



Republic of Sudan

Sudan

First State of Environment and Outlook Report **2020**

Environment for Peace and Sustainable Development

UN
environment
programme





Republic of Sudan



ISBN: 978-92-807-3795-0

Job number: ROA/2293/GE

This report was co-produced by the United Nations Environment Programme and the Higher Council for Environment and Natural Resources in Sudan. The designations employed and the presentation of the material throughout this publication do not imply the expression of any opinion whatsoever on the part of the United Nations Environment Programme and the Higher Council for Environment and Natural Resources in Sudan, concerning the legal status of any country, territory, city or area or of its authorities, or the delimitation of its frontiers or boundaries. The term “country” as used in this publication also refers, as appropriate, to territories or areas. The designations “developed and developing” regions are intended for statistical and analytical convenience and do not necessarily express judgment about the stage reached by a particular country or area in the development process. No use of this publication may be made for resale or for any other commercial purpose without prior permission in writing from the United Nations Environment Programme and the Higher Council for Environment and Natural Resources in Sudan.

Photos:

Unless otherwise credited, images in this report were taken by the United Nations Environment Programme staff

Design and layout:

EcoVisuel: Bruno Mottini & Kathleen Morf
www.ecovisuel.com

Icons:

www.thenounproject.com

First published on 7 October 2020

© 2020 United Nations Environment Programme



Sudan

First State of Environment and Outlook Report **2020**

Environment for Peace and Sustainable Development



Table of Contents

ACKNOWLEDGEMENTS	10
PREFACE	11
FOREWORD	12
ABBREVIATIONS AND ACRONYMS	14
EXECUTIVE SUMMARY	17
INTRODUCTION TO THE REPORT	24
CHAPTER 1 SOCIO-ECONOMIC STATUS AND ENVIRONMENT	26
1.1 Introduction	27
1.2 Environmental governance	28
1.3 Secession of South Sudan	29
1.4 Demographic characteristics	30
1.5 Youth and environment	33
1.6 Ethnic and cultural diversity	34
1.7 Population mobility	35
1.8 Health	36
1.9 Education and environment	36
1.10 Gender and environment	37
1.10.1 Situation of women in Sudan	37
1.10.1.1 Women in decision-making	39
1.10.1.2 Women's economic rights	39
1.10.1.3 Women's education and employment	40
1.10.1.4 Women and environment	40
1.10.1.5 Strategies and policies for female empowerment	41
1.11 International migration	41
1.12 Poverty and environment Nexus	41
1.13 Human settlements and environment	41
1.14 Urbanization and environment	42
1.15 Fuelwood and charcoal for domestic use	42
1.16 Agriculture and environment	42
1.17 Livestock and environment	44
1.18 Fisheries and environment	44
1.19 Industry and environment	44
1.20 Mining and environment	45
1.21 Tourism and environment	45
1.22 Environmental policies and development	46
1.23 Mainstreaming environment into development	47
1.24 Challenges	47
1.25 Conclusion	47
References	48
CHAPTER 2 ENVIRONMENTAL GOVERNANCE	52
2.1 Introduction	53
2.2 Overarching policies	54
2.2.1 Islamic laws and the environment	54
2.2.2 Interim National Constitution	54
2.2.3 Federal and state governance	57
2.2.4 Statutory and customary laws	57
2.2.5 Sustainable development goals	58
2.2.6 National goals	59
2.2.7 Multilateral environmental agreements	60
2.2.8 Regional initiatives	62
2.2.9 Natural resources management laws	62
2.2.10 Policy goals	64



Table of Contents

2.3 Institutional arrangements	64
2.3.1 Land Commissions and related institutions	67
2.3.2 Institutional arrangements for water, rangelands and forests	71
2.3.3 Conflict management structures	74
2.3.4 Capacity of environmental institutions	74
2.4 Conclusion	76
References	78
 CHAPTER 3 ATMOSPHERE	 82
3.1 Introduction	83
3.2 Climate	83
3.2.1 Climatic zones	84
3.2.2 Rainfall	84
3.2.3. Temperature	87
3.2.4 Wind	87
3.2.5 Sunshine hours	89
3.3 Climate change and variability in Sudan	89
3.3.1 Climate change impacts	91
3.3.2 Adaptation and mitigation	91
3.4 Air quality	93
3.4.1 Air pollution	94
3.4.2 Impacts of air pollution	95
3.4.3 Air pollution management	95
3.5 Conclusion	100
References	102
 CHAPTER 4 LAND RESOURCES	 104
4.1 Introduction	105
4.2 Overview of land resources	105
4.2.1 Arable land	105
4.2.2 Soils	105
4.2.3 Water resources	108
4.2.4 Forests	109
4.2.5 Rangelands	110
4.2.6 National parks and protected areas	110
4.2.7 Oil fields	113
4.2.8 Gold mines	114
4.3 Agriculture	114
4.3.1 Rain-fed agriculture	114
4.3.2 Mechanized farming	117
4.3.3 Irrigated agriculture	117
4.3.4 Nomadic pastoralism	120
4.4 Land-related challenges	121
4.4.1 Conflict	121
4.4.2 Internally displaced persons and refugees	121
4.4.3 Returnees	122
4.4.4 Urbanization	123
4.4.5 Land degradation	124
4.5 Land management and administration	125
4.5.1 Land tenure	125
4.5.2 Land use policies	127
4.5.3 Interim poverty reduction strategy	128
4.5.4 Investment Act (2013)	128
4.5.5 Institutional issues	129
4.6 Conclusion	129
References	130



Table of Contents

CHAPTER 5 WATER RESOURCES	134
5.1 Introduction	135
5.2 Water availability	135
5.2.1 The Nile River System	135
5.2.2 Seasonal wadis and khors	138
5.2.3 Groundwater	138
5.2.4 Marine water	140
5.2.5 Lakes	140
5.2.6 Non-conventional water	142
5.3 Uses of water in Sudan	142
5.3.1 Irrigated agriculture	142
5.3.2 Domestic and industrial use	142
5.3.3 Hydropower generation	144
5.4 Coastal and marine resources and their economic importance	145
5.4.1 Marine protected areas	146
5.4.2 Coastal tourism	147
5.4.3 Navigation	149
5.5 Threats and challenges to water resources	149
5.5.1 Water stress	149
5.5.2 Safe drinking water, sanitation and hygiene	150
5.5.3 Water supply and demand imbalance	151
5.5.4 Climate change and extreme climatic events	152
5.5.5 Coastal zone vulnerability and adaptation to climate change	153
5.5.6 Catchment degradation, floods and droughts	154
5.6 Threats and pressure on marine resources	156
5.7 Institutional and policy arrangements	156
5.8 Transboundary water resources	156
5.9 Opportunities for sustainable water resources development	157
5.9.1 Water harvesting and the Zero Attash (Thirst) programme	157
5.9.2 Integrated water resource management.	157
5.9.3 Cooperative approach to water resources management	158
5.10 Conclusion	159
References	160
CHAPTER 6 BIODIVERSITY	164
6.1 Introduction	165
6.2 Ecosystems and habitats	165
6.3 Forest biodiversity	170
6.3.1 Threats to forests	171
6.3.2 Forest protection measures	176
6.4 Conservation of forest genetic resources	178
6.5 Wildlife resources and protected areas	179
6.5.1 Protected areas in Sudan	179
6.5.2 Dinder and Radom national parks	181
6.5.3 Threats to wildlife	182
6.5.4 Trade in wildlife	185
6.6 Wetlands, floodplains and Nile riverine forests	186
6.6.1 Avifauna and waterfowl	190
6.6.2 Inland waters biodiversity	190
6.6.3 Native reptiles	191
6.6.4 Fish biodiversity	192
6.7 Introduced invasive species	193
6.8 Conclusion	196
References	198



Table of Contents

CHAPTER 7 PERSISTENT ENVIRONMENTAL ISSUES	204
7.1 Introduction	205
7.2 Desertification	205
7.2.1 State of desertification in Sudan	205
7.2.2 Causes of desertification	210
7.2.3 Effects of desertification	212
7.2.4 Responses to desertification	213
7.3 Pesticides	215
7.3.1 Persistent organic pollutants	217
7.3.2 Obsolete pesticides and wastes	218
7.3.3 Pesticides management	220
7.3.4 Policy response measures	221
7.4 Solid Waste	222
7.4.1 Waste production and streams	222
7.4.2 Waste management	233
7.5 Conclusion	233
References	234
CHAPTER 8 EMERGING ENVIRONMENTAL ISSUES	240
8.1 Introduction	241
8.2 Artisanal gold mining	241
8.2.1 Mining policy	244
8.2.2 Gold mining demographics	244
8.2.3 The mercury threat	245
8.2.4 Other impacts of artisanal mining	248
8.3 Electronic waste	249
8.3.1 Mobile phones	250
8.3.2 Hazards of electronic waste	253
8.4 Transport and energy	253
8.4.1 Three-wheel motorcycles (rickshaws)	253
8.4.2 Electricity generators	256
8.5 Conclusion	257
References	258
CHAPTER 9 POLICY ANALYSIS	262
9.1 Introduction	263
9.2 Environmental policy landscape	263
9.2.1 Macroeconomic policies	264
9.2.2 Economic policies	264
9.2.3 Natural resources policies	264
9.3 Assessing Sudan's environmental policies	268
9.3.1 Impact of selected environmental legislation	269
9.3.2 Unintended consequences of environmental legislation	270
9.3.3 Policy gaps and overlaps	270
9.3.4 Policy coordination	271
9.3.5 Enforcement and implementation	272
9.3.6 Potential for upscaling and replication	272
9.4 Conclusion	273
References	274



Table of Contents

CHAPTER 10 SCENARIOS AND POLICY OPTIONS	278
10.1 Introduction	279
10.2 Imagining the future	279
10.3 Drivers of change in Sudan	281
10.3.1 Demographic dynamics	281
10.3.2 Economic development	281
10.3.3 Climate change and variability	283
10.3.4 Governance	283
10.4 Future Scenarios	285
10.4.1 Business as usual scenario	285
10.4.2 Bending the curve scenario	289
10.4.3 Business as usual versus bending the curve	291
10.5 Policy options for future sustainable development	294
10.5.1 Policy options	294
10.5.2 Sudan in 2030	299
References	302
Annexes	306



Acknowledgements

The Sudan First State of the Environment and Outlook 2020 Report is an outcome of a coordinated and concerted effort made by a team of officials, experts and stakeholders from a wide spectrum of institutions. Although the contribution of each member of this team varies according to their position and mandate, it was part of an integrated process without which this report would not have been produced.

The below institutions, officials, organizations and experts (a full list with individual contributors is available at the end of this report) are acknowledged in the production of this milestone report in 2020 – the year when Sudan enters a new peace era:

- ➔ United Kingdom's Foreign, Commonwealth and Development Office;
- ➔ United Nations Environment Programme Sudan and Geneva Offices;
- ➔ Sudan Higher Council for Environment and Natural Resources;
- ➔ GRID-Arendal; Norway;
- ➔ National SoE Advisory and Production Team;
- ➔ Technical Advisory Committee;
- ➔ National Coordinator and assistants;
- ➔ Chapters Lead authors;
- ➔ Contributing authors;
- ➔ Reviewers; and
- ➔ Regional workshops participants;
- ➔ Special thanks to Mr. Clever Mafuta, Head of Programme, Waste and Marine Litter, GRID Arendal, Norway for training and guiding the team in the production of this report.



Compiling this first-ever Sudan State of the Environment and Outlook 2020 Report (SoE) has been a totally new experience, particularly for me as the Technical Lead Author, and for all the national SoE team. The SoE 2020 report was produced despite a number of technical, institutional and political challenges. Some of these are highlighted here:

1. One formidable challenge has been how and where to get authentic data on all the components of the Sudanese environment, taking into account that some of the available data related to the era before the secession of South Sudan in 2011.
2. The data kept changing by the year and lately by the month and day. One example is the rate of inflation – it was about 30 per cent in 2017; at the time of writing this preface, it stands at over 150 per cent.
3. The shifting and changing of different federal ministries names and mandates have restricted the completion of the regional workshops.
4. Political and institutional changes had a particular impact on the SoE process. In September 2018, the Ministry of Environment, Natural Resources and Physical Development was dissolved and replaced by the National Council for Research, which had no clear mandate and powers. From December 2018 to April 2019, the country was experiencing political unrest and nationwide revolution. Even when the Transitional Government was formed in August 2019, it was devoid of a Ministry of Environment. Only in April 2020 was the Environment Protection Act 2001 amended and a new Higher Council of Environment and Natural Resources (HCENR) established with its Secretary-General appointed in May 2020. All these events have had their implications on the SoE, rendering its team working under no guidance of a national legitimate authority.

Despite these obstacles and constraints, the SoE team has produced a report that is now available for the current Transitional Government, and for policymakers, universities, NGOs and the public at large. For the government, the SoE 2020 report is a milestone document which not only describes the current status and trends of Sudan's environment, but also offers policy analysis and proposes different scenarios on how the country would manage its natural resources and preserve its environment through the 2020–2030 period.

As the first Sudan SoE report, no one can claim it to be a perfect report. But the lessons learned and the experiences gained will benefit all those who contributed to its production, including Sudanese environmentalists, experts and government institutions. This report will also be valuable to future versions of Sudan SoE report. It is envisaged that Sudan SoE 2020 will present a new face of Sudan to the world, and specifically to the donors and investors.

Finally, I would like to express my deep and sincere gratitude to the United Kingdom's Foreign, Commonwealth and Development Office (FCDO), UNEP staff in Sudan and abroad, and to GRID, Norway. Without their dedication, the SoE 2020 would not have been conceived and produced.



Dr. Osman M.M. Ali

Technical Lead Author

Sudan State of Environment and Outlook Report 2020



It is my great pleasure to present this first State of Environment and Outlook Report of the Republic of Sudan, which demonstrates the Transitional Government's political commitment to a sensible stewardship of Sudan's natural capital. The report reflects the determination of Sudan's leadership to integrate the protection of environmental health, as well as a sustainable and inclusive utilisation of the country's natural resources, in the development strategies of all sectors of economic activity. This report comes out at a very opportune time: Sudan is transitioning to a democratic, people-centered political system and has made significant strides towards its full integration as an active member of the international community.

I would like to commend all national experts and environment enthusiasts affiliated to governmental and non-governmental institutions and civil society organizations who contributed their knowledge, professional competences, and collaborative support to the production of this report. This report would not have been possible without the indispensable support from Sudan's Higher Council for the Environment and Natural Resources (HCENR), the United Nations Environment Programme (UNEP) and the United Kingdom's Foreign, Commonwealth and Development Office (FCDO).

The theme of this report – Environment for Peace and Sustainable Development – is aptly chosen not only because it highlights the intricate nature of the nexus between environment, peace and sustainable development, but also because it comes at a time when the new Sudan seeks peaceful rebuilding of the nation, the establishment of a vibrant economy, and a politically stable future under the emblem of the December 2019 Revolution: Freedom, Peace, and Justice. Sudan aspires to utilise its rich natural resources for the welfare of its current and future generations.



Dr. Abdalla Hamdok

Chairman
Higher Council for Environment
and Natural Resources (HCENR)
Government of the Republic of Sudan



Foreword

Sudan has witnessed multiple milestones in its history, the most recent a profound democratic transition. The United Nations Environment Programme (UNEP), as a part of the UN family in Sudan, remains committed to supporting the Sudanese people and the Transitional Government to achieve their 2030 Agenda goals on environment, peace, development and human rights.

Sudan, like many countries, is seeking to build back better in the face of the ongoing severe economic crisis and additional challenges brought on by the pandemic. Environmental concerns lie at the heart of many of these challenges and natural resources are the foundation of Sudan's agriculture-dominated economy. This is why this report – the first State of the Environment and Outlook Report for the Republic of Sudan – is so important to the country's development trajectory.

At a time when the triple planetary crisis of climate change, nature loss and pollution are driving an unprecedented degree of risk, we must understand and address these critical obstacles to human development. The report looks at Sudan's specific environmental challenges in detail, covering everything from deforestation and land degradation to waste management to food security. In a country mainly covered by desert and semi-desert expanses, the report finds that it is essential to wisely use precious natural resources such as water, land and valuable mineral resources. In particular, the report identifies an urgent need to address conflicts over natural resources, particularly transboundary freshwater.

UNEP has been delivering environmental assistance to Sudan since the 1990s. Our first effort to assess the nation's environmental challenges took the form of the 2007 Sudan Post-Conflict Environmental Assessment. This report, released with the Government of the Republic of Sudan and led entirely by Sudanese national environmental experts, is part of this long cooperation.

I would like to express my gratitude to the Government of the Republic of Sudan and the United Kingdom's Department for International Development for their support in the publication of this report. The Government of the Republic of Sudan has shown commitment to the many international processes designed to tackle the triple planetary crisis. I fully expect this publication to help the government to continue to make wise policy decisions that place a healthy environment at the heart of Sudan's future prosperity.



Inger Andersen

Executive Director,
UN Environment Programme and
Under-Secretary-General of the United Nations



Abbreviations and Acronyms

AfDB	African Development Bank
ARC	Agricultural Research Corporation
AREP	Agricultural Revival Executive Programme
ARRC	Animal Resources Research Corporation
BOD	Biochemical Oxygen Demand
CAHW	Community Animal Health Worker
CBO	Community Based Organisation
CBS	Central Bureau of Statistics
CCS	Carbon Capture and Storage
CEIC	Census and Economic Information Center
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COD	Chemical Oxygen Demand
DDT	Dichlorodiphenyltrichloroethane
DECARP	Sudan's Desert Encroachment Control Programme
DNP	Dinder National Park
DVRRC	Darfur Voluntary Return and Resettlement Commission
ECOS	European Coalition on Oil in Sudan
EPA	Environment Protection Agency
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIS	Geographical Information Systems
GoS	Government of Sudan
HAC	Humanitarian Affairs Commission
HCENR	Higher Council for Environment and Natural Resources
HCH	Hexachlorocyclohexane
ICPAC	IGAD Climate Predication and Application Centre
IDDRSI	IGAD Drought Disaster Resilience and Sustainability Initiative
IDMC	International Displacement Monitoring Centre
IDP	Internally Displaced People
IEM	Integrated Ecosystem Management
IGAD	Intergovernmental Authority for Development
INRM	Integrated Natural Resources Management
IUFRO	International Union of Forest Research Organizations
IWRM	Integrated Water Resources Management
IFAD	International Fund for Agricultural Development



Abbreviations and acronyms

IMF	International Monetary Fund
INDC	Intended Nationally Determined Contributions
IOM	International Organization of Migration
IPCC	Intergovernmental Panel on Climate Change
ISESCO	Islamic World Educational, Scientific and Cultural Organization
IUCN	International Union for Conservation of Nature
IUCN-EARO	International Union for Conservation of Nature, Eastern Africa Regional Office
JICA	Japan International Cooperation Agency
KWH	kilowatt-hour
LDN	Land Degradation Neutrality
LTSR	Land Tenure Systems and Rights
MAB	Man and the Biosphere
MAF	Ministry of Agriculture and Forestry
MAR	Ministry of Animal Resources
MCIT	Ministry of Communications and Information Technology
ME	Ministry of Education
MENRPD	Ministry of Environment, Natural Resources and Physical Development
MFA	Ministry of Foreign Affairs
MFEP	Ministry of Finance and Economic Planning
MFGC	Ministry of Federal Governance Chamber
MH	Ministry of Health
MHES	Ministry of Higher Education and Science
MI	Ministry of Interior
MIWRE	Ministry of Irrigation, Water Resources and Electricity
NAP	National Action Plan
NAPA	National Adaptation Plan of Action
NBI	Nile Basin Initiative
NCCD	National Council for Combating Desertification
NDMC	National Drought Mitigation Centre
NGO	Non- governmental Organisation
NIC	National Interim Constitution
OCHA	Office for the Coordination of Humanitarian Affairs (United Nations)
PCB	Polychlorinated biphenyl
PDS	Partners in Development Services
PERSGA	Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden
POPs	Persistent Obsolete Pollutants



Abbreviations and Acronyms

PPPRRC	Public Private Partnership Relief and Rehabilitation Commission
PRSP	Poverty Reduction Strategy Paper
REDD+	Reducing Emissions from Deforestation and Forest Degradation and the Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Countries
RoS	Republic of Sudan
SADC	Southern African Development Community
SAP	Structural Adjustment Programme
SDGs	Sustainable Development Goals
SMA	Sudan Meteorology Authority
SMNP	Sanganeb Marine National Park
SPLA	Sudan People's Liberation Army
SPLM	Sudan People's Liberation Movement
SSA	Sudan Survey Authority
SSMO	Sudan Standards and Metrology Organization
SUDNAIP	Sudan National Agriculture Investment Plan
tCO ₂	Ton of carbon dioxide
UNCBD	United Nations Convention on Biodiversity
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNDRO	United Nations Disaster Relief Organization
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations International Children's Fund
UN PBSO	United Nations Peacebuilding Support office
UNU	United Nations University
USAID	United States Agency for International Development
WB	World Bank
WCMC	World Conservation Monitoring Centre
WFP	World Food Programme
WHO	World Health Organisation
WCGA	Wildlife Conservation General Administration
WMO	World Meteorological Organisation
WRC	Wildlife Research Centre



INTRODUCTION

The Sudan State of Environment and Outlook Report (2020) is the first to comprehensively take stock of the condition of the country's environment and the trends affecting it. It 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, Sudan is the third largest African country by area after Algeria and the Democratic Republic of the Congo, covering 1.88 million km². The secession of South Sudan in 2011 reduced its size by 24.7 per cent. 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. The secession also led to Sudan losing 75 per cent of its oil reserves to South Sudan.

