). The expansion of crop farming has created competition between small-scale crop farmers and pastoralists over land and water resources, and even forced some people to occupy marginal land (Sullivan and Nasallah 2010).

Weak policy enforcement is a challenge for Sudan and has caused a number of policies to fail. For example, the target laid down in the Forest Act 1989 that 5 per cent of irrigated agricultural schemes and 10 per cent of rain-fed schemes should be planted with tree belts has been undermined by poor budgetary support and weak enforcement of laws. The same fate befell the programme to expand gum arabic production to 0.5 million tonnes per year (UNEP 2020).

Land tenure and land use policies have a profound impact on both the economics of agriculture and protection of the environment. One prominent piece of legislation in this area is the Native Administration Act (1998), which gives power to local communities and traditional leaders to administer policies, including environmental policies (Government of Sudan 2016c). In a federal system in which the government designs policies that are then implemented at state and local levels, the Native Administration Act is helpful. However, low funding, conflicting authority and overlapping institutional roles complicate the situation.

### FUTURE OUTLOOK

Sudan's future outlook will largely be shaped by the size of its population, currently estimated at 44.4 million and expected to expand to 57.3 million by 2030 (Central Bureau of Statistics 2018). The greatest impact of this population growth will be more competition for resources, especially land and water.

The situation will not be helped by galloping urbanisation, with Khartoum expected to absorb a significant portion of the country's population. Social services in the city, such as housing, safe drinking water and sanitation, will be stretched. It is also likely that some of the country's pristine environments will be converted into settlements.

Sudan's economic performance has been lukewarm in recent years, characterised by high inflation and the loss of major oil revenues following the secession of South Sudan. The growth of artisanal gold mining, which attracts foreign currency, is bringing some welcome relief, but the resulting damage to the environment through mercury pollution and land degradation will take generations to correct.

Governance will be critical in shaping the future of Sudan. For many years the environmental sector has suffered from a lack of representation at the central government level – its administration has been shunted from one government ministry to another. However, in April 2020 the government invested responsibility for environmental affairs in the new Higher Council for Environment and Natural Resources, following amendments to the Environment Protection Act 2001.

Sudan aspires to be a key world player and meet its targets for social and economic development. The country is committed to its Zero Hunger and Zero Thirst programmes, even though these programmes lack a clear mandate, while also aspiring to meet its targets under the SDGs.

To gauge Sudan's prospects of meeting the SDGs, this report puts forward two scenarios: Business-as-Usual and Bending-the-Curve. Business-as-Usual envisages Sudan having no major policy shifts in the future, while under the Bending-the-Curve scenario the country will make major policy shifts to meet its 2030 agenda.

### Business as usual scenario

Despite having a convenient climate for solar and wind power, Sudan's atmospheric resources remain under-used. The intensity and frequency of flash floods are unchanged, but their impacts are magnified due to higher population densities and lack of investment in climate-proof infrastructure.

Land remains the country's prime asset for economic development, food security and personal wealth. Productivity of major cereals on a unit area basis remains low and has been declining from 350 kg/ feddan for sorghum in the late 1950s to less than 200kg/feddan in 2016, due to overuse of the land. Agricultural production will not match the growing food needs of the expanding population. Pastoral routes are closed as more land is privatised rather than held by communities. Tensions between sedentary farmers and pastoralists are increasing, with



negative impacts on food security and access to water points. As a result, the country fails to meet its SDG targets for poverty, food security, health and safe drinking water.

The Nile and the Nubian aquifer remain the country's key freshwater resources. However, Sudan is constrained on the amount of water it can tap from the Nile River system due to the country's historical agreement with Egypt, which limits its water use to 18.5 km<sup>3</sup> per year. Countries upstream of the Nile will continue to develop the basin, with Sudan accessing cheap hydropower from neighbouring Ethiopia. There is no expansion in the amount of groundwater that is tapped for domestic and industrial uses due to lack of water drilling capacity.