The country's population is estimated at 44.43 million and is predicted to increase to 57.3 million by 2030. 64 per cent of the population lives in rural areas. Despite being a largely desert and semi-desert country, natural resources are the backbone of the economy. The agricultural sector contributes around 39 per cent to the nation's GDP, constitutes a source of livelihood for about 65 per cent of the population and employs about 50 per cent 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 and better lives, while others have been driven there by drought and famine in Kordofan and Darfur. The conflict in Darfur region resulted in 1.86 million internally displaced persons, many of whom ended up living in towns.

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.

Given Sudan's location, which predisposes it to desert creep and drought, the country is vulnerable to poverty. According to governmental data, 46.5 per cent of Sudan's population is living in poverty. Poverty results in a higher dependence on the natural environment for livelihoods and resources, including forests for energy. A 2010 report estimated that annual fuelwood consumption in Sudan would be 15.5 million m³ by 2020 and 30 million m³ by 2030.

ENVIRONMENTAL GOVERNANCE

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. Through the federal system, the country's governance is devolved to three levels: national, state and local. 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. Customary laws are central to Sudan's governance system, prescribing 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 aimed 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, and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes. Some of Sudan's laws are derived from its membership of regional bodies such as the Inter-Governmental Authority on Development (IGAD) and the Nile Basin Initiative.

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 the environment. On 30 April 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.

ATMOSPHERE

Sudan's climate is generally hot for most of the year, with seasonal rainfall that decreases the further north you go. 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. Khartoum has a three-month rainfall season extending from July to September, with rainfall averaging 120 mm per year. In the areas closer to the border with Egypt, no rain falls at all in most years.

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. High altitude areas and the coastal regions are generally cooler.

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

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 about 23.5 million hectares (56 million feddan) is under cultivation. 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 area. Sorghum and millet are the major crops, while sugarcane, sesame, groundnut and cotton are among the cash crops. About 25.6 per cent of Sudan's total land area is rangeland.

The Food and Agriculture Organization of the United Nations (FAO) Global Forest Resources Inventory (1990-2015) indicated 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 as some of the largest reserves in the country. A small portion of Sudan's land is taken up by oil fields and by organized and artisanal gold mining.

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. To compensate for the falling yields, farmers have been expanding the land under cultivation at a rate of 3.71 per cent per year. Mechanised farming is practiced on around 6.7 million hectares (16 million feddan); some of this land has over-worked soils.



Executive Summary

About 3.5 million hectares (8.3 million feddan) is used for irrigated farming growing mainly sugarcane, cotton, wheat and alfalfa. Nomadic pastoralism is practiced by 13 per cent of Sudan's population.

Major land-related issues in Sudan include conflicts, degradation and urban encroachment, such as the dramatic expansion of the city of Khartoum since 1984. Serious conflicts have occurred recently in Darfur and Kordofan. Local conflicts have taken place between pastoralists and sedentary farmers over livestock routes, and over mining rights and mining allotment boundaries. Land degradation, mainly in the form of soil erosion, is rife, causing siltation of water resources.

WATER RESOURCES

Sudan's annual per capita water availability is about 700 m³ based on the Falkenmark Water Stress Indicator, significantly below the "water scarcity margin" of 1000 m³ per capita. 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. Many of its groundwater sources are also shared with neighbouring countries. For example, the Nubian Sandstone Aquifer is shared by Sudan, Egypt, Libya and Chad. Sudan has a significant share of the Red Sea with a coastline that extends for 853 km, including embayments and inlets.

The Nile River system provides 73 per cent of Sudan's annual freshwater supplies. Based on the 1959 agreement with Egypt, Sudan receives 18.5 km³ of water per year from the Nile River as measured at Aswan in southern Egypt. 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.

Seasonal wadis and khors are also critical freshwater sources for Sudan. They contribute an additional 5.5 km³ of water per year. The total annual surface water available for Sudan is 26.0 km³. Natural lakes, wetlands and hafirs (water impounded in basins during rain season) are also valued as important sources of freshwater. Groundwater sources have a storage capacity of 5.6 km³ and an annual recharge of about 2.0 km³.

Groundwater sources have a storage capacity of 5.6 km³ and an annual recharge of about 2.0 km³. The Nubian aquifer and the Umm Ruwaba formation are the major groundwater sources for Sudan. An estimated 0.02 million m³ of water per day is produced from non-conventional sources, including the desalination of sea water from Sudan's portion of the Red Sea. These non-conventional sources also include wastewater.

Sudan uses its water for domestic purposes, irrigation, hydropower generation, navigation and recreation. 70 per cent of the population in urban areas and 63.5 per cent in rural areas have access to safe drinking; while access to sanitation services averages 39.5 per cent (57 per cent in urban areas and 22 per cent in rural areas).

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 can produce 320 MW. The Roseires, Sennar and Khashm El-Girba dams can generate 280 MW, 15 MW and 10 MW, respectively.

Sudan's coastal and marine resources are largely dedicated to biodiversity conservation. The Sanganeb and Dugonab Bay–Mukkawar Marine Protected Areas are important eco-tourism bases, 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. However, the heightening of the Roseires dam in 2013 has raised its storage capacity from 3.35 to 5.8 km³. Water withdrawals also continue to increase due to growing population, changing consumption patterns and climate change.

BIODIVERSITY

Sudan is home to a variety of ecosystems and habitats. There are 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.



Executive Summary

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. 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 cover most of eastern and central Sudan. They are home to many birds, reptiles and mammals such as antelopes and gazelles. Sudan has an estimated 653 species of birds, 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. 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.

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). 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 km²), 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, an important export commodity. During the 2014/15 fire season, more than 1 million hectares of forest were burned. Forests are also lost during exploration for oil and the construction of pipelines. To address the loss of forests, Sudan has significantly expanded its afforestation activities. For example, in 2016 the country planted 210,000 hectares of trees (0.5 million feddans).

Biodiversity loss is especially pronounced among wild animals. Species such as white antelope (*Addax nasomaculatus*), East African oryx (*Oryx beisa*) and Common eland (*Taurotragus oryx*) have become locally extinct, while the Northern giraffe (*Giraffa Camelopardalis*) and the African wild dog (*Lycaon pictus*) are

endangered. The most significant effort to guard against biodiversity loss has been through protected areas, but the number of protected areas has not been increasing.

Sudan also has problems with invasive species. These 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

A number of environmental problems have afflicted Sudan over many years. 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. While the FAO estimates that deserts constitute 60.4 per cent of the country, the Ministry of Agriculture and Forests puts it as high as 72 per cent. The United Nations Environment Programme (2007) reported that the Sahara had advanced south by 200 km from 1935 to 2000, while other sources estimate the southerly expansion at between 5 and 40 km.

Overgrazing is a significant problem with the country's livestock population far exceeds the national carrying capacity. Studies have 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.

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.

Long-life pesticides used in Sudan include DDT (Dichlorodiphenyltrichloroethane), which was first used in the country in 1945 and banned in 1981; aldrin, dieldrin, heptachlor and chlordane, mainly used in sugarcane plantations to control termites; and persistent organic pollutants (POPs), which are known



Executive Summary

to cause cancer and disruption of the endocrine and immune systems.

Poor storage and the exposure of obsolete pesticides and leaky containers to various climatic conditions have caused widespread contamination. Organochlorine pesticides have even been detected in the blood of residents living in areas of limited pesticide use in northern Sudan. The agricultural scheme stores contain about 600 tonnes of pesticides of which 90 tonnes are POPs.

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. Khartoum also has the challenge of dealing with toxic waste that is dumped in landfills and ends up leaching into groundwater. 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: it is estimated that Sudan produces 3-6 kg per person per year of electronic waste. 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, partly in response to the decline in foreign currency revenues due to reduced oil exports. In 2012, gold mining licences doubled from 318 to 700, and the number of processing mills increased six-fold from 714 to 4,464. In 2014, artisanal gold miners produced 60 tonnes of gold, almost six times more than large-scale miners. The quick returns have encouraged farmers to switch from farming to mining.

The use of mercury in gold extraction has negative effects on the environment and human health, causing a wide range of symptoms. One study has suggested that as much as two to three tonnes of mercury are needed to extract a tonne of gold. Another consequence is that vast tracts of land that would otherwise be used for farming are instead used for mining and degraded. Even though trade in mercury is banned by the Minamata Convention, the metal continues to be imported into Sudan.

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. 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.

As Sudan goes through a period of reduced electricity generation, diesel- and petrol-powered generators are 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

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 previous regime formed the 25-Year Development Strategy (2007-2031), which was planned to conclude a year after the end date of the SDGs. The 2005 Comprehensive Peace Agreement and the Interim National Constitution are also key to the environment. The constitution is clear on the need to provide a clean environment, protect biodiversity and better manage land resources.

Most 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 improve the quality of rangelands and protect livestock drinking water facilities. By contrast, some economic policies disregard their impact on the environment. For example, oil and gold mining policies



Executive Summary

have resulted in the contamination of water bodies in West Kordofan state and the destruction of pastures in eastern Sudan, respectively. At the same time, some policies have in-built provisions for environmental protection but suffer from weak enforcement.

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; 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. The Wildlife Conservation and National Parks Act (1986) protects species and licenses hunting, but it does not protect habitats and ignores community participation. The country's oil and gas policies are silent on the unintended consequences of exploration and drilling.

Weak policy enforcement 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. Some pieces of legislation are beneficial but poorly implemented. The Native Administration Act (1998), which gives power to local communities and traditional leaders to administer policies, including environmental policies, has been hindered by low funding, conflicting authority and overlapping institutional roles.

FUTURE OUTLOOK

Sudan's 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. 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.

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. 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, 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 impacts of flash floods are magnified due to higher population densities and lack of investment in climate-proof infrastructure.

Productivity of major cereals remains low due to overuse of land. Agricultural production fails to meet 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 increase, 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 remains constrained on the amount of water it can tap from the Nile River system due to the country's historical agreement with Egypt. There is no expansion in the amount of groundwater available for domestic and industrial uses.



Executive Summary

While the country makes significant progress in reducing its carbon footprint through the use of hydropower, it fails to make the SDG targets for wastewater treatment, sanitation and safe drinking water. Lack of investment in its marine water resources results in little progress on the 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, and the country fails to meet its SDG targets for life below the ocean and life on land. Emerging environmental issues – which include artisanal gold mining, diesel/gasoline generators and rickshaws – continue to plague the country as Sudan struggles to diversify its economy. Meanwhile desertification remains a major persistent environmental challenge for Sudan.

Bending the curve scenario

A large-scale private and public investment in both grid and off-grid renewable energy ensures that by 2030 most Sudanese have access to clean electricity. Sudan also significantly reduces its carbon footprint. Cases of upper respiratory infections caused by indoor pollution are dramatically cut.

The country's land use and land tenure laws are overhauled, resulting in not only protection of land as private property but also the 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 following the availability of high-yielding seed. As a result, Sudan achieves its SDG targets for reducing hunger and poverty.

The widespread adoption of rainwater harvesting techniques results in more water availability, while investment in water drilling ensures that groundwater sources such as the Nubian aquifer are carefully used. Sudan joins the rest of the world in protecting its marine environment from pollution. Improved protection for Sudan's diverse ecosystems means that populations of endangered species rebound, and Sudan meets its Aichi Biodiversity Targets, as well as its SDG targets for life under water and life on land.

Sudan changes its mining laws to include a total ban on the use of mercury. Degraded land is rehabilitated, and new mining operations are made more environmentally friendly. The measures lead to a significant improvement in the quality of life and health of miners. Investments in public transport systems result in the disappearance of the rickshaw and improved air quality in towns and cities.

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



OBJECTIVES

The overall objective of the Sudan First State of the Environment and Outlook 2020 Report (SoE) is to document and to assess the current status of the environment in Sudan and to propose scenarios and policy options. The implication of having such a document is that Sudan now has – for the first time – a baseline of environmental knowledge and an outlook for sustainable development, like many of its neighbours. The report not only establishes the causes and effects of environmental trends, but also addresses the country's policy and institutional response mechanisms. This SoE report will constitute a solid platform and provide leverage to Sudan to form a clear environmental vision, to build new policies and to establish stronger and more efficient environmental institutions.

The SoE report is motivated by and strives to answer the following questions:

1. What is happening in the Sudanese environment and why?
2. What are the consequences to the environment and humans?
3. What is being done and how effective is it?
4. Where is the country's environmental status heading?
5. What actions could be taken for a more sustainable future?
6. How will Sudan meet its national and international commitments in the realm of the Sustainable Development Goals (SDGs), climate change and other commitments.

THEME

Peace for Environment and Sustainable Development was chosen as the theme of Sudan's first SoE report. This is to establish the need for peace as a prerequisite to conserving the environment and achieving sustainable development in Sudan, and to underline that sustainable development will enhance and stabilize peace in the country.

FRAMEWORK AND METHODOLOGY

The report is produced using the integrated Environmental Assessment and Reporting (IEAR) approach based on the **Drivers-Pressure-State-Impact-Response** (DPSIR) methodology. The data in this report were gathered through several sources, including government sources, reports by international organisations,

peer reviewed scientific papers and stakeholder consultations via three regional workshops in ten states.

The different versions of the SoE report were subjected to a rigorous, elaborated process of reviewing involving both national and international reviewers. The culmination of the reviewing process was a federal review where the community was invited to solicit comments via an online platform due to the COVID-19 situation. The reviewing processes allowed more feedback and comments, and at the same time, provided a venue where information was sought and injected to improve and update the report. The information gathered was augmented by satellite images, maps, infographics, case studies and high-quality photos.

STRUCTURE

The report covers two major domains. The first is the documentation and analysis of the state of environment in Sudan, starting with 2011, the year of the South Sudan secession, and ending with 2020. The second domain envisages the future of the environment of Sudan up to the year 2030, to coincide with the realization of the SDGs. The report consists of ten chapters structured around four parts. Each chapter contains an introduction, a main text and a conclusion that assesses how the issues raised will impact Sudan's development and environmental integrity. Each chapter was assigned to a national expert supported by a co-author and contributing authors.

Part One: Environment-Human Society-Development Nexus

Chapter one is an overview of the country's geography and socio-economy. It describes Sudan's demographic and population mobility, settlements, urbanization, ethnic and cultural diversity, gender and youth issues, and environment. It also explores the links between the environment and education, health, education, agriculture, industry, mining, tourism and economic development.

Chapter two describes the environmental governance system in Sudan. It covers overarching policies, previous constitutions, federal and state governance, statutory and customary laws, national goals, MEAs, natural resources management laws, institutional arrangements for natural resources, conflict management structures and capacities of environmental institutions.



Introduction to the Report

Part Two: The Environment of Sudan: Status and Trends (2011–2020)

Across the next four chapters, the report discusses the environmental aspects of the Atmosphere, Land Resources, Water Resources and Biodiversity. The general features of Sudan's climate and its air quality are described in chapter three, including climate change and the country's response in the form of adaptation and mitigation.

Chapter four explores the many issues associated with Sudan's land resources, soils and rangelands, including nomadic pastoralism, land-related challenges such as conflict, IDPs, refugees and returnees, urbanization and land degradation. Land management and administration issues such as land tenure and land use policies are highlighted.

Chapter five focuses on Sudan's water resources, which include surface waters such as the Nile system, groundwater sources such as aquifers, and the Red Sea. Water availability and use are major components of this chapter. Threats to water resources in Sudan include scarcity, supply and demand imbalance, sanitation and hygiene, and climate change and extreme climatic events. The chapter also discusses institutional and policy arrangements, and the transboundary dimension.

Chapter six is about biodiversity. It highlights the country's diverse inland and marine ecosystems and habitats, as well as the threats and protection measures.

Part Three: Persistent and Emerging Environmental Issues

Chapter seven analyses the serious problem of desertification, describing the causes and the government's response. The chapter also tackles pesticides – the threats they pose and how they are managed – and the persistent issue of waste, including solid, liquid, domestic, industrial and medical waste. Emerging environmental issues are the subject of chapter eight. The most significant and recent of these is artisanal gold mining, which poses a severe threat to the environment and people's health through land degradation and the use of mercury in gold extraction. Electronic waste in the form of mobile phones, computers, radios and TVs is also emerging as a serious issue. In the field of transport and energy, rickshaws are causing severe traffic and air pollution problems.

Part Four: Environmental Outlook (2020–2030)

Chapter nine contains a detailed analysis of the country's current policy and institutional arrangements (Policy Analysis). The report concludes with Chapter 10: Scenarios and Policy Options, which compares the current "business as usual" scenario with an alternative "bending the curve" scenario for the period 2020–2030.

ADMINISTRATION

1. National Technical Advisory Committee (TAC): appointed by the former Ministry of Environment Natural Resources and Physical Development (MENRPD), the TAC has overseen all the process of the SoE and endorsed its structure, theme, chapters, chapter lead authors, co-authors, contributing authors and national reviewers.
2. Technical Lead Author (TLA): Selected by the MENRPD and appointed by the United Nations Environment Programme (UNEP), the TLA has been responsible for the technical aspects of the project, coordinating with the authors and reviewers, and ensuring that the chapters are written to the highest standards of data presentation and analysis.
3. National Coordinator (NC): Appointed by the MENRPD, the NC was responsible for logistic and institutional aspects and for coordinating with the TLA in the various activities of the SoE, especially the regional workshops.

INSTITUTIONALIZATION

Besides the above objectives, this report will lay the foundations for the regular future production of the SoE. Institutionalizing the SoE in this way is important because it ensures that it will remain a national asset and a planning tool. Publication of the SoE is not an end-in-itself. Rather, it is the first step in an ongoing process: to collect environmental data, to engage a range of cross-governmental stakeholders, and to better understand the challenges Sudan faces and the opportunities available regarding its natural environment.



1

Socio-Economic Status and Environment

1.1 INTRODUCTION

Sudan is in northeast Africa and shares borders with seven countries – Central African Republic, Chad, Egypt, Eritrea, Ethiopia, Libya and South Sudan (Figure 1.1). It covers 1.88 million km², making it the third largest country in Africa after Algeria and the Democratic Republic of the Congo. Before the secession of South Sudan in 2011, which reduced Sudan's size by 24.7 per cent, the country was the largest in Africa.

Sudan lies between latitudes 10-22° North and longitudes 22-38° East. Its landscape consists of gentle plains dotted with hills and mountains, including the Jebel Marra volcanic massif, the Nuba hills in South Kordofan, the Ingessana hills in Blue Nile state and the Red Sea hills near the border with Egypt (World Atlas 2017). The country borders the Red Sea with a continental coastline of about 853 km, including embayments and inlets (FAO 2019a) – the coastline contains sheltered bays (*marsas*), which provide natural harbours and places to land fish, and lagoons fringed by mangrove forests (Ministry of Environment, Forestry and Physical Development 2013).

The country is divided into five ecological zones defined by the amount and pattern of rainfall and by the dominant vegetation type, as shown in Table 1.1. Average annual rainfall varies considerably across the country, from nil in the desert and semi-desert of the north to more than 800 mm in the south (Mohamed et al. 2014). Within these ecological zones there are five different soil types: desert soils (sands and gravel), Goz soils (sands), alkaline catena soils, alluvial soils and lacustrine soils.

Sudan's economy has contracted in recent years due in part to falling oil revenues after the secession of South Sudan in 2011, which resulted in the country losing 75 per cent of its oil resources (IFAD 2013). Sudan's Gross Domestic Product (GDP) fell from 96.742 billion USD in 2015 to 30.873 billion USD in 2019 (World Bank 2019). Inflation rose from 11.2 per cent in 2009 to 35.6 per cent in 2012, almost doubling to 63.3 per cent in 2018 before soaring to 81.3 per cent in 2020 (Statista 2020). Over the long term, economic sanctions imposed on Sudan by the United States of America from 1997 until 2017 have impaired social development and devalued the local currency (FAO 2018).

Figure 1.1 Sudan on the map of Africa (GRID-Arendal)



Table 1.1 Ecological zones of Sudan

Aridity Zone	Ecological zone	Area (sq.km.)	% (Area of the Sudan)	Annual Rainfall (mm)
Hyper-arid	Desert	776,000	41.2	< 20
Arid	Semi-desert	630,000	33.5	20–100
Semi-arid	Grassland Savanna	340,000	18.1	100–300
Dry sub-arid	Low Rainfall Woodland Savanna	65,000	3.4	300–500
Sub-tropic	High Rainfall Woodland Savanna	70,000	3.8	500–800
TOTAL		1,881,000	100	

Source: Mohamed et al. 2014

Many of Sudan's ecological assets such as forests and rangelands are threatened by environmental degeneration. As much as 50.7 per cent of the landscape is bare soil or seriously degraded (FAO 2012; Ministry of Environment, Forestry and Physical Development 2013). The country is seriously affected by deforestation, biodiversity loss, reduced rangeland carrying capacity, pollution and increased incidence of environment related diseases. The problems are exacerbated by inadequate environmental policies and laws, poor enforcement, a lack of coordination among institutions and government departments, a low level of environmental public awareness, inadequate technology and weak resource management.

This chapter describes the environmental situation in Sudan and considers the pressures that are impacting its natural resources.

1.2 ENVIRONMENTAL GOVERNANCE

Sudan is a federal nation divided into 18 states (Ministry of Information 2018): Al Bahr al Ahmar (Red Sea), Al Jazirah (Gezira), Al Khurtum (Khartoum), Al Gedaref (Gedaref), An Nil al-Abyad (White Nile), An Nil al-Azraq (Blue Nile), Sennar (Sennar), Ash Shamaliyah (Northern), Kassala (Kassala), Nahr an Nil (River Nile), Sharq Darfur (East Darfur), Shimal Darfur (North Darfur), Gharb Darfur (West Darfur), Janub Darfur (South Darfur), Wasat Darfur (Central Darfur), Gharb Kurdufan (West Kordofan), Janub Kurdufan (South Kordofan) and Shimal Kurdufan (North Kordofan) (Figure 1.2).

Sudan's system of governance was established by the Interim National Constitution of 2005. The Constitution

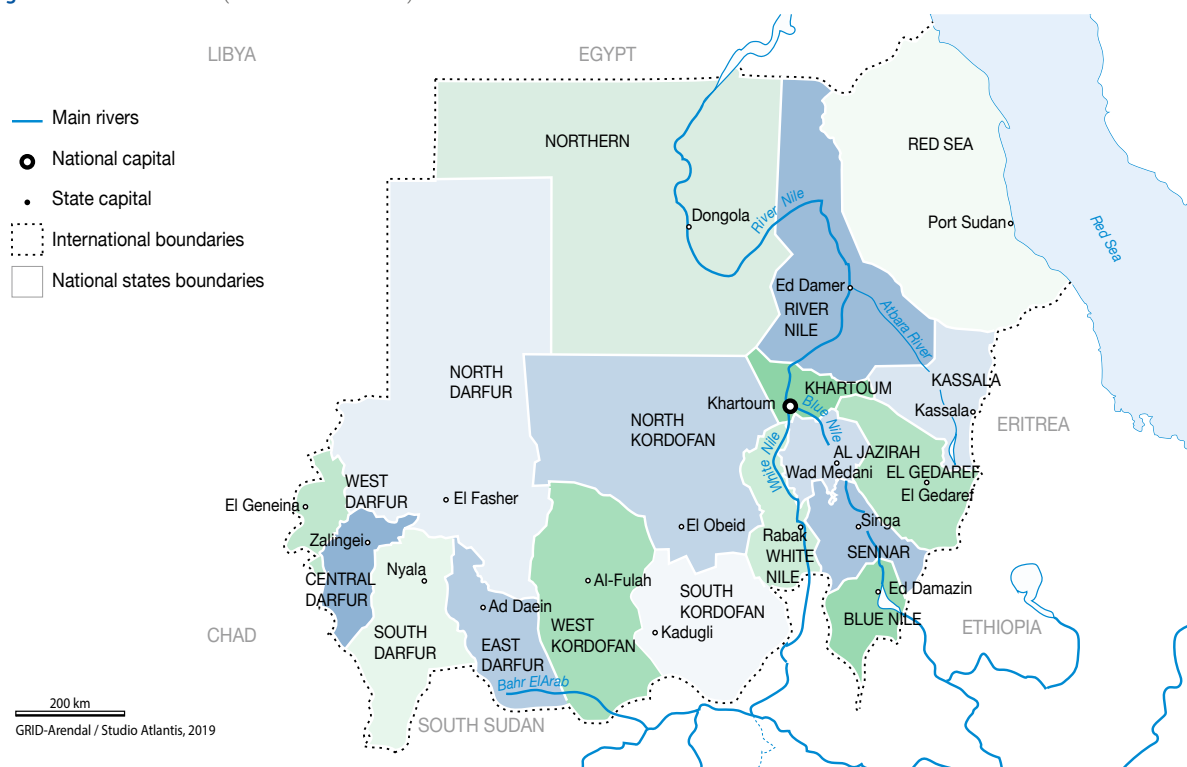
reflects the Comprehensive Peace Agreement between the central government in Khartoum and the Sudan People's Liberation Movement (SPLM), which was signed in January that year. Among its many provisions, the Comprehensive Peace Agreement devolved certain decision-making powers from the national level to the states. It defined several levels of authority. At state level the highest office is the governor (Wali), who is supported by ministers. The second tier is the locality, which is headed by the commissioner (Mo'tamad) and supported by the executive director and related committees. The third tier is the administrative units, each headed by an administrative officer and assisted by various committees. Beneath this are the neighbourhood councils in the urban areas and the village councils in the rural areas.

Most environmental laws are based on the Environment Protection Act 2001, which provides controls and guidelines and gives the states the right to establish environmental councils and to set policies and laws (Ministry of Environment and Physical Development 2001).

Other acts provide protection for natural resources. Sudan has also signed and ratified most multilateral environmental agreements and abides by the requirements of investors such as the World Bank and the African Development Bank, and major donors such as the United States Agency for International Development (USAID) and the United Kingdom's Department for International Development (DFID).

The Ministry of Environment, Natural Resources and Physical Development was established in 1995 and derived its mandate from a constitutional decree. At the time, the Higher Council for Environment and

Figure 1.2 Sudan states (GRID Arendal 2019)



Natural Resources (HCENR) was the ministry's technical arm and was responsible for coordinating policy for all sectors that have a role in the protection of the environment or the use of natural resources. HCENR also managed all the multilateral environmental agreements.

In September 2018, a presidential decree abolished the environment ministry and replaced it with the National Council for the Environment while still retaining the HCENR. On 30 April 2020, the Transitional Supreme Council endorsed amendments to the Environment Protection Act 2001 that established a new Higher Council for Environment and Natural Resources (Republic of Sudan 2020).

1.3 SECESSION OF SOUTH SUDAN

Since Sudan gained independence from British colonial rule in 1956, the country has had few extended periods of peace. In 2005, in an attempt to end more than 20 years of civil war, the government entered peace talks with the Sudan People's Liberation Movement (SPLM). The talks culminated in the Comprehensive Peace Agreement and the establishment of an Interim National Constitution and a unity government later that

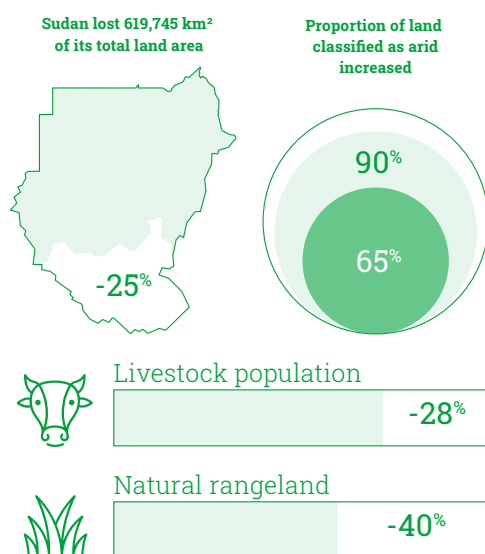
year. In January 2011, the people of the south voted in a referendum to secede from Sudan, resulting in the birth of South Sudan on 9 July that year. This was a turning point in the history of Sudan.

The secession of South Sudan had a significant impact on Sudan's economic growth, inflation and employment opportunities. Oil revenues, which accounted for about 80 per cent of exports and 30 per cent of total government revenues, declined sharply. Official sources estimated that the secession cost Sudan 75 per cent of its oil production, 50 per cent of budget revenues, more than 65 per cent of foreign exchange revenues and 80 per cent of total exports. As a result, real GDP growth, which has been slowing since the onset of the global financial and economic crisis in 2007, declined from 5 per cent in 2010 to 2.5 per cent and 1.4 per cent in 2011 and 2012, respectively (Tahir 2013).

These economic shocks were accompanied by a deterioration in the value of the Sudanese pound and rising inflation and unemployment rates.

As a result of South Sudan's secession, Sudan lost 25 per cent (619,745 km²) of its total land area, including 68 per cent of its forest and woodland

areas and 47 per cent of its wildlife reserves and protected areas. The proportion of land classified as arid increased from 65 per cent to 90 per cent. More critically, while the livestock population fell by only 28 per cent to 104 million head, the natural rangeland resources, on which livestock depends, fell by 40 per cent (Abdel Magid and Warrag 2011). The decrease in the availability of rangeland is a potential cause of conflict between tribes along the border separating the two countries.



All this had a damaging effect on the living standards of the Sudanese people. To mitigate this, in 2011 the government initiated a three-year economic recovery programme called the Three-Year Economic Salvation Programme (2012–2014). The programme was aimed at restructuring the general budget and rectifying the overall deficit of the budget and its expected effect on the socio-economic situation that evolved due to the secession of South Sudan. The objectives of the programme were to: (i) increase tax collection and rationalize spending; (ii) mobilize and tap productive sectors capacities to bridge the gap in major basic commodities; (iii) activate human resources and reduce unemployment rate; and (iv) increase foreign private sector investments (FAO 2015).

In December 2013, war broke out in South Sudan and spread throughout the country. This seriously affected Sudan's oil distribution infrastructure and the flow of goods between the two countries. Thousands of South Sudanese fled to Sudan for food and shelter, and in some areas in the states of White Nile, West Kordofan and South Kordofan they outnumbered the local inhabitants. The number of South Sudanese

in Sudan reached 65,055 in 2015 and exceeded 852,000 in 2016, according to the United Nations High Commissioner for Refugees (UNHCR 2018).

1.4 DEMOGRAPHIC CHARACTERISTICS

According to the Central Bureau of Statistics (CBS), the population of Sudan in 2011 was estimated at 44.4 million, but this declined by 23.5 per cent to 33.98 million following the secession of South Sudan (Central Bureau of Statistics 2018). In 2018 the country's population had expanded to 42 million, and is estimated to grow to 57.3 million by 2030 (Central Bureau of Statistics 2018). The annual population growth rate is 2.4 per cent, and the 2008 census found that there are 5.2 births per woman (Ministry of Finance and Economic Planning 2016). The Central Bureau of Statistics and the United Nations Children's Fund (UNICEF) Sudan estimated the level of infant mortality at about 52 infant deaths per 1000 live births, though there are extreme variations among the states of Sudan (Central Bureau of Statistics and UNICEF 2016). For example, infant mortality is 116 per 1,000 live births in Red Sea, while it is 43 per 1,000 live births in Gezira. Maternal mortality for Sudan is estimated at 215.6 deaths per 100,000 births (Central Bureau of Statistics 2018).



State of Gezira
43/1000

Infant mortality
52/1000

State of Red Sea
116/1000

The average household size in Sudan is 5.7 people. The country is considered a sparsely populated country with an average population density of 24 persons per square kilometre (Central Bureau of Statistics 2018). However, in the wetter and agriculturally rich regions, especially along the River Nile, population densities tend to be much higher. Table 1.2 shows selected demographic and socio-economic indicators for the country.

The population of Sudan is young. Children under the age of 15 years comprise 42.60 per cent of the total population, whereas youth aged between 5 and 24 years old comprise 47.38 per cent of the total population. This reflects a high dependency ratio. Those aged 60 and above represent 5.2 per cent of the total population. At 61.8 years, life expectancy is relatively short in Sudan (Ministry of Finance and Economic Planning 2016).

Table 1.2 Selected Demographic and Social Indicators (Ministry of Finance and Economic Planning 2016)

Demographic Indicators	Value
Population growth rate (2008)	2.4
Urban population (% of total pop.) (2016)	36.0
Population aged 5–24 (% of total pop.) (2008)	47.4
Population under 15 years of age (% of total pop.) (2008)	42.6
Population under 5 years of age (% of total pop.) (2008)	14.9
Population aged 60 or more (% of total pop.) (2008)	5.20
Life expectancy at birth (2008)	61.8
Dependency ratio (household survey) (2011)	80.3
Prevalence of children below age 5 who are underweight (2014)	33.5
Infant mortality rate (per 1000 live births) (2014)	52.0
Mortality rate in children under age 5 (per 1000 live births) (2014) Northern States i.e. post secession	68.0
Maternal mortality rate (per 100,000 births) (2010)	215.6
Total fertility rate (2008)	5.2
Women aged 15-49 who have ever heard of HIV/AIDS (%) (2010)	74.8
Women-headed households (% of total households) (2008)	28.6
Average household size (persons) (2008)	5.70
Population below the national poverty line (%) (2009)	46.5

As a result of the influx of internal migrants from rural areas fleeing an episode of drought and famine in 1983 and the war in the south of the country and in Darfur at the turn of the century, Sudan's urban population has grown rapidly since the 1980s. In 2016, Sudan's urban population represented almost 36 per cent of its total population (Ministry of Finance and Economic Planning 2016).

Figure 1.3 shows population expansion between 2011 and 2018. Figure 1.4 shows the projected population between 2020 and 2030 by gender (Central Bureau of Statistics 2018). Figure 1.5 shows population distribution by state. Figure 1.6 shows the population pyramid in 2019.

Agriculture is the mainstay of the national economy with about 80 per cent of the workforce engaged in crop and animal production (Mahgoub 2014).

Sudan's most densely populated states are Khartoum, Gezira and Southern Darfur, while the least densely populated states are North, Central and West Darfur, and River Nile (Figure 1.5). The states with large

agricultural lands – covering about 17 million hectares out of the total agricultural area of 24 million hectares – are North Kordofan, Gedaref, Sennar, South Darfur, Gezira and White Nile (FAO 2012).

The rapid population growth in Sudan is affecting the development of the country, and may be considered a serious threat to the environment. Rapid population growth increases social and economic problems such as unemployment, poverty and poor health. Moreover, in conditions of environmental degradation such as desertification, rapid population growth makes the alleviation of poverty more difficult and the reduction of unemployment among young people almost impossible. At current rates, the population of Sudan will double every 20 to 23 years (Central Bureau of Statistics 2008). Fertility rates are high in Sudan, estimated at 5.2 births per woman (Central Bureau of Statistics and UNICEF 2016), although this is said to be declining.

There is much disparity in population growth between states. Khartoum is growing fastest, while Northern and River Nile states, which tend to be labour exporters, have the lowest rates of population growth (Ministry

Figure 1.3 Population of Sudan between 2011 and 2018 (Central Bureau of Statistics 2018)

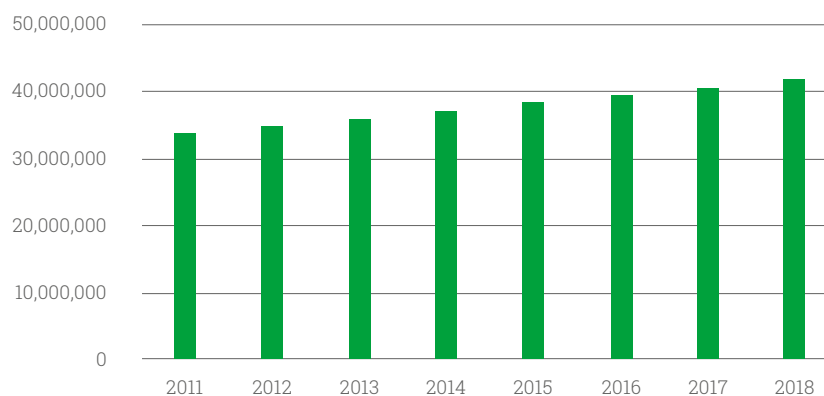


Figure 1.4 Projected population of Sudan by gender between 2020 and 2030 (Central Bureau of Statistics 2018)

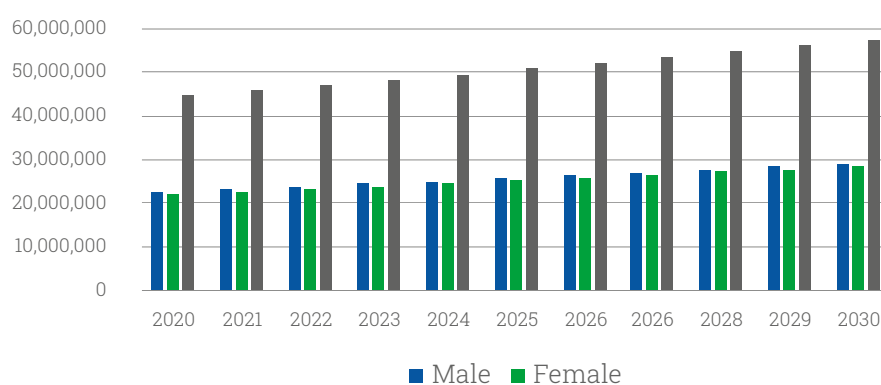


Figure 1.5 Projected population of Sudan by state between 2016 and 2020 (Central Bureau of Statistics 2018)

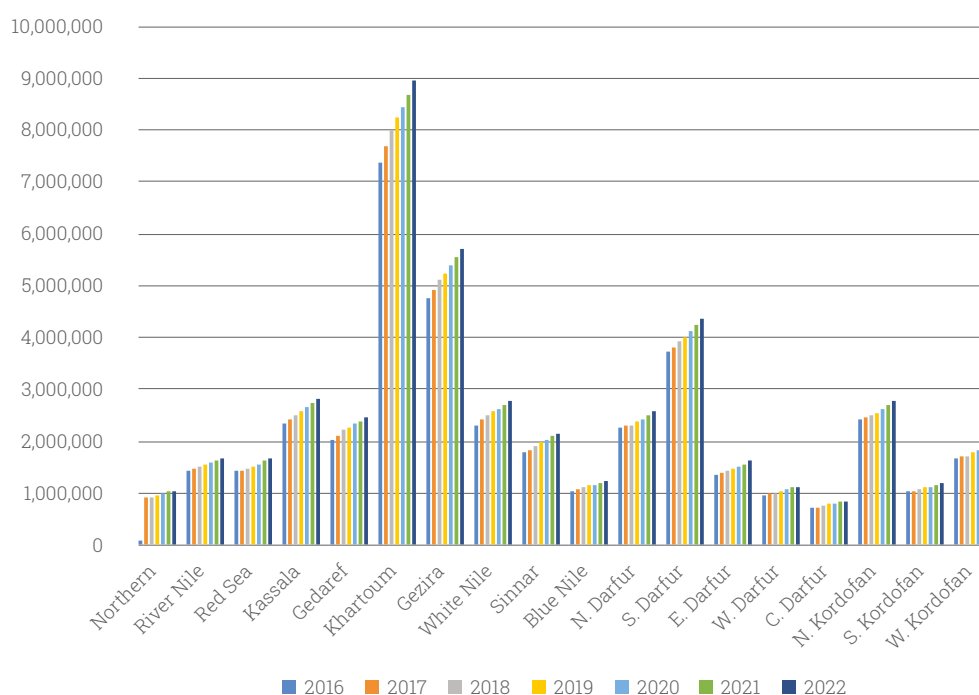
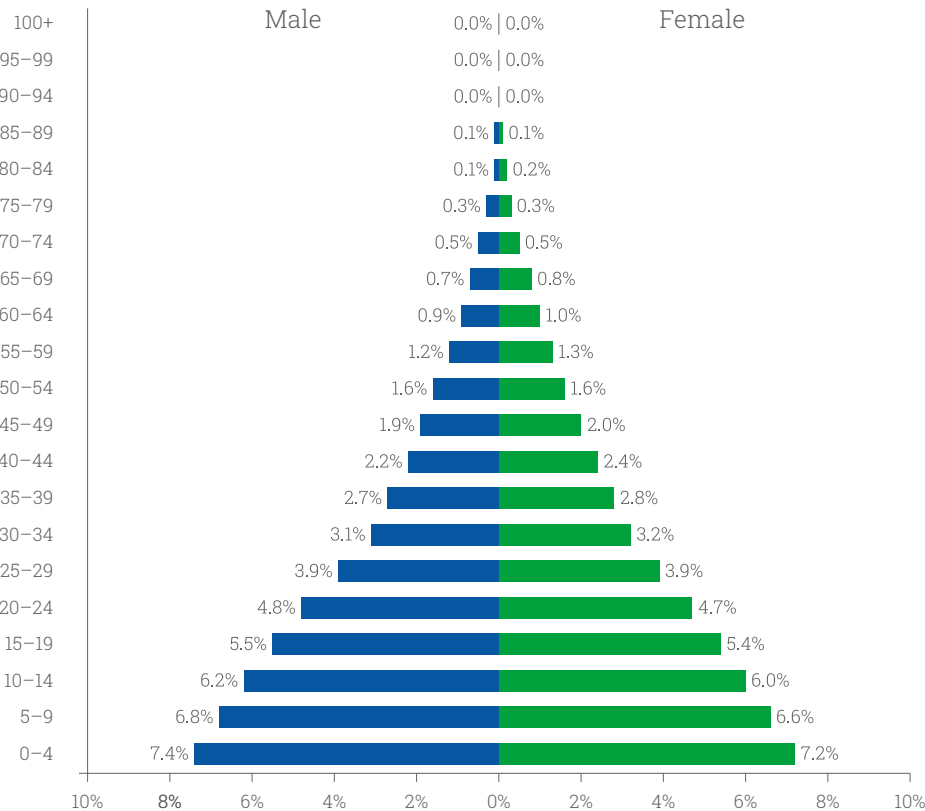


Figure 1.6 Sudan Population Pyramid in 2019 (Source: PopulationPyramid.net)

of Finance and Economic Planning 2016). As well as the internal movement of people from rural areas to Khartoum and the central regions, Sudan receives a lot of migrants from outside. According to the United Nations High Commissioner for Refugees, Sudan houses over one million refugees and asylum seekers from many countries such as South Sudan, Chad, Ethiopia, Eritrea, Syria and Yemen (UNHCR 2019).