While the country makes significant progress in reducing its carbon footprint through the use of hydropower, it fails to make the SDG goals and targets for wastewater treatment, sanitation and safe drinking water. The country's marine water resources continue to play an important role in Sudan's nascent blue economy through fisheries, navigation, conservation and tourism. However, lack of investment in this important asset will see the country making very little progress on SDG targets for marine litter.

Sudan's rich biodiversity continues to face many threats due to the harsh climate, habitat fragmentation and weak conservation efforts. The country fails to meet its Aichi Biodiversity Targets under the Convention on Biological Diversity as there is intense competition for land from a growing population and other uses such as gold mining. SDG targets for life below the ocean and life on land are also not met by 2030.

Emerging environmental issues – which include artisanal gold mining, diesel/gasoline generators and rickshaws – to plague the country as Sudan struggles to diversify its economy for the purposes of generating foreign currency. Electric power generation remains weak. There is little investment in mass public transport systems, and the country fails to meet air pollution targets. Though the import of mercury is banned under the Minamata Convention, the heavy metal continues to find its way onto the Sudanese market, causing both soil and air pollution.

Despite efforts to create a green belt of trees, the southern boundary of the Sahara Desert continues to shift, depending on the quality of the rainy season. Desertification remains a major persistent environmental challenge for Sudan, even though the country was among the first to sign up to the United Nations

Convention to Combat Desertification. Efforts to safely dispose of stockpiles of obsolete pesticides are too slow, while contaminated soils and water continue to cause a health risk to both people and wildlife.

### Bending the curve scenario

Because of the country's long hours of sunshine and improving investment climate, there is a large-scale private and public investment in both grid and off-grid renewable energy, especially solar and wind power. By 2030, most Sudanese have access to clean electricity, which leads to huge savings for the country as it does not need to import electricity. Sudan also significantly reduces its carbon footprint. Cases of upper respiratory infections caused by indoor pollution are dramatically cut, and the country meets its health targets.

The country's land use and land tenure laws are overhauled, resulting in not only protection of land as private property but also use of this asset as collateral for bank loans. The loans are used to invest in farming, which is well supported by research and extension services. Yields of important cereals such as millet and sorghum increase substantially on a unit area basis following the availability of high-yielding seed on the market. Sedentary farmers and pastoralists live in harmony as new methods of farming are introduced. As a result, Sudan achieves its targets under the SDGs for reducing hunger and poverty.

With a well-functioning land tenure system, water use rights are also improved across much of Sudan. The widespread adoption of rainwater harvesting techniques results in more water availability, while investment in water drilling, aided by an investor-friendly regime, ensures that groundwater sources such as the Nubian aquifer are carefully used. There is consensus around the Nile Basin Initiative, resulting in a more equitable sharing of the water resources of the basin by the 10 riparian countries that share it. Sudan joins the rest of the world in protecting its marine environment from pollution, while also extending the area under protection for the conservation of marine resources. The SDG targets for safe drinking water, sanitation and life under water are met by 2030.

Sudan's diverse ecosystems – including deserts, forests, wetlands and coastal and marine environments – are well protected, while there are also significant efforts to develop the country's agrobiodiversity. Population numbers rebound for endangered species such as the Northern giraffe
























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(*Giraffa Camelopardalis*) and the African wild dog (*Lycaon pictus*), and rarely seen species such as the Nubian ibex (*Capra ibex nubiana*) and Gazella albenetata. With large-scale investment in protected areas for both the terrestrial and marine environments, Sudan meets its Aichi Biodiversity Targets, as well as SDG targets for life under water and life on land.

Following the recognition of the negative impacts of unregulated artisanal gold mining, Sudan changes its mining laws to include a total ban on the use of mercury. Support is provided to the miners to organise themselves into groups so that they can jointly use ore-processing facilities and organise their marketing. Degraded land is rehabilitated, and new mining operations are more environmentally friendly. The country not only adheres to the Minamata Convention, but also significantly improves the quality of life and health of the miners.

Large-scale investments in public transport systems result in the disappearance of the rickshaw, resulting in significant improvements in the quality of air in towns and cities. Investments in solar, wind and hydropower ensure that the country has surplus electricity and therefore no need to use fuel-powered generators. As a result, people's quality of life, including their health, improves significantly.