1.5 YOUTH AND ENVIRONMENT

Sudanese youth have faced environmental issues since as early as the 1970s when the Sudanese Environment Conservation Society was established in 1975. They have been exerting remarkable efforts to take action and raise the public awareness of environmental problems. Other organizations include Sudanese Environmental Community Organization, Youth Green Creep Organization, and the Sudanese Youth Parliament for Water. The youth-environment nexus became clearer and more prominent with the onset of the climate change phenomenon. Within

this realm, the Sudan Youth Organization on climate change and Youth and Environment are active on both local and international levels. A member of these two organizations is a junior negotiator at United Nations Climate Talks for the African Group of Negotiators and a co-organizer of the UN Youth Climate Summit.

Most of the youth-led initiatives are related to awareness-raising, capacity development, and supporting government agencies in the implementation of national programmes.

Some youth-led initiatives are aiming towards the implementation of global and regional frameworks, such as the Sudan MAB Youth Forum, which is the youth arm under the UNESCO Man and Biosphere Program. In addition, the Sudan Youth Biodiversity Network – part of the Global Youth Biodiversity Network which, acts as the youth advisory group for the Convention of Biological Diversity (CBD) – aims to bring the positions and voices of the youth to the CBD activities as well as to the national level.

Some of these youth-led initiatives won global awards, such as the Mutasim Nimir Center for Environmental Culture for its proposed project Documenting Local Climate Knowledge; the center received the Climathon Global Award for Culture Innovation, which is a celebration of transformative solutions tackling climate change on a local level.

Nevertheless, youth-led initiatives in Sudan face a number of challenges to promote their environmental activities and achieve their objectives. Key challenges include:

- ➔ Lack of sufficient institutional and financial support from the government, civil society, international donors and the private sector;
- ➔ No clear national vision on volunteerism and youth leadership and participation on a national level;
- ➔ There is no effective engagement of youth-led organizations into government and non-governmental environmental work. This includes the poor participation and consultation of youth in the environmental decision-making process.

1.6 ETHNIC AND CULTURAL DIVERSITY

Sudan is a country with a multitude of geographical and environmental features. This gave rise to a population of diverse ethnic groups (UNEP 2007). Some reports suggest that Sudan has about 300 tribes and 100 dialects (Ateem 2007). There are eight main tribal groups: 39 per cent claim to be of Arab descent, 30 per cent are of African origin, 12 per cent are Beja, 15 per cent are Nubian and 4 per cent are from other origins. Some populous tribal groups include:

- ➔ Nubian tribes in the far North;
- ➔ Arab tribes in central Sudan, Kordofan and Darfur;
- ➔ Fur, Zaghawa and Masalit in western Sudan;
- ➔ Beja tribes in eastern Sudan;
- ➔ Mapan and Angassana tribes in southern Blue Nile;
- ➔ Nubian tribes in South Kordofan.

Islam is the largest religion in Sudan and according to UNDP Sudan, the Muslim population is 97%, including numerous Arab and non-Arab groups.



Sudan is a land of diverse ethnic groups and cultures. Photo credits: top left and right © UNAMID, bottom left and right © UNEP

The remaining 3% ascribe to either Christianity or traditional animist religions.

In Sudan there exist more than 160 native languages. The most popular and dominant mother language in Sudan is Sudanese Arabic. Other major languages spoken by ethnic groups are the Beja in the east, spoken by the Beja community, the Fur and Haoussa, spoken by the western communities, and the Nubian language spoken by the Nubian communities in the north and the Hill Nubian spoken by the Nuba Mountains communities in Southern Kordofan (UNESCO 2020).

Historically, ethnic groups that lived close to each other were in constant competition for resources, which resulted in occasional conflicts over cattle and grazing land, particularly between pastoral communities such as the Baggara and Abbala (camel owners) and sedentary farmers. However, these conflicts were limited, since traditional mechanisms existed to resolve them, and neighbouring tribal groups usually inter-married, ensuring a relatively peaceful and harmonious co-existence.

The decision-making processes at the village level were controlled by the traditional leadership. Village heads and elders solved problems and ran the affairs of the village. The decisions taken by the village head and elders were respected by all. Currently, conflicts are solved by both the traditional leaders and Village Popular Committees (Tubiana et al. 2012). Although the role of tribal chiefs is fading, they represent part of the Native Administration and are significant players in rural areas such as in Darfur, mainly in conflict resolution (Tubiana et al. 2012).

The dominant form of administration introduced by the colonial regime in 1928 was the tribal leaders and the chiefs' courts (Local Government Acts 1928). The members of the chiefs' courts were tribal representatives and followed the general organizational structure of each tribe. The chiefs' courts were responsible for justice and other obligations of government such as the collection of taxes. They were also in charge of resolving inter-tribal conflicts. Today, traditional leaders play important roles in environmental conservation, enforcing local customs that protect the environment, implementing statutory laws to safeguard natural resources such as forests and rangelands, and planning areas for farming, animal corridors and fire guards (UNEP 2012).

1.7 POPULATION MOBILITY

Big agricultural development projects such as the Gezira irrigation scheme have resulted in large population movements in Sudan. Agricultural development policies have been geared towards attracting more people to the large-scale agricultural operations in the irrigated and fertile areas and encouraging them to settle (Craig 1991).

The transformation from nomadic to sedentary life and improvements in income and standards of living have led the pastoralists to a more settled type of life. At the same time, the increase in formal employment has led to urban growth and to the expansion of health and education services (Humanitarian Policy Group 2011). While only 29.8 per cent of the population was considered urban in 2008, about 36 per cent of Sudan's population now lives in urban areas (Central Bureau of Statistics 2018). Overall, Sudan is experiencing a major demographic shift. Its population is increasingly a young and urbanized one.

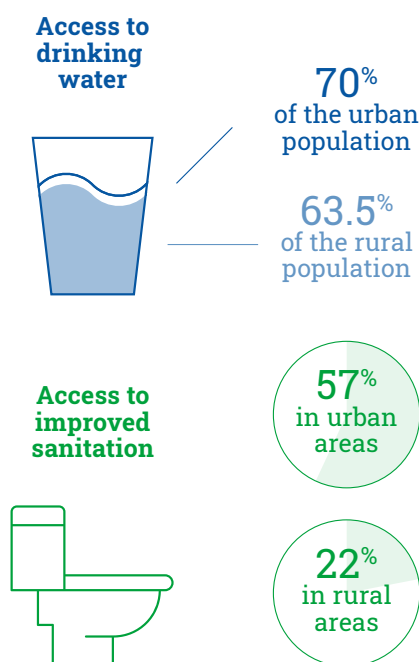


Pastoralists on the move, En Nahud, West Kordofan.
Photo credit © UNEP

1.8 HEALTH

Malaria is the most significant public health concern in Sudan. While the prevalence of the disease declined from 7.5 million reported cases in 1990 to 2.3 million in 2009, the numbers are still high (Central Bureau of Statistics and UNICEF 2016).

The public expenditure on health is 8.4 per cent of total GDP (Index Mundi 2017). There is a worrying urban-rural divide in healthcare provision. Sudan has one doctor per 11,000 people, and 95 per cent of the doctors are in urban areas (Central Bureau of Statistics and UNICEF 2016). Seventy per cent of the total population has access to health services, yet in rural areas the figure is only 20 per cent (Central Bureau of Statistics and UNICEF 2016). Seventy per cent of the urban population and 63.5 per cent of the rural population have access to safe drinking water (Central Bureau of Statistics and UNICEF 2016). Access to improved sanitation is available to 57 per cent of those in urban areas and just 22.1 per cent in rural areas. As a result, rural people are more exposed to water-related diseases such as diarrhea.



Disability rates in Sudan, according to the 2008 population census, are 26.3 per cent, 66.7 per cent and 7.0 per cent in urban, rural and nomad populations, respectively (Abbaker, 2017).

The incidence and prevalence of HIV/AIDS are low in Sudan. A study by the government and UNAIDS in 2014 estimated that 0.2 per cent of adults aged

15 to 49 were carrying the virus (Central Bureau of Statistics and UNICEF 2016). The total number of people of all ages living with HIV is around 53,000, of whom 49,000 are between 15 and 49. Some 23,000 women aged 15 and above are living with HIV. 2,900 people died from HIV/AIDS in 2014 (Central Bureau of Statistics and UNICEF 2016). Meanwhile, the number of people dying each year from tuberculosis declined by more than half from 53 per 100,000 in 1990 to 25 per 100,000 in 2014 (Central Bureau of Statistics and UNICEF 2016). Tuberculosis is concentrated in eastern Sudan (Central Bureau of Statistics and UNICEF 2016).

1.9 EDUCATION AND ENVIRONMENT

While the provision of education services generally falls short of demand, particularly in rural areas, Sudan has made significant progress in this sector. New schools have been built across the country, especially for girls, and as a result there is now gender equality in basic education (see Section 1.9). Girls have also surpassed boys in secondary and tertiary education (UNICEF 2017).

Unfortunately this success has not been emulated in the area of environmental education. The importance of environmental education came into sharp focus after the drought and famine in Kordofan and Darfur in western Sudan between 1983 and 1985. The link between desertification and environmental degradation became obvious, and it was clear that the success of any rehabilitation measures or conservation programmes would depend on raising environmental awareness among citizens and decision-makers.

Recognizing the need to improve environmental education in Sudan, the Institute of Environmental Studies at the University of Khartoum held a two-week workshop in 1983 titled "Planning for Environmental Education in the Sudan". Among other things, the workshop emphasised that the first step in implementing any programme on environmental education was to train teachers (Institute of Environmental Studies 1983).

The following year, the Institute of Environmental Studies launched a teacher-training programme in environmental education. It emphasised that a successful programme of environmental education in Sudan would require the necessary institutional arrangements, the development of instructional materials and proper facilities, and the training of teachers at elementary and secondary levels.

After a series of workshops, a collaborative project was begun in 1987 called Hope in the Desert. Its objective was to bring environmental education into the existing school curriculum. Despite these efforts, environmental education is still not part of the formal system except at the basic education level.

1.10 GENDER AND ENVIRONMENT

Article 32 of Sudan's Interim National Constitution of 2005 declares that "women and men have equal entitlements to all civic, political, economic, social and cultural rights". It also states that "the state shall emancipate women from injustice, promote gender equality and encourage the role in family and public life" (Government of Sudan 2005).

The bill of rights that is included in the Interim National Constitution pays attention to the specific needs of women and calls for positive discrimination in favour of women to remove constraints impeding their development and advancement. The participation of women in decision-making at the national, state and local levels was considered a national priority by civil society organizations and women's groups.

In 2010, the government adopted a 25 per cent quota system to guarantee the participation of women in national and state parliaments. The quota was increased to 30 per cent in 2015. In 2017, the quota decreased to 28 per cent after the formation of the National Consensus Government, an outcome of President Omar al-Bashir's National Dialogue initiative (Baldo 2017). The political parties that participated in the National Dialogue were provided with a specific number of seats in the national and state parliaments and most of the parties nominated male members to represent them. Although the quota is due to increase again, women are still obstructed from holding positions of political power, and the number of women in leadership positions in other sectors is low.

Sudanese civil society has always played a critical role in advocating and supporting women's rights and gender justice. One example was the successful collaboration between the Sudanese Women's General Union and women's groups in the joint campaign to repeal the Khartoum state governor's decree that prohibited women from joining certain professions. The case went to the constitutional court, which ruled that the decree represented a breach of the 1998 constitution (Government of Canada 2002). The

decree was duly cancelled. This was a step forward in ensuring equal opportunities for women and men in the workplace. However, gender equality will be hard to achieve until women are better represented in senior levels of government and policy-making institutions.

1.10.1 Situation of women in Sudan

One of the success stories of the campaign for women's empowerment is the adoption of the National Policy of the Empowerment of Women by the government in 2007 (Abdelghafar 2017). The policy calls for the promotion of gender equality and encourages employers and policy-makers to recognize the following:

- ➔ Women have a major role to play in building and sustaining peace in areas of conflict.
- ➔ Macroeconomic policies should be based on fairness and equality and should account for the fact that it can be hard for women to obtain assets and credit.
- ➔ With unemployment and poverty on the increase, it is important to increase opportunities for women to obtain technology and learn new skills.

Since then, government ministries, women's groups and NGOs have developed other plans to empower women and promote gender justice in different fields. These include National Action Plan for the United Nations Security Council Resolution (UNSCR) 1325, Gender Based Violence (GBV) National Strategy, Document of Women Economic Empowerment, and Women Rights Document, which integrates women's rights into the national constitution and international conventions. All these policies are waiting to be endorsed by the Council of Ministers (Baldo 2012).

Like other countries in the Afro-Arab region, Sudan is characterized by deeply entrenched cultural norms and a misinterpretation of religion. This has led not only to gender inequalities but also to discrimination against women. Unjust socio-economic conditions and unequal power relations means Sudanese women have limited access to economic resources and assets and are prevented from participating in politics and decision-making. While Sudan's constitution gives women equal rights with men, this has not yet had a significant impact on the status and situation of women because it has not been reflected in the country's laws and policies.

1 Socio-Economic Status and Environment



Working women in urban and rural areas. Photo credit © UNEP

One area of public life where women have been deeply engaged, albeit with little official recognition, is in promoting peace and security at national and community levels. For example, women were involved in the talks before and during the signing of the Comprehensive Peace Agreement in 2005 to end the longest war in Africa, though they were not formally included in the negotiation and mediation delegations (Baldo 2012).

1.10.1.1 Women in decision-making

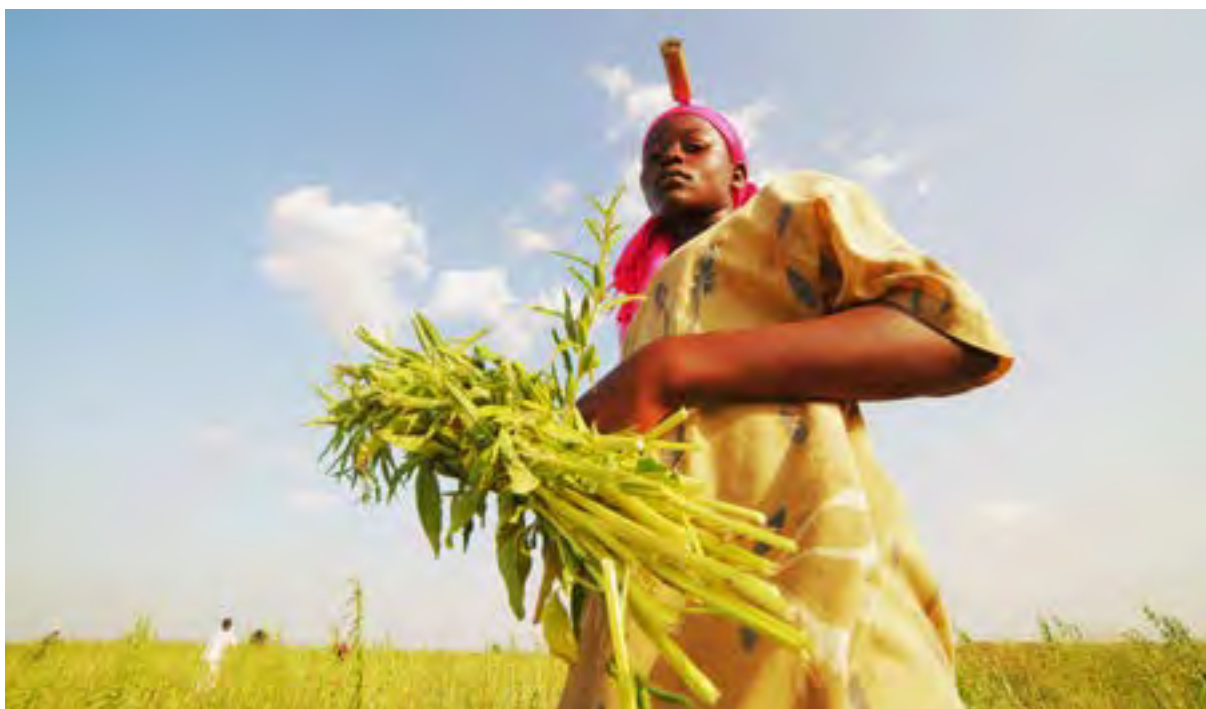
Sudanese women bear an unequal share of the hardships caused by poverty, conflict and the socio-cultural traditions that promote strict male hierarchy and authority. This is exacerbated by religious and cultural limitations on the role and status of women in society. As a result, gender inequality is deeply rooted. Sudanese women are either excluded from formal decision-making and asset ownership or they are forced to act through a patriarchal filter. Despite this, Sudanese women have demonstrated great resilience in their fight to achieve gender justice and equal opportunities through advocacy, law reform and public awareness, as well as providing for their families during the conflicts in Darfur, South Kordofan and Blue Nile. They are active as effective peace-making mediators at local levels and within civil society organizations (CSOs) (Baldo 2012).

The lobbying efforts of Sudanese women have ensured that they occupy 28 per cent of the Sudan National Parliament, though this is below the 30 per cent target. 134 of the 450 members of the National Assembly are women; out of these, 130 were elected and 4 were appointed as a result of the National Dialogue. Women are also represented at the state level (Baldo 2012).

1.10.1.2 Women's economic rights

Women's political participation and economic empowerment have emerged as two key areas for advancing gender equality and female empowerment in Sudan. More needs to be done to improve women's participation in the economy and allow them to engage in profitable income-generating activities.

The conflict in Sudan has had an especially negative impact on women. Since the majority of Sudanese women have limited education or marketable skills, they are unable to obtain good jobs in the formal economy and are obliged to take lowly paid, menial jobs or to work in the informal sector. Women do not earn enough in these jobs to allow them to be economically independent and therefore find themselves dependent on men and their families. Women who have had to flee their homes face additional challenges, having lost their assets and livelihoods.



Farmer woman in Showak town on the Atbarah River in eastern Gedaref State. Photo credit © UNEP



Girls in mixed basic education school in Darfur State. Photo credit © UNAMID

1.10.1.3 Women's education and employment

Although by law women have equal access to education and employment, in many parts of Sudan the reality is very different. Social norms discourage families from sending their daughters to school, while child marriage is still common in many states. Furthermore, most villages only have primary schools for girls, and families do not approve of sending girls away to finish their education. Consequently, because of their lack of formal education, women are excluded from taking roles in traditional decision-making systems. Efforts have been made to ensure that women can participate in institutions such as local councils and unions.

Despite these obstacles, women occupy positions in all sectors of society, including the legal, medical and governmental fields, while the majority are engaged in teaching and nursing. A considerable number work in the banking system and occupy positions in the army and police that were traditionally dominated by men. There are also women judges and lawyers. Many women are engaged in humanitarian and community support organizations that provide assistance to war-affected populations.

1.10.1.4 Women and environment

Sudan faces numerous challenges in the management of its natural resources. These include the impact of

climate change, the increased frequency and severity of droughts and floods, a growing population, changing livelihoods and expectations, and rapid urbanization. The pressure on natural resources is one of the main causes of conflict in the Darfur region (Mohammed et al. 2017). Climate change and prolonged conflict exert almost the same impacts on the environment. Both affect natural resources, either degrading or depleting them, and this in turn affects people's livelihoods and their ability to survive (UNEP 2007).

In conflict areas, many women have become heads of their households, and so their roles have expanded. In Darfur, for example, women constitute 80-90 per cent of the agricultural labour force and recently have joined the workforce building towns such as Nyala and El Fasher. In fact, the number of economic activities of women in Darfur are out-numbering those of women in the whole of Sudan (Baldo 2012).

Sudanese women have a major role to play in preventing environmental degradation, developing early warning systems and ensuring food security for their communities. It is essential that they receive support in these endeavours. In rural areas, women are farmers, livestock herders and collectors of water and firewood, in addition to performing their domestic household activities. In the internally displaced persons' camps in Darfur, women have become house-builders and have been learning new jobs suitable to urban settings (Baldo 2012). They are

also involved in petty trading, particularly in food items such as vegetables, and have been able to sustain their families through this.

The future of Sudan depends on enabling women to engage more effectively in peace processes around natural resources and the environment. Gender equality and sustainability are directly linked: countries that ratify international environmental treaties usually have more women in their parliaments, and air pollution and other environmental degradation are generally worse when gender inequality is high (Baldo 2012).

1.10.1.5 Strategies and policies for female empowerment

Regarding policies and strategies to promote gender equality and women's empowerment, there has been both progress and regression in Sudan. For example, the government is trying to promote the National Policy of the Empowerment of Women, officially endorsed by the President in 2007 (Baldo 2012). According to employment laws, women and men have equal opportunities for employment, with equal pay for equal work. Women have the right to pass their nationality to their children, and are offered special protection under the law during armed conflict (Baldo 2012).