The scourge of desertification continues to affect Sudan, but people have learnt to adapt to the desert conditions. Afforestation programmes are implemented and the vegetation cover is increased. Stockpiles of obsolete pesticides are destroyed, while contaminated soils and water are remediated.

Scenarios Issues	Business as Usual scenario (No change in policies)	Bending the Curve scenario (Change in policies)
 <b>Population</b>		
 <b>Economy</b>		
 <b>Environment</b>		
 <b>Equity/Equality</b>		
 <b>Technology</b>		
 <b>Conflict</b>		
 <b>Urbanization</b>		



Archaeological site, Naqaa and Musawarat, River Nile state, Bajrawiya. Photo credit © Robbert Bekker

### CONCLUSION

The state of the environment in Sudan is directly linked to the health and quality of life of its people. In this largely agrarian nation, many Sudanese derive their livelihoods from direct access to land for food production, pastoralism and mining, among other uses. It is therefore critical that the government protect its land resources for the food and economic needs of both current and future generations.

Sudan, like many other countries, shares resources with neighbouring nations. Fresh water is the most important resource, shared through the Nile River system and the Nubian aquifer. The governance of such transboundary resources requires international

consensus and given Sudan's large share of both the Nile basin and Nubian aquifer, the country's voice is critical in obtaining such consensus. Sudan can play a central role in changing the Grand Ethiopian Renaissance Dam from a source of conflict to a platform for cooperation among Sudan, Ethiopia and Egypt.

Institutional oversight of the environment in Sudan has been inconsistent over the years, shifting between various federal government ministries. The new Higher Council for Environment and Natural Resources, which is now the key state body dealing with environmental issues, would benefit immensely from an expansive mandate and greater support from the federal government.

# References



### REFERENCES

1. Abdelbagi, A. O., Elbeshir, A.B., Hammad, A.M. A., Elzorgani, G.A. and Laing, M.D. (2015) Organochlorine levels in human blood from residents in areas of limited pesticide use in Sudan. *Toxicological & Environmental Chemistry*, 97:2, 266–273. Retrieved from: DOI: 10.1080/02772248.2015.1031669
2. Abdelhameed, S. M., Eljack. A. O. and Abdelbagi. H. M. (2013). Jebel Al Dair Management Plan. Western Sudan Resources Management Programme/Italian Fund for Agricultural Development WSRMP/IFAD.
3. Abdelhameed, S. M., Eljack. A. O. and Abdelbagi. H. M. (2013). Jebel Al Dair Management Plan. Western Sudan Resources Management Programme/Italian Fund for Agricultural Development WSRMP/IFAD.
4. Adam, A. M. and Abdo, G. M. (2017). Water and Hydrology (Surface and Groundwater). In A. M. Salih (Ed.). *Water Resources of the Sudan*. (1<sup>st</sup> ed., 41–81). Water Research Center, University of Khartoum.
5. Ahmed, H. E. (2017). Water for Human Needs and Livestock Requirements. In A. M. Salih (Ed.). *Water Resources of the Sudan* (1<sup>st</sup> ed., pp. 266–289). Water Research Center, University of Khartoum, Sudan.
6. Avibase (2020). Bird checklist of the world-Sudan. The World Bird Database. Retrieved from [avibase.bsc-eoc.org/checklist.jsp?region=SD&list=howardmoore](http://avibase.bsc-eoc.org/checklist.jsp?region=SD&list=howardmoore)
7. Al Tayeb, K. and Nimir, H. (2017). Pollution by 2-stroke Engines (Motorbikes and Rickshaw). Paper Presented to a Special Workshop on 2-stroke Lube. Sudan Standards and Metrology Organization. Khartoum.
8. Ali. M. E. (2016) Policy Assessment on Biodiversity and Ecosystem Management. Higher Council for Environment and Natural Resources, Khartoum, Sudan.
9. Ali, O.M. (2016). The Argun Palm, *Medemia argun*, in the Eastern Nubian Desert of Sudan. *PALMS Journal of the International Palm Society*, 60 (3),146–153.
10. Antonio, A. (2017). *UNESCO Biosphere Reserves at Red Sea Coast and Islands*. Sudan Mission November 2017. Khartoum.
11. Avibase (2020). Bird checklist of the world-Sudan. The World Bird Database. Retrieved from: <http://avibase.bsc-eoc.org/checklist.jsp?region=SD&list=howardmoore>
12. Ayob, A. T. (1998). Extent, severity and causative factors of land degradation in the Sudan. *Journal of Arid Environment*,138, 397–409.
13. Azubir, W.A.A. (2016). Landfills: City Sanitation Plan of Khartoum. Alternative Hydro Energy Centre Roorkee. Khartoum.
14. Badi .H. and Magid, T.D. (2017). Preventive Attributes Against Forest Fires with Particular Reference to The Low Rainfall Savannah Region of Sudan: *Journal of Natural Resources and Environmental Studies* 5(1), 16–23. Retrieved from: <http://researchpub.org/journal/jonares/number/vol5-no1/vol5-no1-2.pdf>
15. Baldé, C.P., Forti V., Gray, V., Kuehr, R. and Stegmann, P. (2017). The Global E-waste Monitor. *United Nations University, International Telecommunication Union and International Solid Waste Association*. Bonn/Geneva/Vienna. Retrieved from <https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf>
16. Ballal, M.E. (2002). Yield trends of gum Arabic from *Acacia senegal* as related to some environmental and managerial factors. (Doctoral thesis, Faculty of Forestry, University of Khartoum, Sudan).
17. Central Bureau of Statistics CBS, UNICEF Sudan (2016). Multiple Indicator Cluster Survey 2014 of Sudan, Final Report. Khartoum, Sudan. Retrieved from: <http://mics.unicef.org/files/job=W1siZiIsIjIwMTYvMDUvMTgvMjEvNTkvNTEvODg3L1N1ZGFuXzIwMTRfTU1DU19FbmdsaXNoLnBkZiJdXQ&sha=32907fc39e6e2e6e>
18. Central Bureau of Statistics (CBS). 2018. Population Statistics of Sudan, 1973 - 2018. Retrieved from: <https://knoema.com/SDPS2009/population-statistics-of-sudan-1973-2018>
19. Dams Implementation Unit, (2018) Glimpses on Sudan Dams (in Arabic) <https://www.facebook.com/DAMSINSUDAN>
20. El Hindi, A.M. (1994). Some poisoning accidents. (1985–1991): in Proceedings of the Second Scientific Conference of the Sudanese Society of Food Science and Technology 10–12 May 1994, Khartoum, Sudan