1.11 INTERNATIONAL MIGRATION

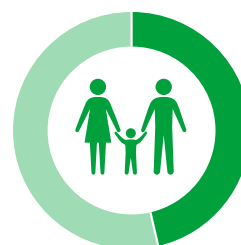
Civil strife, drought, flooding and other natural hazards have caused mass internal migration in Sudan on several occasions. Recently, the country has become a temporary home to many international migrants hoping to find their way to Europe and other destinations in the west. Most of them stay in big cities such as Khartoum, scraping together a living through meagre jobs. The number of international migrants and their impact on Sudan's natural and social environments are unknown.

1.12 POVERTY AND ENVIRONMENT NEXUS

In Sudan, poverty and the environment are inextricably linked. Poverty is driven not only by ill-conceived economic policies, but also by natural disasters, the misuse of environmental resources and conflict. Human deprivation and environmental degradation are mutually reinforcing, since poor people are forced to generate income by exploiting natural resources.

During the last two decades, Sudan has experienced several episodes of drought, which has resulted in many people losing their livelihoods. Millions of people in rural areas have been forced to move elsewhere, to places that are hardly equipped to absorb large numbers of migrants. Estimates by the United Nations and other international organizations showed that at the end of 2018 there were 1,864,200 internally displaced persons in Sudan, 88 per cent of them in Darfur (UNHCR 2018). Some rural people move to cities without the skills or training to compete in the urban labour market, and live in hastily constructed shanty towns that bring their own environmental and social problems.

46.5 per cent of the Sudanese population live below the poverty line, though this varies from state to state – the rate is lowest in Khartoum (26.0 per cent) and highest in North Darfur (69.4 per cent), and is higher in rural areas (57.6 per cent) than in urban areas (26.5 per cent) (United Nations 2014). The government of Sudan is implementing a number of social policies for poverty reduction. These include cash transfers to poor families, social protection networks, micro-financing for small-scale enterprises, and the provision of low-cost housing and health security. In its 2015–2019 programme for economic reform, the government aimed to reduce poverty to below 35 per cent by 2019, but this has not been achieved.



46.5%
of the Sudanese
population live below
the poverty line

1.13 HUMAN SETTLEMENTS AND ENVIRONMENT

The two dominant demographic trends in Sudan are rapid population growth (estimated at 2.4 per cent per year) and urbanization (MFEP 2016). Urbanization is itself fuelled by population growth and a range of compounding factors, including:

- ➔ Drought and desertification reducing the quality of rural livelihoods;
- ➔ Mechanized agricultural schemes disrupting traditional farming communities;
- ➔ Conflict-related insecurity forcing people to leave rural areas;
- ➔ Rural poverty driving people to search for better livelihoods in cities.

Decent quality data for population urban growth is only available for Khartoum city, which grew by over 5 per cent per year from 1973 to 1993 (UNEP 2007). Studies published from 1993 to 2006 indicate that this growth rate has not declined (UNEP 2007). It is likely to continue, given the city's economic boom and the flow of internal migrants fleeing the Darfur crisis and the environmental problems of the north.

Khartoum's rapid expansion has not been adequately managed or controlled by regional or local authorities, resulting in chaotic urban sprawls and slums, with all their associated health, environmental and social problems. This issue is not confined to the capital: informal settlements or slums are found on the outskirts of virtually every town in Sudan.

1.14 URBANIZATION AND ENVIRONMENT

The population of Greater Khartoum – which is made up of three towns, Khartoum, Omdurman and Khartoum North – grew from 240,000 people in 1955-1956 to about 7 million in 2018, and is still increasing. 43 per cent of the country's urban population is in Khartoum state (Ministry of Environment, Forestry and Urban Development 2014). Most of the rest of Sudan's urban population is in the central regions of Gezira, Sennar and Blue Nile. Many people are driven to cities from rural areas by drought, famine and conflict, or drawn by the better infrastructure and services. Camps for internally displaced persons that are close to urban centres, such as those outside El Fasher and Nyala in Darfur, have grown so much that they have become part of the towns.

Urbanization and industrialization bring diverse environmental problems. These are mainly caused by two factors: inadequate urban planning, and the lack of safety regulations for businesses and industries, which leads to pollution and environmental degradation. Urban evils such as over-population, congestion, unemployment, shortage of services, crime and juvenile delinquency are turning some urban areas into centres of squalor. Many urban areas are as deprived of services such as proper roads, electricity and safe drinking water as the poorest rural areas.

1.15 FUELWOOD AND CHARCOAL FOR DOMESTIC USE

The cutting of trees for fuelwood and for charcoal production happens throughout Sudan, but the impact is more damaging in the north where resources are limited. Most forested areas around urban centres are under intense pressure. As with many natural resource issues in Sudan, the data on wood consumption is incomplete and often out of date. But what is available gives a clear picture of substantial and growing demand for fuelwood. Biomass supplies 56 per cent of energy demand in Sudan; a third of it is from fuelwood (Rabah et al. 2016). Projections for fuelwood consumption in 2020 range from 15.5 million cubic metres (Gafaar 2011) to 25.7 million cubic metres, rising to almost 30 million cubic metres in 2030 (FAO 2010).

1.16 AGRICULTURE AND ENVIRONMENT

Agriculture is the main driver of the national economy, employing 49 per cent of the labour force (FAO 2018) and accounts for 32 per cent of the country's economic output (African Development Bank 2020). About 80 per cent of the working population is engaged in crop and animal production, including the informal economy. As a result, the majority of people in the country are directly dependent on natural resources for their livelihood and employment. An area of nearly 292 million feddans (122.6 million hectares), constituting half of Sudan's land area, is classified as suitable for agriculture. Rain-fed agriculture accounts for 29.5 million feddans (12.4 million hectares), representing 96.1 per cent of the total area under cereals (Ministry of Agriculture and Forests 2018). The land under irrigation, where various crops are grown, covers approximately 8.3 million feddans (3.5 million hectares). The main crops include sorghum, millet, wheat, cotton, ground nuts, sesame, sugar cane and vegetables such as potato, onion, okra and tomato. Semi mechanized rainfed agriculture is practiced in a broad belt of 15.0 million feddan (6.7 million hectares) which runs through Kassala, Gedaref, Blue Nile, Sennar, White Nile and South Kordofan states (FAO 2019b). This belt is effectively the granary of the country, with sorghum accounting for about 80 percent of the cultivated land. Other crops include sesame, sunflowers, millet and cotton.

1 Socio-Economic Status and Environment



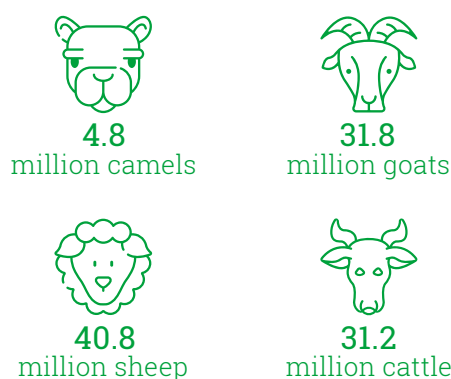
Biomass supplies 56 per cent of energy demand in Sudan. Photo credit © UNEP

Sudan's agricultural sector policies cover poverty alleviation, food security, land tenure, improving nutritional status, raising productivity and supporting other sector policies (FAO 2012). Technology use is limited. In mechanized farming, the use of tractors for tillage, harvesting and the spraying of pesticides is widespread. The mechanization of farming in Sudan has had a significant impact on the environment, leading to forest clearance, soil erosion and land degradation.

1.17 LIVESTOCK AND ENVIRONMENT

Much of Sudan's land area is more suited to livestock grazing than to the cultivation of crops. The country's livestock population was estimated at over 130 million head prior to 2011. This includes cattle, sheep, goats and camels, which are kept under both nomadic and sedentary traditional pastoral systems (UNEP 2012; UNEP 2013). Estimates for 2018 showed that Sudan's livestock population is 108.6 million, made up of 4.872 million camels, 31.837 million goats, 40.846 million sheep and 31.223 million cattle (FAO 2018). Livestock accounts for half of agricultural GDP and 25 per cent of total GDP (IGAD Center for Pastoral Areas & Livestock Development 2013).

Livestock population in 2018



1.18 FISHERIES AND ENVIRONMENT

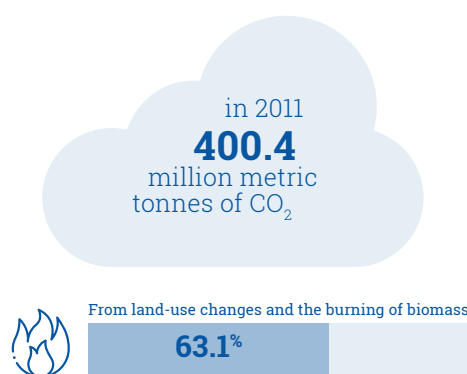
Sudan has a wide range of freshwater and marine fish, particularly in the River Nile system and the Red Sea. 450 bony fish species have been identified in the Red Sea; 250 of these species are found on the Sudanese coast, and about 93 fish species have been identified from commercial fish catch in Sudan. Of these, approximately 65 are considered of economic importance (UNIDO 2017).

Both the Red Sea and the River Nile provide good fishing sites for local fishers, mostly men, though commercial fishing is limited to the Red Sea. The total potential catch from Sudan's fisheries has been estimated at 74,550 tonnes per year. The potential output from capture fisheries (industrial and small-scale) is estimated at 34,000 tonnes per year: 29,000 tonnes from inland water catches and 5,600 tonnes from marine. The aquaculture sector is still developing and annual production is estimated at 2,000 tonnes (UNIDO 2017).

1.19 INDUSTRY AND ENVIRONMENT

Sudan's industry is responsible for only a small proportion of the country's GDP, less than 3 per cent in 2018 (Central Intelligence Agency 2020). It consists of four sectors: manufacturing, which contributes 56 per cent of industry's share of GDP; construction (30 per cent); electricity and petroleum (15 per cent); and mining and extraction (1 per cent) (Ministry of Information 2011).

Sudan's industry is inefficient, highly dependent on imported materials and dominated by the production of consumer goods. Carbon dioxide is responsible for about 60 per cent of Sudan's greenhouse gas emissions. Sudan's total greenhouse gas emissions in 2011 were 400.4 million metric tonnes of carbon dioxide equivalent, which represents 0.85 per cent of global greenhouse gas emissions. 63.1 per cent of these emissions came from land-use changes and the burning of biomass (USAID 2017).





Despite the loss of 75 per cent of oil reserves in 2011 due to the secession of South Sudan, oil is still an important resource in Sudan. Photo credit © UNEP

basin, oil production decreased. Sudan has significant gas reserves, but is currently only producing a small amount as a by-product of oil production in central Sudan (Siddig 2012).

Apart from petroleum products, the country does not produce any chemicals, though it imports chemical fertilizers and pesticides. Pollution caused by the disposal of industrial waste receives little official and public attention. Most of the industrial facilities dispose of their wastes without any treatment.

1.20 MINING AND ENVIRONMENT

Following the loss of most of its oil reserves with the secession of South Sudan, gold production is now Sudan's main source of hard currency. The Central Bank of Sudan placed restrictions on hard currency, which now impede the development of the mining industry and also encourage traditional miners to smuggle their gold to neighbouring countries (Sudan Tribune 2019). Gold mining, both artisanal and industrial, is having serious negative impacts on the environment and human health in Sudan (Ibrahim 2015).

1.21 TOURISM AND ENVIRONMENT

Thanks to Sudan's diverse ecosystems, the country is home to several world-class natural attractions. These could help the growth of the tourism industry and appeal to tourists in search of culture, adventure, wildlife and scuba diving opportunities. The country's touristic attractions are based on its unique cultural and natural resources. In terms of culture, the country is well endowed with temples, monuments and tombs dating back to the time of ancient Egypt. In fact, Sudan hosts a collection of pyramids that greatly outnumbers those found in Egypt (World Bank 2014).

Tourism in Sudan dates back to pre-independence days. Foreign visitors started coming to Sudan as early as the 19th century, mainly to hunt big game and to explore. The first tourism office opened in 1939 and later developed into the Tourism and Hotels Corporation in the 1970s. The first tourism legislation was the Tourism and Hotels Corporation Act of 1977 (Government of Sudan 1981).

Sudan has the opportunity to become an important global tourism destination. It has the foundation for a productive and dynamic tourism sector that can make significant contributions to economic growth, employment generation, cultural and environmental preservation and social inclusion (World Bank 2014).



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

1.22 ENVIRONMENTAL POLICIES AND DEVELOPMENT

After independence, Sudan made the great mistake of adopting the western model of “development”. The country chose capital-intensive, large-scale agricultural schemes, with the primary objective of exporting raw materials. The aim was to “catch up” economically with the rest of the world, when what the country really needed was an alternative, more traditional mode of development. The western-style, centrally planned approach to development had many negative impacts. For example, traditional agricultural techniques were sidelined, and there was no consideration for the environment or the preservation of natural resources.

Large projects such as the anti-thirst campaign of the 1960s, the expansion of rain-fed and irrigated agriculture, building dams on the Nile and other rivers, and so on, resulted in much environmental degradation.

Concern about natural resources was not a feature of government policy until the 1977-83 Six Years Plan, which called for soil conservation, reforestation and the protection of resources (Bayoumi 1996). Over the next two decades, there were several attempts to make environmental protection a central part of government strategy. Many delegates to the National Economic Conference in 1986 expressed deep concerns with ecology and the environment. Sound environmental management and poverty alleviation ranked high in the Salvation Recovery

and Development Programme of 1988–1992 (Bayoumi 1996). The National Comprehensive Strategy of 1992–2002 focused on poverty alleviation and sustainable development and encouraged the participation of local communities and indigenous knowledge.

However, the National Comprehensive Strategy ended up being of limited effectiveness because of institutional, financial and structural problems, conflicts between federal and state governments, and the low level of public awareness over the environment (Mohamed 2001). The previous regime devised a number of strategies to reduce poverty and protect water resources and other natural assets, but few of them were carried out. Like so many plans in Sudan's post-independence history, they were scuppered by civil strife, top-down planning, a lack of local participation and a dearth of political will.

More recently, Sudan and other less developed nations have received some help in their development strategies from the international community. In 1996, the World Bank and the International Monetary Fund launched an initiative aimed at reducing the amount of debt owed by the Least Developed Countries (Nwonwu 2008). At that time, Sudan was classified as one of the 10 to 15 least developed countries. The initiative led to what was known as the "Environmental Debt Swap", which allowed countries to write off a portion of their debts in exchange for a commitment to protect the environment (Nwonwu 2008).

In 1999, the World Bank and the International Monetary Fund introduced another initiative, this time linking debt reduction with the alleviation of poverty. It required countries to complete Poverty Reduction Strategy Papers detailing their plans to reduce poverty. Once approved, a country would qualify for debt relief and aid. This initiative was widely welcomed as the first serious attempt by the international community to put poverty reduction at the centre of development planning and finance, and for encouraging countries to take responsibility for their own development strategies. Civil society organisations have been involved in drawing up and implementing the plans, another welcome innovation. Sudan produced its Interim Poverty Reduction Strategy Paper in 2012, a step towards completing its full Poverty Reduction Strategy Paper (Ministry of Finance and Economic Planning 2011).

1.23 MAINSTREAMING ENVIRONMENT INTO DEVELOPMENT

Sustainable economic growth is not feasible without sound environmental management. Accurate studies are needed to assess the extent of environmental degradation in Sudan and the loss of its natural resources. Investing in environmental management will boost the country's

economic development, which depends greatly on its natural resources. Proper management is needed, for example, to stem the loss of nutrients from soil, regulate the disposal of hazardous waste by industry, and ensure the conservation of precious ecological resources.

1.24 CHALLENGES

Environmental degradation not only has a negative impact on livelihoods, it can also threaten stability and development. The peaceful co-existence of tribes or other social groups depends on the sustainable use of shared natural resources. However, rural communities consider access to land and its resources as a right and privilege, and so land issues in Sudan are never properly addressed. As the United Nations Development Programme's 2013 paper "Land Issues and Peace in Sudan" points out, the "elimination of conflicts and sustainability of social peace in Sudan requires land tenure reform, sustainability of natural resources, elimination of poverty, good governance and respects of human rights".

1.25 CONCLUSION

Society and the environment in which people live are shaped by national and international driving forces that include population growth, economic development and technology, as well as natural phenomena such as changing climate. Such forces impact the provision of basic human needs, quality of life, equal opportunities between social groups and the judicious use of natural resources. These forces are behind the current state of the environment in Sudan.

Sudan has undergone several major developments in recent times, including rapid population growth, a big increase in the number of young people of working age, and dramatic urbanization. The most profound change has been the secession of South Sudan, which resulted in a significant reduction in land resources and the loss of oil revenues. Sudan has struggled to maintain peace and security internally, especially in the Darfur region. Furthermore, its policies for economic growth have been constrained by high poverty levels and misplaced resources.

Despite these challenges, the country has made economic progress, particularly in telecommunications, transport, power generation and in constructing dams for irrigation. However, its future prosperity will depend very much on how it manages its natural resources and controls environmental degradation. The role of the environment in shaping people's livelihoods is often overlooked. Sudan, which is acutely dependent on its natural resources, cannot afford to do that.

References

REFERENCES

1. Abbaker, E.A.B. (2017). Sudan experience in the Measurement of Disability. Retrieved from: <https://unstats.un.org/unsd/demographic-social/meetings/2017/oman--disability-measurement-and-statistics/Session%206/Sudan.pdf>
2. Abdelghafar, L. (2017). Sudan National Council for Population and Development, Ministry of Welfare and Social Security. Presentation at the 5th Session of the Commission on Population and Development, New York.
3. Abdel Magid, T. D. and Warrag, E. I. (2011). The Present and Future Impact of Agro forestry Systems in Sudan. *The Eco- forum Sudanese Environment Conservation Society*, Khartoum, Sudan.
- 4.. African Development Bank Group (2017). Sudan: Country Brief 2017-2019. Retrieved from: https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/SUDAN_-_Country_Brief_2017-2019.pdf
5. African Development Bank (2020). Sudan Economic 2020 Outlook. Retrieved from: <https://www.afdb.org/en/countries/east-africa/sudan/sudan-economic-outlook>
6. Ateem, E. S. M. (2007). Conflict prevention and development cooperation in Africa: A policy workshop. Country Case Study: *The root causes of conflicts in Sudan and the making of the Darfur tragedy*. UNDP, Wilton Park and JICA. Retrieved from http://www.operationspaix.net/DATA/DOCUMENT/5425~v~The_root_causes_of_conflicts_in_Sudan_and_the_makink_of_the_Darfur_tragedy.pdf
7. Baldo, R. (2017). Women's political participation. A workshop paper presented by the author as an internal document for UN Women.
8. Bayoumi, A.M.S. (1996). Sudan National Report on Forestry Policy. In *Forestry Policies of Selected Countries in Africa*. FAO Forestry paper 132, pp, 465-482.
9. Central Bureau of Statistics (CBS). (2018). Government of Sudan. Annual reports. Retrieved from: <http://www.cbs.gov.sd>
10. 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=W1siZiIsIjIwMTYvMDUvMTgvMjEvNT-kvNTEvODg3L1N1ZGFuXzlwMTRfTUIDU19Fbmd-saXNoLnBkZiJdXQ&sha=32907fc39e6e2e6e>
11. Central Intelligence Agency (2020). Sudan Economy 2020. World Factbook. Retrieved from: https://theodora.com/wfbcurrent/sudan/sudan_economy.html
12. Craig, G. M. (1991). *The Agriculture of the Sudan*. Oxford University Press. Retrieved from: <https://www.cambridge.org/core/journals/journal-of-agricultural-science/article/agriculture-of-the-sudan-ed-g-m-craig-xiii-468-pp-oxford-oxford-university-press-1991>
13. Food and Agriculture Organization (2010). Global Forest Resources Assessment 2010, Country Report, Sudan. FRA2010/198. FAO, Rome. Retrieved from: <http://www.fao.org/3/al633E/al633E.pdf>
14. Food and Agriculture Organization (2012). Land Cover Atlas of Sudan. Retrieved from: <http://www.fao.org/3/a-be896e.pdf>
15. Food and Agriculture Organization (2015). Country Programming Framework for Sudan. PLAN OF ACTION (2015-2019): Resilient Livelihoods for Sustainable Agriculture, Food Security and Nutrition. FAO representation in Sudan. Retrieved from: <http://www.fao.org/3/a-i4785e.pdf>
16. Food and Agriculture Organization (2018a). FAO Country Profiles: Sudan. Retrieved from: <http://www.fao.org/countryprofiles/index/en/?iso3=SDN>
17. Food and Agriculture Organization (2018b). FAO Food and Agriculture data. Country Profiles: Sudan. Retrieved from: <http://www.fao.org/faostat/en/#data>
18. Food and Agriculture Organization (2019a). Fishery and Aquaculture Country Profiles. The Republic of the Sudan. Retrieved from: <http://www.fao.org/fishery/facp/SDN/en#CountrySector-Statistics>
19. Food and Agriculture Organization. (2019b). FAO Crop and Food Supply Assessment Mission to the Sudan – Special Report. Retrived from: <http://www.fao.org/3/ca3660EN/ca3660en.pdf>

20. Gafaar, A. (2011). Forests Plantations and Woodlots in Sudan. *African Forests Forum Working Paper Series*, 1, (15), pp 74. Retrieved from <https://www.sifi.se/wp-content/uploads/2012/02/Forest-plantations-and-woodlots-in-Sudan.pdf>
21. Government of Canada: Immigration and Refugee Board of Canada (2002). Sudan: The Sudanese Women's Union (SWU) including activities, roles, organization and problems faced in Sudan, 8 February 2002, SDN 38394.E. Retrieved from: <https://www.refworld.org/docid/3df4bea84.html>
22. Government of Sudan (1981). Laws of the Sudan. Vol (10). 1976-1977. Retrieved from: <https://www.ilo.org/dyn/natlex/docs/MONO-GRAPH/108048/133328/F895087253/SND108048%20Eng.pdf>
23. Government of Sudan (GoS). (2005). The Sudan Interim Constitution (2005).
24. Higher Council for Environment and Natural Resources (2019). Sudan Environmental Outlook Report. The Higher Council for Environment and Natural Resources.
25. Humanitarian Policy Group (HPG) (2011). City limits: urbanization and vulnerability in Sudan – Synthesis report. Retrieved from: <https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/6518.pdf>
26. Ibrahim, M.S. (2015). *Artisanal Mining in Sudan – Opportunities, Challenges and Impacts*. Presented at the 17th Africa OILGASMINE Conference, Khartoum, Sudan. Retrieved from: <https://unctad.org/meetings/en/Presentation/17OILGASMINE%20Mohamed%20Sulaiman%20Ibrahim%20S4.pdf>
27. IGAD Center for Pastoral Areas & Livestock Development (ICPALD). (2013). The Contribution of Livestock to the Sudan Economy. Policy Brief Series IGAD Center for Pastoral Areas & Livestock Development. Retrieved from: https://igad.int/attachments/714_The%20Contribution%20of%20Livestock%20to%20the%20Sudan%20Economy.pdf
28. Institute of Environmental Studies (1983). Planning for Environmental Education in Sudan. (Unpublished report).
29. International Fund for Agricultural Development (IFAD) (2013). Republic of the Sudan: Country Strategic Opportunities Programme. Retrieved from: https://www.ifad.org/documents/38711624/40235553/sudan_cosop2013.pdf/f946886d-b51f-43f9-a4b5-a90ec59a2f12
30. Mahgoub, F. (2014). Current Status of Agriculture and Future Challenges in Sudan. Current African Issues 57. Nordic Africa Institute. Retrieved from: <http://nai.diva-portal.org/smash/get/diva2:712485/FULLTEXT01.pdf>
31. Ministry of Environment, Forestry and Urban Development and United Nations Human Settlements Program (UN-HABITAT). (2014). Sudan's report for United Nations' Third Conference on Housing and Sustainable Urban Development (Habitat III), 2016. Retrieved from: <http://habitat3.org/wp-content/uploads/Sudan-National-Report.pdf>
32. Ministry of Environment, Forestry and Physical Development (2013). Second National Communication to the United Nations Framework Convention on Climate Change. Higher Council of Environment and natural Resources. Retrieved from: <https://unfccc.int/resource/docs/natc/sudnc2.pdf>
33. Ministry of Environment and Physical Development (2001). Environment Protection Act 2001. Higher Council of Environment and Natural Resources.
34. Ministry of Finance and Economic Planning (MFEP) and World Bank (2011). The Sudan Interim Poverty Reduction Strategy Paper Status Report – A Joint World Bank Group and Sudan's Ministry of Finance and Economic Planning Assessment. Retrieved from: <http://documents.worldbank.org/curated/en/980991479985933855/pdf/110503-WP-SudanFlipbookEnglish-PUBLIC.pdf>
35. Ministry of Finance and Economic Planning (MFEP) (2016). The Economic Exhibition. For 2016 (in Arabic).
36. Ministry of Information (2011). Sudan: The Land of Opportunities: Facts and Figures: Khartoum. pp. 51.
37. Mohamed, Y.A. (2001). Sudan policy and institutional changes for the implementation of Agenda 21. In H. Abdel Atti (Ed.) *Sustainable development in Sudan: Ten years after Rio. A civil society perspective*. Proceedings of the National Civil Society Preparatory Conference.
38. Mohamed, N. A. H, Fadul, H.M. and Zaki El Deen, S. (2014). Rainfall changes in central Sudan between 1960-2010. *International Journal of Geosciences and Geomatics*, 2 (1) 61–67. Retrieved from: <https://www.researchgate.net/publication/299629717>

39. Mohammed, A., Zhang, K., Kabenge, M., and Keesstra, S. (2017). Analysis of drought and vulnerability in the North Darfur Region of Sudan. *Land Degradation and Development*, 29 (12), 4424–4438. Retrieved from: http://catalogue.unccd.int/322_Article_Mohammed_et_al-2018-Land_Degradation_&_Development.pdf
40. Nwonwu, F. (2008). Eradicate Extreme Poverty and Hunger. In F. Nwonwu (Ed.) *The Millennium Development Goals: Achievements and prospects of meeting the targets in Africa*. (pp 9–36). Publisher: Africa Institute of South Africa. Retrieved from: <http://www.africanbookscollective.com/books/millennium-development-goals>
41. 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://hindawi.com/journals/jen/2016/5082678.pdf>
42. Republic of Sudan (2020). Assorted Amendments Act "The Amalgamation of Environmental Councils" The Republic of Sudan Gazette, Issue No. 1901. 30/4/ 2020 Ministry of Justice.
43. Siddig, Khalid H.A., 2012. Oil and Agriculture in the Post-Separation Sudan, Agricultural Economics Working Paper Series 122341, Department of Agricultural Economics. University of Khartoum
44. Statista. (2020). Sudan inflation rate from 1984 to 2021. Published by H. P;lecher. Retrieved from: <https://www.statista.com/statistics/727148/inflation-rate-in-sudan>
45. Sudan Tribune. (2019). Sudan produces 93 tons of gold in 2018: ministry. Retrieved from: <https://www.sudantribune.com/spip.php?article67083>
46. Tahir, G. A. (2013). Update on Macroeconomic Developments in Sudan. United Nations Development Programme.
47. Tubiana, J., Tanner, V. and Abdul-Jalil, M. A. (2012). Traditional authorities' Peacemaking Role in Darfur. United States Institute of Peace. Peaceworks, 83, pp104. Retrieved from: <https://www.usip.org/publications/2012/11/traditional-authorities-peacemaking-role-darfur>
48. United Nations (2014). The Millennium Development Goals Report. Retrieved from: <http://mdgs.un.org/unsd/mdg/Resources/Static/Products/Progress2014/English2014.pdf>
49. United Nations Environment Programme (UNEP) (2007). Sudan: Post-Conflict Environmental Assessment. Retrieved from: https://postconflict.unep.ch/publications/UNEP_Sudan.pdf
50. United Nations Educational, Scientific and Cultural Organization (UNESCO) (2020). International Mother Language Day 2019 in the Khartoum / Omdurman / Bahri Metropolis. Retrieved from: <https://en.unesco.org/news/international-mother-language-day-2019-khartoum-omdurman-bahri-metropolis>
51. United States Agency for International Development (USAID) (2017). Greenhouse Gas Emissions Factsheet: Sudan. Retrieved from: https://www.climate-links.org/sites/default/files/asset/document/2017_USAID_GHG%20Emissions%20Factsheet_Sudan.pdf
52. United Nations Industrial Development Organization (UNIDO). (2017). Republic of Sudan. Building industrial capacities for the sustainable management of the marine fishery in the Red Sea State. Independent Mid-Term Evaluation. Retrieved from: https://www.unido.org/sites/default/files/2017-03/MTE_Sudan_Marine_fishery_Red_Sea_State_130130_2016_0.pdf
53. United Nations High Commissioner for Refugees (UNHCR) (2018). Global Trends. Forced Displacement in 2018. Retrieved from <https://www.unhcr.org/statistics/unhcrstats/5d08d7ee7/unhcr-global-trends-2018.html>
54. United Nations High Commissioner for Refugees (UNHCR) (2019). Sudan- Factsheet. Retrieved from: <http://reporting.unhcr.org/sites/default/files/UNHCR%20Sudan%20Fact%20Sheet%20-%20August%202019.pdf>
55. World Atlas (2017). Highest Mountains in Sudan. Retrieved from: <https://www.worldatlas.com/articles/highest-mountains-in-sudan.html>
56. World Bank (2014). Republic of the Sudan Diagnostic Trade Integration Study – Update. Reducing Trade Costs to Increase Competitiveness and Resilience. Retrieved from: <http://documents.worldbank.org/curated/en/260641468188681749/pdf/97404-Replace-ment.pdf>
57. World Bank (2019). Sudan Domestic Product. Retrieved from: <https://data.worldbank.org/country/sudanAccessed>



2

Environmental Governance

2.1 INTRODUCTION

Sudan is a federal country as established by the 4th constitutional decree of 1991 (El Harizi et al. 2007) and later by the Interim National Constitution (INC) of the Republic of Sudan of 2005 endorsed after the signing of the peace accord between the government of Sudan and the Sudan People's Liberation Movement. The Interim National Constitution specified four levels of governance: the federal/national level, the South Sudan level, the state level and the locality level. With the secession of South Sudan in 2011, only the national, state and locality levels remain (Table 2.1). The country is divided into 18 states, each of which is further divided into several localities. The Interim National Constitution defines the relationship between the different levels of governance, as well as the limits of authority of each state and the balance of power between the states and the federal government.

Islamic Law is a major source of legislation in the country. Aspects of customary law – accepted ways of doing things – are also recognized and applied mainly by traditional administrations and tribal leaders. Most rules governing the environment and natural resources, such as those relating to fisheries, game, wildlife, forestry, rangelands and pastures, are based on statutory law (law passed by a legislative authority). Attitudes to these different types of law vary considerably. For example, while customary law is less widely recognized than statutory law, it carries more legitimacy among local communities, especially in relation to land and natural resources.

Environmental governance at both the federal and state levels is the responsibility of multiple institutions and small units that are not closely linked or integrated. The most important federal institution was the former Ministry of Environment, Natural Resources and Physical Development. This ministry was abolished in 2018 and a National Council for the Environment was established. On 30 April 2020, the Transitional Supreme Council endorsed amendments to the Environment Protection Act of 2001 whereby a new Higher Council for Environment and Natural Resources was established (Ministry of Justice 2020).

Other key institutions include the Ministries of Agriculture and Forests; Animal Resources, Fisheries and Range; Industry and Trade; Investment; Irrigation and Water Resources; and Interior as well as the Wildlife Conservation General Administration and the National Council for Research.

Environmental governance in Sudan is at a cross-roads. Many of the laws governing natural resource management and land tenure have been made irrelevant by the rapid social, economic, environmental and ecological changes in the country over the last four decades, particularly the severe drought of the mid-1980s and the tragic and devastating famine associated with it. Although the Interim National Constitution includes provisions to reform governance structures, the country's institutions continue to suffer from a lack of coordination and accountability. Furthermore, the central government has steadily been encroaching on the powers of the states,

Table 2.1 Federal and state powers over natural resources

Federal powers	State powers	Joint federal and state powers
National land and natural resources	Local government	Environmental management, conservation and protection
The management of the Nile, transboundary waters and disputes arising from the management of interstate waters and national protected ecosystems	State land and state natural resources	Regulation of land tenure, usage and exercise of land rights
	The management, lease and utilization of land belonging to the state	Water resources other than interstate waters
	Enforcement of state laws	Disaster preparedness, management of relief and epidemics control
	Laws in relation to agriculture within the state	Pastures, veterinary services and animal and livestock diseases control
	Pollution control	Urban development, planning and housing
	Traditional and customary law	

particularly in relation to land, meaning that local interests are not properly represented in decisions about sustainable development. This in turn has made it harder to manage natural resources equitably and heightened the risk of conflict.

Sudan's internal conflicts are in one way or another all related to land and natural resources. They are exacerbated by the erosion of environmental governance, weak law enforcement, poorly implemented policies and weak institutional arrangements. Good governance in Sudan is seen not only as essential to sustainable development, but also as a path to peace.

The environmental movement in Sudan began in 1975 with the establishment of the Sudanese Environment Conservation Society, the first Sudanese civil society group concerned primarily with the issue of environment (UNEP 2007a). Other groups were formed soon afterwards, including the Environmentalists Society, the Sudanese Social Forestry Society, the Engineering Society, and Al Massar Organization for Nomads and the Environment. Although some Sudanese civil society organizations have gained international and regional recognition, civil society movements are largely urban-based.

2.2 OVERARCHING POLICIES

Policy is a tool of governance, and governance is the manner in which a society exercises control over its resources. Governance can take place through the state, the market or civil society groups and local organizations, and through a variety of mechanisms such as law, social relationships, property rights and tenurial systems, norms, beliefs, customs, value systems and codes of conduct, as well as multilateral environmental agreements, international conventions and financing mechanisms. Environmental governance relates to the norms, rules and institutions that control the way government, civil society and the private sector regulate the environment (UNEP 2012).

2.2.1 Islamic Laws and the environment

Sudan partly derives its environmental laws and governance systems from the Islamic Laws and Teachings. Islamic Laws or Sharia in Sudan are mainly applied within the domain of family affairs such as marriage, divorce, theft, adultery, punishment and inheritance. The Qur'an and the Prophet's teachings, the Hadith, do not explicitly mention the word "environment" in Arabic, but they speak about the "signs" of Allah, linking the creation with divine revelation and

seeing the natural world as testimony of Allah's all-encompassing presence (Khalid 2002).

Islam is seen as promoting reverence for all forms of life, including the fair treatment of non-human species. Religious literature, especially the Hadith, contains an abundance of traditions on this theme. The emphasis in Islamic teaching is on living in harmony and in balance with creation and with Allah who is all-encompassing (Hope and Jones 2014). The Qur'an teaches that humans were given responsibility to act as stewards and custodians of creation, and therefore by extension it is the responsibility of Muslims to protect the environment from disturbance and use natural resources without causing pollution and degradation.

2.2.2 Interim National Constitution

The Interim National Constitution (INC) of 2005 was amended in 2015. Further amendments took place in 2016, 2017 and 2018. As of 17 August 2019, with the signing of the Constitutional Document, Sudan is governed under the Sudan Transitional Constitution 2019.

The INC established a National Legislature composed of the National Assembly and the Council of States. The members of the Council of States are indirectly elected by the State Legislature. The responsibilities of the National Legislature include to assume legislation in all national powers; approve plans, programmes and policies relating to the country and society; approve the annual national budget; and ratify international treaties, conventions and agreements. The function of the Council of States is to introduce and oversee legislation relevant to the states, particularly concerning the decentralized system of government. As well as passing laws, the Council of States is charged with fostering social harmony, endorsing state policies, monitoring the performance of the executive legislature and promoting good governance.

The Interim National Constitution includes guiding principles and directives stipulating that the people of Sudan have the right to a clean and diverse environment, and that both the state and the citizens must preserve and promote the country's biodiversity. The constitution also takes a strong stand against any policy or action that may adversely affect any species of animal or vegetative life or their habitat. The constitution therefore makes it the duty of the state to promote the sustainable use and management of natural resources (Government of Sudan 2005).

Table 2.2 Legal frameworks in water and natural resources sectors in the realm of regional conflict areas

State	Water	Range, Pastures and Forests	Remarks
South Kordofan	Water Corporation Law	South Kordofan Pasture Act 2014	<p>The creation of protected pastures is hampered by lack of resources, inability to fence reserved areas.</p> <p>There is departmental disagreement over control of pasture administration within different ministries.</p> <p>Sudan Peace Building and Development Project and state government successfully distributed pasture seeds and recovered vegetation cover in many areas</p>
	Land use policy, water and public health document Native administrative law	Livestock Routes document Native administration law	<p>The livestock document was implemented and recognized by different stakeholders.</p> <p>The draft water document was not approved by the public council.</p>
North Darfur	Water Corporation Law	<p>Organization of agriculture and grazing law</p> <p>Tree shelter belts, and gum arabic belt development law</p> <p>Native administration law</p>	<p>Water law is implemented.</p> <p>Pasture law is partially implemented with no by-laws in effect.</p>
South Darfur	South Darfur Water Authority of 2003	<p>Agriculture and Grazing Organization Act 2011</p> <p>Local Order No.1–9 for pasture protection in Idd El Fursan Locality</p> <p>Legislative Council Decree No. 17/2005 to reduce NRM conflict between government departments particularly the MOA and Sudan Survey Authority</p>	<p>The Act was applied in South Darfur.</p> <p>Local orders and decrees are applied and their functions determined.</p>

2 Environmental Governance

Table 2.2 continued

State	Water	Range, Pastures and Forests	Remarks
West Darfur	<p>South Darfur Water Authority of 2003</p> <p>West Darfur Water Law 2013</p> <p>Protection of Water Sources Act</p> <p>Rationalization of Water Uses Act</p>	<p>Organization of agriculture and pasture law 2014</p>	<p>The law is not strongly enforced. There is little grassroots awareness of the law. The ineffectual local government and native administration weakened the implementation of the law.</p> <p>The West Darfur water law bans the drilling of any water source without the approval of the water department. It is implemented but weakened because of political influence, with politicians intervening and making the decision to drill for water.</p> <p>In October 2015, a workshop was held in EL Geneina to explain to participants both the federal range law and state pasture and range-land laws with the aim of raising awareness of the law and improve applicability.</p>
East Darfur	<p>East Darfur State Water Corporation Act of 2013</p>	<p>Range and Pastures Law for East Darfur State 2015</p>	<p>The state water corporation controls all water stations within the state.</p> <p>The degradation of pasture and of forests continues despite the law because of lack of rangers, vehicles and means of enforcement.</p>
Central Darfur	<p>Water Corporation Act 2013</p>	<p>Organization of Agriculture and Pasture Law in West Darfur 2009</p> <p>The state is two years old established in 2016 and is located in the midst of Darfur conflict as well as suffering tribal conflicts. Legislation is mostly derived from West Darfur from which most institutions and ministries were originated. There are no laws governing the demarcation of pastures, however around 100 km of grazing routes were demarcated.</p>	<p>The Water Corporation Act 2013 was passed by the State Legislature and the State Council of Ministers.</p>

Source: Partners in Development Services 2016

2.2.3 Federal and state governance

Responsibilities for environmental management in Sudan are divided between the federal and state governments. The federal government has jurisdiction over matters relating to natural resources, minerals and other underground wealth, and trans-boundary waters. Detailed regulations on land, forests, agriculture, livestock and wildlife are the responsibility of the state, but are subject to federal planning and coordination. Environmental issues at state level are dealt with under the custody of the State Ministry of Agriculture, Irrigation and Natural Resources. After the Ministry of Environment, Natural Resources and Physical Development was dissolved in 2018, environmental and natural resources administration was assigned in most states to the Ministry of Production and Economic Resources, an umbrella ministry embracing agriculture, industry, mining and investment.

The division of responsibility over natural resources between federal and state powers is laid out in the Interim National Constitution and shown in Table 2.1.

The Interim National Constitution stipulates that government institutions at all levels should not encroach on the power or function of institutions at other levels, and that they should promote cooperation and communication between all levels of government. The constitution also maintains that new legislation on the use of land must take account of customary laws and practices, local traditions and international trends.

In 2015, the Interim National Constitution was amended to allow the presidency to take decisions over land tenure issues, including the sale of land for investment (Government of Sudan 2015). This has complicated the process of devolving decisions about the management of natural resources from the federal government to the states.

2.2.4 Statutory and customary laws

There are numerous federal laws governing the way the environment is protected and natural resources used. Examples include the Land Resettlement Act (1925), the Civil Transaction Act (1984), Forests National Corporation Act (2001), Physical Planning Act (1994), National Water Act (2007) and Range and Pastures Law (2015).

At the state level, there are laws covering water, rangelands and forests. In Darfur, Blue Nile and South Kordofan states, natural resources have been at the centre of conflicts, and state laws have been helpful in managing some of the conflicts (Partners in Development Services 2016). Table 2.2 shows some of such legal frameworks in Darfur and South Kordofan.

Customary law encompasses tribal territorial rights and social customs that were established during successive indigenous kingdoms of pre-colonial Sudan and reinforced through legislative provisions during the British colonial administration. Within the tribal homelands, these rights constituted the collective security of the tribe. They recognized individual rights to use land which could be inherited, though the land would remain under the ownership of the tribe (Shazali 2006).

Under customary law, an individual's access to land was legitimized through their membership of a village or community. Among pastoralists, access to the rangelands was legitimized through membership of fluid tribal structures which controlled strategic resources, or through negotiated arrangements with village leaders.

The main feature of customary law is that it guarantees every tribal group and village resident access to resources on the principle of "No harm inflicted; no antagonism created" (*la darer wa la dirar*) (Esen 2017). In other words, you have the right to access and use land, pasture and water provided you do not cause loss or harm to life and property. Such rights are accepted because they are a democratic way to allow people access to land whether they are a tribal resident, a passer-by or a member of a migratory group. This is especially beneficial to the poorest groups, who find representation through their sheikhs or the Nazir (or Emir) of the tribe. Local government administrations are closely tied to these traditional structures, unlike state government departments which are only accessible to wealthy or urban groups.