21. English, C., Richards, T. S., and Moheidin, Y. E. (1997). GIS and remote sensing applications to desert margin vegetation and land use monitoring in Sahelian Sudan: methodology, data integration problems, and solutions: In McGinty (ed.) *International Symposium and Workshop on Combating Desertification: Connecting Science with Community Action*, Tucson, Arizona, USA.
22. Food and Agricultural Organisation of the United Nations (FAO). (2010). Global Forest Resources Assessment: Country Report – Sudan. FAO. Rome.
23. Food and Agricultural Organisation of the United Nations (FAO). 2012. *The Land Cover Atlas of Sudan*. FAO. Rome.
24. Food and Agricultural Organisation of the United Nations (FAO). (2013), Policy Forum Workshop Paper on Range and Pasture Situation in Butana Area, Gedaref State, Sudan. State Ministry of Animal Resources. Butana, Sudan.
25. Food and Agricultural Organisation of the United Nations (FAO). (2017). AQUASTAT Information System on Water and Agriculture. Sudan Country Profile. Retrieved from: [http://www.fao.org/nr/water/aquastat/countries\\_regions/SDN/index.stm](http://www.fao.org/nr/water/aquastat/countries_regions/SDN/index.stm)
26. Food and Agricultural Organisation of the United Nations (FAO). (2018). Country Profiles: Sudan. <http://www.fao.org/countryprofiles/maps/map/en/?iso3=SDN&mapID=601>
27. Food and Agriculture Organization of the United Nations (2019). Fishery and Aquaculture Country Profiles. The Republic of the Sudan. Retrieved from: <http://www.fao.org/fishery/facp/SDN/en#CountrySector-Statistics>
28. Governments of Sudan and Egypt (1959). Nile Water Agreement 1959: *Agreement between the Republic of the Sudan and the United Arab Republic For the Full Utilization of the Nile Waters*. Retrieved from: <http://www.fao.org/3/w7414b/w7414b13.htm>
29. Government of Sudan. (1992). Ten Years National Comprehensive Program 1992–2002. Ministry of Finance and National Economy. Khartoum.
30. Government of Sudan. (2014). Ministry of Energy: Annual Report. Government of Sudan. Khartoum.
31. Government of Sudan. (2015). National Biodiversity Strategy and Action Plan (NBSAP) 2015–2020. Ministry of Environment, Natural Resources and Physical Development and HCENR. Khartoum.
32. Government of Sudan. (2016a). Proceedings of the First Meeting of the Higher Council for Mining held on June 2016 (in Arabic). Khartoum
33. Government of Sudan. (2016b). Sudan Sustainable Natural Resources Management Project: Integrated Land Management Action Plan – Final Draft Report. Ministry of Environment, Forestry and Physical Development. Khartoum.
34. Hamad, O. E. (2015). *Sudan Water Governance – Laws, policies and institutions*. Global Water Partnership and United Nations Environment. Khartoum, Sudan.
35. Hassan and Tag Consultants. 2018. In-depth analysis of Drivers of Deforestation & Forest/Range Degradation. Republic of Sudan REDD+ Programme
36. Harrison, M. N. and J. K. Jackson. (1958). Ecological Classification of the Vegetation of the Sudan. *Forest Bulletin, 2*, Agriculture Publications Committee, Khartoum.
37. Ibrahim, M. S. (2015). Artisanal Mining in Sudan – Opportunities, Challenges and Impacts. Presented at the United Nations Conference on Trade and Development (UNCTAD) 17<sup>th</sup> Africa OILGASMINE, Extractive Industries and Sustainable Job Creation. Khartoum, 23-26 November 2015.
38. International Monetary Fund (2020). Sudan 2019 Article IV Consultation Press Release: Staff Report and Statement by the Executive Director of Sudan. Country Report No. 20/72. Retrieved from: <https://www.imf.org/en/Publications/CR/Issues/2020/03/10/Sudan-2019-Article-IV-Consultation-Press-Release-Staff-Report-and-Statement-by-the-Executive-49254>
39. Khyar, A. and Fota, M. (2001). *Rainfall Atlas for the Republic of Sudan*. Drought Monitoring Centre. Nairobi, Kenya.
40. Klemas, V. (2011). Remote Sensing of Wetlands: Case studies comparing practical techniques. *Journal of Coastal Research, 27*, 418–427.
41. Lamprey, H.F. (1975). *Report on the desert encroachment reconnaissance in northern Sudan: 21 October to 10 November, 1975*. UNESCO/UNEP.
42. Maxson, P. (2017). *Global Mercury Supply, Trade and Demand*. UNEP. Nairobi.
43. Ministry of Agriculture and Forests. (1995). Forests National Corporation. Forests Products Consumption Survey. Khartoum.