Although customary laws are not written, they shape the life of the people. They are highly adaptive. Tribal chiefs often meet in conferences where they agree to change an existing practice if it is perceived to be harmful. One example is the abrogation of the Damage Committee System in the conference held in Abyei, South Kordofan, in March 2018, which was attended by representatives of the Dinka Ngok and Misseriya



A reconciliation conference between two tribes in Darfur initiated by a reconciliation committee composed of traditional leaders from different tribes in the area, 2014. Photo credit © Hamid Abdulsalam, UNAMID

Table 2.3 Main differences between customary and statutory laws

Customary Law	Statutory Law
Concerns the laws, principles and customs of indigenous peoples and local communities.	Created by lawmakers (parliament) and administered through attorneys and judges. It is used throughout the country as a standard.
A rule of conduct established by long usage.	Enacted by the legislature. They are almost always prospective, meaning that they deal with broad, future-looking topics.
Established pattern of behaviour that can be objectively verified within a particular social setting.	A written law set down by the legislature.
Not codified.	Codified law.

tribes. The system was replaced by the five-person Joint Community Peace Committee, a body of community leaders from the two tribes supported by the UN and NGOs working in conflict resolution. The committee is dedicated to resolving disputes over issues such as cattle raids, grazing areas for cattle and access to water (Radio Dabanga 2018). Table 2.3 shows the main features of customary and statutory laws.

2.2.5 Sustainable development goals

Sudan's environmental policies are partly informed by the UN's Sustainable Development Goals (SDGs), which are defined by the 2030 Agenda for Sustainable Development. Sudan's government has adopted Agenda 2030 and the SDGs global planning framework. The 17 goals and 169 targets are designed to integrate the social, economic and environmental dimensions of sustainable development. Sudan is striving to incorporate this approach into its plans and strategies at the national and state levels. The focal point for implementing the SDGs into Sudan's development agenda used to be the National

Population Council, which is working in collaboration with the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), the World Food Programme and the World Bank. The council has drawn up the National Programme for Sustainable Development 2016–2030 and aims to make the SDGs the guiding principle for all development in the country (Government of Sudan 2018). This process will involve all sections of Sudan's society, including government, members of Parliament, civil society organizations, the private sector, researchers and academics.

The government focal point responsible for implementing the SDGs is the Ministry of Finance and Economic Planning.

2.2.6 National goals

To achieve its aims for sustainable development, Sudan has drawn up several goals of its own. These are designed not only to preserve the country's environment, but also to ensure that global targets such as those in the SDGs and the earlier Millennium Development Goals are supported by national policies. The three national goals that are most relevant to the environment are Zero Thirst, Zero Hunger and Poverty Reduction.

Zero Thirst

The Zero *Attash* or Thirst programme is a presidential initiative started in 2016 that aims to ensure that everyone in the rural areas of Sudan is within 500 metres of a reliable water supply by the year 2020. The initiative builds on the ongoing water harvesting activities carried out through the Dam Implementation Unit under the umbrella of the Ministry of Water Resources, Irrigation and Electricity. The objectives of Zero Thirst (Hamad 2017) are to:

- ➔ Develop rural areas and water resources away from the River Nile;
- ➔ Enhance livestock and crop production;
- ➔ Mitigate floods, drought and climate change;
- ➔ Settle nomads and pastoralists;
- ➔ Encourage Internally Displaced People to return to their homes;
- ➔ Improve forests and grazing lands;
- ➔ Support national security and promote peace and stability among neighbouring societies.

Zero Hunger

The Zero Hunger project was born out of a consultation between the World Food Programme and the Government of Sudan, which led to the government

drawing up an interim country strategic plan (World Food Programme 2019). The objective is to provide long-term solutions against hunger in line with the UN's SDG 2 (End Hunger).

The Zero Hunger strategic plan identifies land degradation, land tenure challenges and climate change as major contributors to food insecurity in Sudan and recommends prompt actions to deal with them. The strategy also recognizes the potential negative impacts of improved agricultural systems on the environment and recommends preventative measures. The emphasis is on increasing crop yields using improved technologies and inputs, rather than greater use of fertilisers and pesticides which can be damaging for the environment.

Sudan's Zero Hunger goal will be supported by the Food and Agricultural Organization (FAO) through its Country Programming Framework, which has four priority areas (FAO 2012):

- ➔ Policy development and strengthening of agricultural statistical systems;
- ➔ Enhancing productivity, production and competitiveness;
- ➔ Conservation and development of natural resources; and
- ➔ Disaster risk management.

Poverty Reduction

46.5 per cent of people in Sudan live below the poverty line (Ministry of Finance and Economic Planning 2016). Rural poverty is strongly linked with natural resources since rural communities rely heavily on them for their livelihoods. The deterioration of natural resources leads to land degradation, deforestation and competition over water and pasture. These can result in the displacement of people into urban centres, triggering further environmental deterioration.

In 2012, with support from the World Bank, Sudan produced an Interim Poverty Reduction Strategy Paper (Government of Sudan 2012), which provided a roadmap for implementing the country's full Poverty Reduction Strategy Paper in 2019–2025. Poverty Reduction Strategy Papers are a requirement of the World Bank's debt relief initiative, in which Sudan is taking part; they contain details of a country's poverty-reduction plans. The interim strategy is based on four pillars: strengthening the governance and institutional capacity of the public sector; reintegrating internally displaced persons and other displaced populations; developing human resources; and promoting economic growth and employment creation.

2 Environmental Governance

Sudan's progress in implementing the Interim Poverty Reduction Strategy Paper was assessed in 2016 by the World Bank and the Ministry of Finance and Economic Planning (World Bank and Ministry of Finance and Economic Planning 2016). The evaluation concluded that although the interim strategy correctly highlighted the important role of the agricultural sector in reducing poverty, it failed to address the environmental consequences of agriculture and the effects of this sector on natural resources.

2.2.7 Multilateral environmental agreements

Sudan has signed and ratified many international conventions, some of which have been domesticated into the country's national laws. Among the prominent conventions signed by Sudan are the United Nations Framework Convention on Climate Change and the associated Paris Agreement on Climate Change; the Convention on Biological Diversity; the Convention to Combat Desertification; the Ramsar Convention on Wetlands of International Importance; and the

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (Table 2.4). The international conventions have influenced Sudan's domestic policies, especially those policies concerned with environmental issues.

Sudan's dedication to environmental protection began in the mid-1970s following the desertification and drought that badly affected the African Sahelian States – including Sudan – from 1968 to 1973. Global awareness about the state of the environment and the need for regional and national cooperation received a boost with the Stockholm Conference on Human Environment of 1972, and again with the 1982 Nairobi Declaration on the State of the Worldwide Environment, and in 1987 with the publication of Our Common Future by the World Commission on Environment and Development. These events and other regional and international conferences have helped strengthen Sudan's commitment to the protection of the environment and human health and to sustainable development.

Table 2.4 Multilateral Environmental Agreements (MEAs) which Sudan has ratified.

Agreement Signature	Agreement Name	Ratifications (or similar)
16/10/1945	Constitution of Food and Agriculture Organization of United Nations	1956
06/12/1951	Rome International Plant Protection Convention	1971
23/10/1956	Statute of the International Atomic Energy Agency	1958
20/08/1962	Convention for the Establishment of the Desert Locust Control Organization for E. Africa	1968
05/08/1963	Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water	1966
15/09/1968	African Convention on the Conservation of Nature and Natural Resources	1973
02/02/1971	Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat	2005
23/11/1972	Convention for the Protection of the World Cultural and Natural Heritage	1975
10/4/1972	Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons, and on their Destruction	2003
03/03/1973	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	1983
23/11/1972	Convention for the Protection of the World Cultural and Natural Heritage	1975
01/11/1974	International Convention for the Safety of Life at Sea	1990
28/11/1979	International Plant protection Convention	1991
03/03/1980	Convention on Physical Protection of Nuclear Material	2000
10/12/1982	United Nations Convention on the Law of the Sea	1985
14/02/1982	Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	1984

Table 2.4 continued

Agreement Signature	Agreement Name	Ratifications (or similar)
14/02/1982	Protocol Concerning Regional Cooperation in Combating Pollution by Oil and other Harmful Substances in Cases of Emergency	1985
22/03/1985	Vienna Convention for the Protection of the Ozone Layer	1993
26/09/1986	Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency	1992
16/09/1987	Montreal Protocol on Substances that Deplete the Ozone Layer	1993
22/03/1989	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes And their Disposal	2006
30/11/1990	International Convention on Oil Pollution Preparedness, Response and Cooperation	2015
30/01/1991	Convention on the Ban of the Import into Africa and the Control of Trans-boundary Movement and Management of Hazardous Wastes Within Africa	1993
09/05/1992	United Nations Framework Convention on Climate Change	1993
05/06/1992	Convention on Biological Diversity	1995
24/06/1993	Constitution of the Centre for Marketing Information and Advisory Services for Fishery Products in the Arab Region	1995
13/01/1993	Convention on the Prohibition of The Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction	1999
18/02/1993	Agreement on the Establishment of the Near East Plant Protection Organization	1995
16/03/1994	Instrument for the Establishment of the Restructured Global Environment Facility	1994
17/06/1994	United Nations Convention to Combat Desertification	1995
17/06/1994	Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa	1995
16/06/1995	Agreement on the Conservation of African-Eurasian Migratory Waterbirds	1996
10/09/1996	Comprehensive Nuclear Test Ban Treaty (IEA ID# 3249)	2004
11/12/1997	Kyoto Protocol to the United Nations Framework Convention on Climate Change	2004
10/09/1998	Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade	2005
29/01/2000	Cartagena Protocol on Biosafety to the Convention on Biological Diversity	2005
03/11/2001	International Treaty on Plant Genetic Resources for Food and Agriculture	2002
22/05/2001	Stockholm Convention on Persistent Organic Pollutants	2006
11/07/2001	Convention of the African Energy Commission	2006
21/05/2003	World Health Organization Framework Convention on Tobacco Control	2005
22/11/2009	Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing	2016
29/10/2010	Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity	2014
26/01/2009	Statute of the International Renewable Energy Agency	2011
12/12/2015	Paris Agreement under the United Nations Framework Convention on Climate Change	2017

Compiled from: <https://iea.uoregon.edu/country-members/Sudan>

2.2.8 Regional initiatives

Sudan is a member of river basin initiatives such as the Nile Basin Initiative (NBI), and regional and economic communities such as the Intergovernmental Authority on Development (IGAD). Both the NBI and IGAD are important reference points for some of the country's environmental policies (Table 2.5).

The NBI is an intergovernmental partnership of ten Nile Basin countries, namely Burundi, the Democratic Republic of the Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania and Uganda. Eritrea participates as an observer (Nile Basin Initiative 2020). The initiative seeks "to develop the Nile Basin water resources in a sustainable and equitable way to ensure prosperity, security, and peace for all its peoples; ensure efficient water management and the optimal use of the resources; ensure cooperation and joint action between the riparian countries, seeking win-win gains; target poverty eradication and promote economic integration; and ensure that the program results in a move from planning to action" (Nile Basin Initiative 2020).

The NBI helps the ten countries that share the Nile to manage the river sustainably and use its resources equitably (Nile Basin Initiative 2012; Lake Victoria Basin Commission and GRID-Arendal 2017). To achieve this, the NBI member states have committed to developing a common policy and strategy under the Nile Basin Cooperative Framework, which includes guidance on the management and assessment of aquatic ecosystems (Nile Basin Initiative 2012). Under the NBI's Environmental and Social Policy, member countries are required to explain how they will integrate environmental and social concerns in NBI programmes; help Nile Basin countries protect critical environmental resources; and demonstrate commitment to international best practices on the environmental and social management of development activities.

The NBI supports the establishment of "environmental flows", which are defined as "the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated" (Dyson et al. 2008). To date, among the Nile Basin countries, only Tanzania and Kenya have established flow policies and strategies, while Rwanda, Sudan and Ethiopia have written general statements and provisions into their respective water policy documents. The only agreement to which Sudan is a signatory

that applies explicitly to the river Nile is the 1959 Nile Waters Agreement between Sudan and Egypt. IGAD is a trade bloc made up of eight countries in the Horn of Africa: Djibouti, Eritrea, Ethiopia, Kenya, Somalia, Sudan, South Sudan and Uganda. The region has an area of 5.2 million km², 60 to 70 per cent of which receives less than 600 mm in annual rainfall. Much of it is arid or semi-arid with very large climate variability (Intergovernmental Authority on Development 2012). The area is increasingly vulnerable to drought due to growing population, changes in land use, land degradation and desertification. With global warming, droughts are expected to become more severe and frequent, and there is an increasing need for drought monitoring and early warning.

In Sudan, as in many parts of the IGAD region, drought and the harsh ecological circumstances, exacerbated by climate change, war and conflict, have created conditions of chronic vulnerability. Extreme poverty, persistent food insecurity, widespread economic hardship and human suffering are common. Sudan's environmental policies, which are designed to address these problems, are partly informed by the vision of IGAD, including its Regional Platform for Drought Resilience and Sustainability, which aims to provide effective collective action in the management of drought (Intergovernmental Authority on Development 2012).

2.2.9 Natural resources management laws

Sudan's natural resource management procedures date to the beginning of the 20th century and are linked to the country's forestry service. In 1902, during the first years of the Anglo-Egyptian Condominium, the government established the Forests and Woodlands Service, and in 1908 and 1917 issued regulatory acts aimed at conserving nature (Badi et al. 1989). The first formal national forest policy was drawn up in 1932, and in 1935 the Wildlife Act and several national parks were established (Badi et al. 1989).

Over the years, Sudan's environmental legislation has been implemented on a piecemeal basis and has lacked a comprehensive long-term strategy. There are now more than 150 laws and regulations dealing with health, water supply, land tenure, game, protected areas, fisheries and other aspects of natural resources (Ali 2007). Among the most significant are the Environmental Health Act (1976), the Public Health Act (1975), the Labour Act (1998), the Wildlife Protection Act (1935), the Freshwater Fisheries Act (1984), the Road and Traffic Act (1983), the Natural Parks and Protective

Table 2.5 Regional and international conventions and national policies highlighted by the Nile Basin Initiative for Sudan

International and regional conventions, treaties and protocols related to water to which Sudan is a signatory	Sudan's national policies, laws and regulations related to water
<ol style="list-style-type: none"> 1. African Convention on the Conservation of Nature and Natural Resources (1968) 2. Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat (1971) 3. Convention Concerning the Protection of World Cultural and Natural Heritage (1972) 4. Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973) 5. UN Convention on the Law of the Sea (1982) 6. Vienna Convention for the Protection of the Ozone Layer (1985) 7. Montreal Protocol on Substances that Deplete the Ozone Layer (1987) 8. Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (1989) 9. United Nations Convention on Biological Diversity (1992) 10. United Nations Framework Convention on Climate Change (1994) 11. United Nations Convention to Combat Desertification (1994) 12. Agreement on the Conservation of African-Eurasian Migratory Waterbirds (1999) 13. United Nations Framework Convention on Climate Change's Kyoto Protocol (2005) 	<ol style="list-style-type: none"> 1. Land Settlement and Registration Ordinance (1925) 2. Land Acquisition Act (1930) 3. Central Forest Act (1932) 4. Provincial Forest Act (1932) 5. Nile Water Pumps Control Act (1939) 6. Freshwater Fisheries Act (1954) 7. Water Hyacinth Control Act (1960) 8. Unregistered Land Act (1970) 9. Environmental Health Act (1975) 10. Public Health Act (1975) 11. Civil Transactions Act (1984) 12. Wildlife Protection and National Parks Act (1986) 13. Forestry Act (1989) 14. Irrigation and Drainage Act (1990) 15. Seeds Law (1990) 16. Environmental and Natural Resources Act (1991) 17. National Water Policy (1992) 18. Water Resources Act (1995) 19. National Water Corporation Act (1995) 20. Environmental Health Act (1997) 21. Ground Water Act (1997) 22. Groundwater and Wadis Directorate Act (1998) 23. Archaeology Protection Act (1999) 24. Antiquities Protection Act (1999) 25. National Water Policy (2000) 26. Sudan National Biodiversity Strategy and Action Plan (2000) 27. Environment Protection Act (2001) 28. Electricity Act (2001) 29. Forests and Renewable Natural Resources Act (2002) 30. First National Communication (2003) 31. National Plan for Environmental Management (2007) 32. National Adaptation Programme of Action (2007) 33. National Implementation Plan for the Stockholm Convention on Persistent Organic Pollutants (2007) 34. Integrated Water Resources Management Policy (2007) 35. Desertification Control Act (2009) 36. Environmental Health Act (2009) 37. Water Supply and Sanitation Policy (2010) 38. Regulation for Ground Water Control (2016) 39. Regulation for Surface Water Control (2016)

2 Environmental Governance

Areas Act (1986), the Urban Planning and Disposition Act (1994), the Environment Protection Act (2001) and the Investment Act (2013).

One of the most recent and important federal laws is the Regulation of Range and Pasture Resources Development Act (2015), which recognizes public rangeland, private *hema* (a protected area where grazing is restricted), community-held *hema* and privately cultivated rangeland. The Act defines and regulates how rangelands are managed. *Masarat* (passageways) are defined and protected as well as the rational use of pesticides in rangelands.

Sudan's laws and regulations can play a vital role in managing natural resources and strengthening peace-building. One problem is that the administration of these laws and knowledge about them is fragmented across various institutions. This lack of coordination means that the laws are often interpreted and applied subjectively. Another problem is that they are often not properly enforced. Furthermore, ordinary people tend to recognize customary laws but not statutory laws, reflecting a disconnect between the government and local people. This issue is recognized in the Interim National Constitution, which calls for harmonization of customary and statutory law.

2.2.10 Policy goals

Since independence, the goal of Sudan's governments has been to achieve better welfare for the people through development that is based on the judicious and sustainable use of natural resources. Sudanese policy on natural resources and environmental conservation has made great progress in the last three decades, driven in part by the Millennium Development Goals, the SDGs and other international poverty reduction strategies, as well as by domestic efforts to conserve and protect natural resources and promote conflict resolution and peace-building.

The management of natural resources falls under the jurisdiction of several key federal ministries, including the Ministry of Agriculture and Forests and the Ministry of Water Resources, Irrigation and Electricity. However, continuous restructuring and institutional instability have undermined their effectiveness.

As Table 2.6 shows, Sudan has a broad array of policies at its disposal for managing its natural resources. However, some policies are not comprehensive enough, while others have an overly narrow focus. For example, Sudan lacks a comprehensive policy and legislative framework that deals with land use in an integrated way (Atta Elmoula 1985; Abdel Magid, and Elsiddig 1994). Instead, it has several individual policies covering agriculture, forestry, wildlife and other resources. These do not always share common goals. For instance, the forest policies of 1932 and 1986, aimed at the conservation and improvement of forest resources, were drawn up by forestry professionals without consultation with other parties, and as a result they are not well accepted and are poorly enforced (Elmahi and Abdel Magid 2002).

2.3 INSTITUTIONAL ARRANGEMENTS

Sudan's environmental laws are administered and enforced by various government ministries and other statutory bodies such as commissions, as well as by traditional leaders. Civil society also plays a part, especially in raising public awareness of critical issues.

In 1991, the government established the Higher Council for Environment and Natural Resources as the central agency for coordinating sustainable development efforts. Several ministries with major responsibilities for natural resources management, land use planning and socio-economic development are members of the board of the Higher Council for Environment and Natural Resources, including the Ministries of Agriculture and Forests; Irrigation and Water Resources; Industry and Commerce; Energy and Mining; Justice; Health; Culture and Information; General Education; and Higher Education and Scientific Research.

In 1995, the government created the Ministry of Environment and Tourism to oversee environmental management. This was later renamed the Ministry of Environment, Forestry and Physical Development, and then again, the Ministry of Environment, Natural Resources and Physical Development. In September 2018 the ministry was abolished in a government cabinet restructuring, and a new National Council for the Environment was created in its place under a state minister. This means there are now two environment

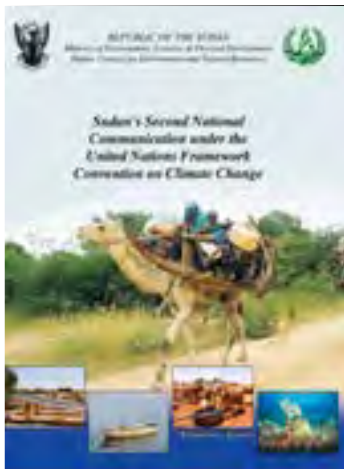
Table 2.6 Some of Sudan's key policies on the environment and natural resources

Policy or plan	Policy goals	Policy measures or programmes	Body responsible for implementing the policy
1. National Comprehensive Strategy for Development (1992–2002)	The sustainable management and development of natural resources and improving livelihoods.	Sudan's main objectives and priorities for achieving sustainable development are spelt out. Desertification control and protection of natural resources are frequently referred.	Higher Council for Strategic Planning assumes overall responsibility for the plan and its implementation.
2. Decentralization Policy (1997)	Conservation and protection of natural resources.	State responsibilities over land and management of natural resources.	Government bodies at locality, state and federal levels.
3. Sudan National Adaptation Plan (2015)	Response to the threats of climate change. Reduce vulnerability to the impacts of climate change. Promote the integration of climate change adaptation into existing and new policies, programmes and activities.	Building adaptive capacity and resilience at various levels. Identify projects and actions through participatory process.	Government, non-government and private institutions at state and national levels.
4. Quarter Century Strategy (2007–2031)	The sustainable management of land.	The environment comes under the economic strategy rather than the national development framework.	Higher Council for Strategic Planning assumes overall responsibility for the plan and its implementation.
5. The Intended Nationally Determined Contribution (INDC) (Contribution to the UNFCCC)	Achieve the objectives of United Nations Framework Convention on Climate Change and its national development objectives.	Measures to facilitate adaptation to climate change.	Higher Council for Environment and Natural Resources is responsible for the convention, but it suffers from poor coordination and funding mechanisms.
6. National Water Policy (1999; revised 2006)	To ensure sustainable and integrated management of valuable water resources. Recognition of water as an instrument for conflict management.	Cost effective and appropriate technologies. Public and private partnerships. Cost-sharing and cost recovery mechanisms.	National Water Corporation.
7. Natural Water Supply and Sanitation Policy (2009)	Ensure equitable and sustainable utilization of safe water and sanitation.	Integrated water resource management.	Ministry of Water Resources to lead integrated water resources management.