44. Ministry of Agriculture and Forests. (2006). Sudan National Action Plan to Combat Desertification (SNAP). *A Framework for Combating Desertification in Sudan in the Context of the United Nations Convention to Combat Desertification*. National Drought and Desertification Control Unit. Khartoum.
45. Ministry of Agriculture and Forests. (2018a). Directorate of Agricultural Planning and Statistics. (2018). *Agricultural statistics 1953/54-2017/2018*.
46. Ministry of Finance and Economic Planning (MFEP). (2016). The Economic Exhibition. Sudan. (in Arabic).
47. Ministry of Mineral Resources (2015). *Minerals Wealth Development and Mining Act, 2015*
48. National Assembly of Sudan. (2015). The Interim National Constitution of the Republic of Sudan Amendment) 2015. Government of Sudan.
49. Omer, S. E., (2015). Safe Use of Pesticides. Sudanese Standard and Meteorology Organization Workshop on Import, Storage, Handling and Use of Pesticides and Fertilizers. Khartoum.
50. Onour, I. (2018). The Cost of Mismanagement of Gold Production in Sudan. School of Management Studies, University of Khartoum, Sudan.
51. Pantuliano, S. and Egemi, O. (2009). *Put out to Pasture: War, oil and the decline of Misseriyya Humur Pastoralism in Sudan*. Humanitarian Policy Group. London: Overseas Development Institute.
52. Rabah, A. A., Nimir, H. B., Doud, K. R. and Ahmed, Q. A. (2016). Modelling of Sudan's energy supply, transportation and demand. *Journal of Energy*, 2016, 1-14. Retrieved from: <http://dx.doi.org/10.1155/2016/5082678>
53. Republic of Sudan (2014). National Implementation Plan for the Stockholm Convention.
54. Salih, A. M. (2007). *Action Programmes for Combating Desertification*. UNESCO Chair of Desertification, University of Khartoum, Sudan.
55. Statista (2019). Sudan – Statistics & Facts. Published by H. Plecher, Retrieved from: <https://www.statista.com/statistics/727142/gross-domestic-product-gdp-per-capita-in-sudan>
56. Sudan Meteorological Authority (SMA). (2019). *Sudan Meteorological Authority Climate Data*. SMA. Khartoum
57. Sudan National Survey Authority. (2017). Sudan Survey Report. Khartoum.
58. Sullivan, P. J. and Nasallah, N. (2010). Improving Natural Resource Management in Sudan: A Strategy for Effective State Building and Conflict Resolution. Special Report. United States Institute of Peace.
59. Tyrab, E., Abd Elrahim, M., Elbagir, M. Y, and Kodi, M. A. (2016). Human mercury exposure associated with artisanal gold miners in Sudan. *International Journal Earth Environment Science* 1, 118.
60. United Nations Environment Programme (UNEP). 2007. Sudan Post Conflict Environmental Assessment. UNEP. Nairobi. Retrieved from: [https://postconflict.unep.ch/publications/UNEP\\_Sudan.pdf](https://postconflict.unep.ch/publications/UNEP_Sudan.pdf)
61. United Nations Environment Programme (UNEP). (2013a). *Republic of Sudan Country Evaluation Programme*. UNEP. Khartoum.
62. United Nations Environment Programme (UNEP). (2013b). *Standing Wealth: Pastoralist livestock production and local livelihoods in Sudan*. UNEP. Khartoum.
63. UN Environment Programme and UKaid. (2020). Lessons Learned and Good Practices in Natural Resources Management. Prepared by Abdel Magid, T.D. and edited by Paul Kerkhof. Retrieved from: [https://postconflict.unep.ch/Sudan/NRM\\_2020\\_EN.pdf](https://postconflict.unep.ch/Sudan/NRM_2020_EN.pdf)
64. United Nations High Commissioner for Refugees (UNHCR). (2018). Global Trends: Forced displacement in 2018. UNHCR. Geneva.
65. White, C. (2012). Understanding water scarcity: Definitions and measures. Retrieved from: <https://globalwaterforum.org/2012/05/07/understanding-water-scarcity-definitions-and-measurements>
66. World Bank and Ministry of Finance and Economic Planning (MFEP). (2016). Sudan IPRSP Status Report 2012–2104. Retrieved from: <http://documents.worldbank.org/curated/en/980991479985933855/pdf/110503-WP-SudanFlipbookEnglish-PUBLIC.pdf>
67. World Bank. (2017). *World Development Indicators database: Country profile Sudan*. World Bank. Washington D.C.
68. Zakieldin, S. A. and Elhassan, N. G. (2015). Climate Change Impacts, Vulnerability and Adaptation in Sudan. *Academy of Science Journal*, (11), 217–233.