2 Environmental Governance

Table 2.6 continued

Policy or plan	Policy goals	Policy measures or programmes	Body responsible for implementing the policy
8. National Biodiversity Strategy (2015)	Management of biodiversity through sound policy advice and best practice.	Programmes that demonstrate sound biodiversity management practices.	Higher Council for Environment and Natural Resources supported by UNDP.
9. Sudan National Forest Policy Statement (2006; updated from Sudan's Forest Policy 1986)	Poverty reduction, improve Sudanese population welfare by enhancing food and income security and combat of desertification.	The measures include alignment with Water Policy, Forest Outlook* and commitment to social development and population policy.	The Forests National Corporation and the Federal Ministry of Federal Agriculture and Forestry.
10. Poverty Reduction Strategy Paper (interim 2012)	Environment as a vehicle for poverty reduction. Recognition of the links between environment, risk management and poverty reduction.	Strengthening people's resilience to environmental risks and climate change. Establishment of institutions for the sustainable management of natural resources (water, forest and land). Comprehensive land reform and security of land title. Preparation of land use maps, especially for marginal areas. Social and water harvesting programs. Promote private investment in gum arabic production. Enhanced community role in resources management.	Federal Ministry of Finance and Economic Planning in coordination with technical ministries and the donor community.
11. The SDGs and 2030 Agenda	Society based on national consensus, peaceful co-existence, social justice and global and regional partnership. Achieve sustainable development and continual improvement in people's livelihoods. Combat desertification and land.	State reform programme. Risk-informed approach to development. Integrated approach to achieving 2030 agenda. Sustainable forest resource management. National agricultural investment plan.	A national mechanism to supervise the implementation of SDGs; the National Population Council is the focal point for this mechanism.



councils: the new National Council for the Environment and the older Higher Council for Environment and Natural Resources. On the state level, state ministries have been reduced to only five per state, while an umbrella state Ministry of Production and Economic Resources has oversight over Agriculture, Industry, Mining and Investment.

Another government body with environmental responsibilities is the Sudanese Standards and Meteorology Organization, which was set up in 1993. Over the years this organization has issued many national environmental standards in the areas of air and water quality, food, building materials and fertilizers.

A list of national institutions responsible for various aspects of natural resources and environmental management is shown in Table 2.7, while Table 2.8 shows the history of environmental institutions in Sudan.

There are several state-level councils, departments and units within certain federal ministries and councils such as the Ministry of Agriculture and Forests and the Higher Council for Environment and Natural Resources. The roles and capacities of the state-level environmental institutions differ from state to state (UNEP 2007b).

2.3.1 Land commissions and related institutions

Sudan's Interim National Constitution of 2005 established a National Land Commission, whose roles include arbitrating between contending parties on land claims, enforcing the law, assessing appropriate land compensation, advising the government on land reform policies and recommending new land reform policies. The Interim National Constitution also created state land commissions for South Kordofan and Blue Nile, while land commissions for Darfur and Eastern Sudan are stipulated in the Darfur Peace Agreement and in the Eastern Sudan Peace Agreement (Government of Sudan 2005). Table 2.9 shows land-related institutions in Sudan and their responsibilities.

2 Environmental Governance

Table 2.7 Federal-level natural resources management institutions*

No.	Name
1.	Higher Council for Environment and Natural Resources
2.	Federal Ministry of Irrigation and Water Resources. Former Federal Ministry of Water Resources, Irrigation and Electricity
3.	Federal Ministry of Agriculture and Natural Resources. Former Federal Ministry of Agriculture and Forests <ul style="list-style-type: none"> • Forest Research Corporation • Wildlife Research Corporation • Agricultural Research Corporation • Food Research Corporation • Range Management Administration
4.	Ministry of Higher Education and Scientific Research. Former Ministry of Science and Technology <ul style="list-style-type: none"> • National Council for Research • Atomic Research Centre • National Centre for Renewable Energy • Range Management Administration
5.	Federal Ministry of Energy and Mining. Former Ministry of Oil and Gas <ul style="list-style-type: none"> • Geological Research Corporation • Sudan Company for the Development of Minerals Resources
6.	Federal Ministry of Livestock and Fisheries <ul style="list-style-type: none"> • Wildlife Research Centre • Animal Resources Research Corporation
7.	Environment Educational and Research Institutes

Source: Institute of Environmental Studies 2016. Updated by the Technical Lead Author

* A National Council for the Environment was formed after the dissolution of the Federal Ministry of Environment, Natural Resources and Physical Development 2018. On 30 April 2020, the Transitional Supreme Council endorsed amendments to the Environmental Protection Act of 2001, establishing a new Higher Council for Environment and Natural Resources as the national environmental authority.

Table 2.8 History of Environmental Institutions in Sudan

Date	Event	Affiliated Institutions Directorates / Councils / Departments
Pre - 1991	No formal environmental institution	National Council for the Environment formed after the dissolution of the Federal Ministry of Environment, Natural Resources and Physical Development
1991	The formation of the Higher Council for Environment and Natural Resources (HCENR)	Higher Council for Environment and Natural Resources
1995–2001	Formation of the Ministry of Environment and Tourism	1. National Council for Physical Development 2. General Directorate for Federal Lands 3. Survey Department 4. National Population Council 5. HCENR (As a separate entity)
2001–2010	Formation of the Ministry of Environment and Physical Development (MEPD)	1. HCENR (2003) 2. National Committee for Geographic Names 3. General Directorate for Federal Lands 4. Higher Council for Physical Development (Under the Minister)
2010–2015	Formation of the Ministry of Environment, Forestry and Physical Development (MEFPD)	1. HCENR (2003) 2. National Committee for Geographic Names 3. General Directorate for Federal Lands 4. Higher Council for Physical Development (Under the Minister) 5. National Forest Corporation 6. General Directorate for the Environment (For the 1 st time)
2015–2018	Formation of the Ministry of Environment, Natural Resources and Physical Development (MENRPD)	Disconnected units: 1. National Forest Corporation 2. Survey Department (The formation of Sudan Survey Authority) Annexed: 1. Sudan Meteorological Authority 2. HCENR (2003) 3. National Committee for Geographic Names 4. General Directorate for Federal Lands 5. Higher Council for Physical Development (Under the Minister) 6. National Forest Corporation 7. General Directorate for the Environment (For the 1 st time) 8. The Sudan Meteorological Authority (SMA)
2018–2019	Abolition of the MENRPD Formation of National Council for the Environment (NCE) (SG State Minister)	1. HCENR existed as a related unit 2. National Council for Geographic Names to Ministry of Transport 3. Higher Council for Physical Development under leadership of Ministry of Transport
2020	Establishment of a new Higher Council for Environment and Natural Resources	

2 Environmental Governance

Table 2.9 Land-related institutions in Sudan and their mandates

Institution	Mandate
Presidency and state governors	<ul style="list-style-type: none"> • Authority of taking land • Appointment of Native Administration leaders • Allocation of land • Establishment of local councils
National Council for Physical Development and Land Disposition	<ul style="list-style-type: none"> • General policies for urban planning • Drafting of laws and regulations concerning physical planning • Training of staff
Forests National Corporation	Reservation, protection, conservation and replacement of forests
Mechanized Farming Administration	Allocation of land and management of the mechanized sector
National Investment Council	Identification of land for agricultural, industrial and other purposes
States Councils of Ministers	Final approval of housing plans
Native Administration	Application of customary law for land management
National and State Fund for Housing and Rehabilitation	Housing security for the poor through rental selling
Physical Planning and Land Disposition committees	<ul style="list-style-type: none"> • Approval of locations and purposes of land use • Designation of governmental land for institutions, individuals and corporations
Physical Planning Administration	<ul style="list-style-type: none"> • Establishment of branch committees • Preparation of physical plans for approval • Carrying out socio-economic studies for planning and establishment of land rights, on behalf of the state
Land Administration	Support to land registration at the judiciary after approval
Ministers of Physical Planning	<ul style="list-style-type: none"> • Approval of housing plans • Approval of changes in village boundaries • Looking into appeals pertaining to land within the power of the Ministry
Department of Surveying	<ul style="list-style-type: none"> • Surveying and mapping of lands • Preparation of land maps • Information centre for land issues • The onsite handing over of land to those entitled
Wildlife Conservation General Administration	<ul style="list-style-type: none"> • Conservation of wildlife and its territories • Overseeing hunting activities and permits • Coordinating efforts to conserve wildlife with other relevant departments • Encouraging research in the fields of wildlife conservation
Land Registration Offices	<ul style="list-style-type: none"> • Keeping land registers of towns • Information centre on town and country planning

Table 2.9 continued

Institution	Mandate
Locality Legislature	Establishment of administrative units
Land Courts	Arbitration and conflicts over land
Range and Pastures Department	<ul style="list-style-type: none"> • Mapping and demarcation of livestock routes • Protection and management of range lands
Land Disposition Committees	<ul style="list-style-type: none"> • Allocation of agricultural land • Policy making on agricultural land uses
Nomads Commission	<ul style="list-style-type: none"> • Policy making for the development of pastoralists • Mapping and demarcation of pastoral routes • Advocacy for and defending of pastoral rights
State Security Committee	Reporting on land and resource-related conflicts
Nomads Development Council	Opening of livestock routes and provision of services
Locality Security Committees	Resolution of conflicts over land
Locality Executive body	<ul style="list-style-type: none"> • Issuing of certificates that confirm that land is free of conflicting interests • Approval of temporary locations for services and related uses

2.3.2 Institutional arrangements for water, rangelands and forests

Key institutions responsible for managing water resources include the Ministry of Physical Planning and Public Utilities and the State Water Corporation, both of which were formed in 2013. Localities have responsibility for the management of water resources at the local level. However, many other organisations play a role, particularly international non-governmental groups, whose humanitarian interventions often involve them in the water sector, and some United Nations agencies such as UNEP and UN-Habitat. Table 2.10 shows the institutions responsible for managing natural resources in certain states.

Rangelands and forests are managed by the Federal Ministry of Agriculture and Forests and its technical departments. However, some states have a separate Ministry for Animal Resources, Range and Pastures. Furthermore, the administration staff responsible for rangelands and forests can be found at both the federal and state levels. This has led to confusion and a lack of clarity over roles and responsibilities.

Sudan's localities, which according to the Interim National Constitution are the third layer of governance after national and state levels, are the main legitimate institution responsible for all aspects of rural development, including management of natural resources. Unfortunately, none of the localities is equipped to carry out this role. This lack of institutional capacity is a pressing and crucial issue that needs to be rigorously addressed at all levels of governance. Experience from Sudan and elsewhere shows that without effective local institutions, peace-building and natural resource management are unlikely to succeed.

All Sudan's institutions are hampered by a lack of skills and resources, particularly when it comes to designing, implementing and monitoring new programmes. There is also a pervasive lack of information, with progress and annual reports difficult to access. The roles of the various institutions are not clear-cut and often overlap, and communication and coordination can be poor. Planning processes tend to take a top-down approach, rather than encouraging participation at all levels. The strengths and weaknesses of various institutions are shown in Table 2.11.

2 Environmental Governance

Table 2.10 Institutions responsible for managing water resources, rangelands, pastures and forests in certain states

State	Water	Range, Pastures and Forests
South Kordofan	<ul style="list-style-type: none"> Ministry of Physical Planning and Public Utilities Towns Water Corporation Rural Water Corporation 	<ul style="list-style-type: none"> Ministry of Agriculture and Forests (Department of Range and Pastures) Forests National Corporation State Department of Forest Localities Native administration and councils
Blue Nile	<ul style="list-style-type: none"> Ministry of Physical Planning and Public Utilities Urban Water Corporation Private water companies operating water stations and catchments in rural areas on contract basis Water, Environment and Sanitation Programme Native Administration 	<ul style="list-style-type: none"> Ministry of Agriculture and Forests Forests National Corporation State Department of Forest Department of Range and Pastures Localities Native administration and councils
North Darfur	<ul style="list-style-type: none"> Ministry of Physical Planning and Public Utilities North Darfur water corporation Localities Native administration 	<ul style="list-style-type: none"> Ministry of Agriculture and Forests Forests National Corporation State Department of Forest Department of Range and Pastures Localities Native administration and councils
South Darfur	<ul style="list-style-type: none"> Ministry of Physical Planning and Public Utilities South Darfur Water Authority Water, Environment and Sanitation Programme Popular Committees 	<ul style="list-style-type: none"> Ministry of Agriculture and Forests Forests National Corporation State Department of Forest Department of Range and Pastures Localities Native administration and councils
West Darfur	<ul style="list-style-type: none"> Ministry of Physical Planning and Public Utilities The National Company for Ground water The National Company for the Manufacture of Water equipment Surface Water Company specialized in dams and water harvesting. Water, Environment and Sanitation The three Corporations have their headquarters in El Fasher, the old capital of Darfur Localities 	<ul style="list-style-type: none"> Ministry of Agriculture and Forests Forests National Corporation Localities Pastoralist Commission State department of forest Department of Range and Pastures Ministry of Animal Resources
East Darfur	<ul style="list-style-type: none"> Ministry of Physical Planning and Public Utilities State water corporation Water, Environment and Sanitation Programme Localities 	<ul style="list-style-type: none"> Ministry of Agriculture and Forests National Forest Corporation State department of forest Department of range and pastures Localities Native Administration and councils
Central Darfur	<ul style="list-style-type: none"> Ministry of Physical Planning and Public Utilities Central Darfur state water corporation Water, Environment and Sanitation Programme Localities Native Administrations 	<ul style="list-style-type: none"> Ministry of Agriculture and Forests National Forest Corporation State Department of Forest Department of Range and Pastures Localities Native Administration

Table 2.11 Strengths and weaknesses of some institutions responsible for natural resources management

Institution	Strengths	Weaknesses
Native Administration	<ul style="list-style-type: none"> • Custodian of customary norms with capacity to address reconciliation issues • Native chiefs active in Peace Councils in Blue Nile • Strong native administration prevented large-scale conflicts between nomads and farmers in south Kordofan • Many members of native administrations are still living in rural areas, particularly Omdas and Sheikhs, or in IDP camps with their tribes and villagers, hence they have strong ties with people • Traditional leaders have an uncontested legitimacy based on custom and inheritance in Blue Nile, South Kordofan and Darfur • In rural areas, native administrations are head of rural courts 	<ul style="list-style-type: none"> • Power and authority eroded due to government policy and conflict in Darfur • Displaced native chiefs lost control over land allocation and management in their original territory • Emergence of new leadership and power patterns are challenging customary authority • Generational conflict due to rise of new social forces that have not been incorporated into the customary structure • Lack of transportation for some native chiefs reduces their ability to respond to contain conflicts
Ministry of Agriculture and Forests	<ul style="list-style-type: none"> • Established institution with clear powers and mandate • Moderately trained staff 	<ul style="list-style-type: none"> • Officials cannot access much agricultural and pasture lands in most states due to banditry and rebel groups • Lack of funds, transport, and resources • Lack of capacity building and training programmes • Unable to provide extension services (supplying scientific research and new knowledge to farmers) • Unable to protect forest and appoint forest rangers • Unable to create reserved pasture and to rehabilitate degraded pastures
Forests National Corporation	<ul style="list-style-type: none"> • Well established, particularly in North Darfur and East Darfur • Moderately trained staff 	<ul style="list-style-type: none"> • Lost control of forest resources in some areas due to insecurity and lack of rangers • Lack of funding • IDP camps have become havens for illegal firewood and charcoal traders • Biodiversity Act deprived it of its legal sources of revenue
Water Corporation	<ul style="list-style-type: none"> • Well established institution in all states • Well trained technical staff 	<ul style="list-style-type: none"> • Lack of equipment and vehicles • Lack of access to rural areas due to insecurity

Source: Partners in Development Services 2016

Table 2.11 continued

Institution	Strengths	Weaknesses
Localities	Close to the people	<ul style="list-style-type: none"> • Conflict over jurisdiction with other government departments • Limited technical capacities • Very limited human resources • Lack of logistics and work facilities
Ministry of Physical Planning and Public Utilities	<ul style="list-style-type: none"> • Well established • Effective conflict resolution institution 	A conflict of jurisdiction with other government departments and state governments has weakened the ministry's state-level representation in local governments

2.3.3 Conflict management structures

In much of Sudan, people are completely dependent on natural resources for their survival. Droughts, floods and other vagaries of nature have an immediate impact on their lives. It is little surprise, then, that much conflict in Sudan relates to access to, control of or use of natural resources.

Sometimes, conflicts arise from the misinterpretation of the country's statutory and traditional laws. For example, under traditional policies nomads have no recognizable rights to land, but they can access water and other resources through their relationship with farmers. In bad years, nomads would be accommodated under an eat-and-go system which permitted them to utilize farmland for three consecutive years before moving on (Partners for Sustainable Development 2016). However, all policies and strategies developed since independence have been working towards the marginalisation of pastoralists. They have led to the expansion of agriculture at the expense of rangeland and livestock routes, and led to conflicts between farmers and pastoralists.

Conflict has been most aggressive in Darfur, where around 26 major tribal wars have broken out over the past two decades (Partners for Sustainable Development 2016). It has been less intense in Blue Nile, where a strong native administration has contained disagreements between farmers and pastoralists and where different ethnic groups co-existing in integrated communities have helped maintain stability. This is also the case in South Kordofan: although a civil war has been raging there since 2011, tribal groups have long been inter-marrying and tensions over resources have

not led to ethnic polarization. In both these states, the traditional mechanism of conflict resolution is still operational and effective (Table 2.12).

2.3.4 Capacity of environmental institutions

The Native Administration in Sudan plays an important role in environmental management. The system was first established in the early decades of the 20th century and institutionalized during the 1920s and 1930s (El-Battahani and Gadkarim 2017). Native administrations had jurisdiction over communal lands and were responsible for the management and conservation of natural resources, including the reporting and resolution of conflicts and disputes. Following the dissolution of the Native Administration System between 1971 and 1986, their powers have been significantly weakened, with most of their duties taken up by modern governance structures.

Government institutions responsible for environmental management suffer from instability, underfunding, a lack of staffing and training, poor coordination, overlapping roles, and the loss of skilled personnel to the brain drain, among other problems. The country's civil society organizations experience some of these issues too. They have difficulty establishing strong functioning networks or alliances with government and other civil society organizations, though many of Sudan's civil society organizations have gained international and regional recognition. Technical deficiencies, lack of funding and restrictive government legislation have meant that most civil society groups are confined to urban areas (UNEP 2009; UNDP 2015).

Table 2.12 Conflict management structures in selected states

State	Remarks
South Kordofan	<ul style="list-style-type: none"> • Tribal chiefs • Local government executive officers • Five-person committees • Good deeds committees
Blue Nile	<ul style="list-style-type: none"> • Native Administration • Peace Conflict Management Committees • Peace Council • Local Courts • Ajaweed system (peace mediators)
North Darfur	Native Administration
South Darfur	<ul style="list-style-type: none"> • Ajaweed (peace mediators) • Nomads Development Commission • Wise Men Committee • Nomadic Forum for Peace and Social Coexistence • Local Peace Committees • Agricultural Season Support Committees (local government committees) • Grazing routes Higher Committee (membership include police, judiciary, chiefs)
West Darfur	Native Administration
East Darfur	Native Administration
Central Darfur	Native Administration of the Rizeigat, Maalia and Birgid paramount chiefs

Source: *Partners in Development Services 2016*

2.4 CONCLUSION

Sudan was one of the first African countries to pass legislation to protect the environment. Many of its laws covering the use and conservation of natural resources have been in place since the colonial era. However, its multiple policies, laws, orders and acts are fragmented and overlapping, and the country lacks a comprehensive approach to environmental protection.

This lack of coordinated governance has contributed to serious environmental degradation, including extensive deforestation, a decline in biodiversity and increasing vulnerability to drought and the effects of climate change. Natural resource management is a major issue of concern in Sudan. Population growth in both humans and animals, at a time of rapid transformation to a market economy, has led to unregulated demand for water, wood, minerals, land and other natural wealth and triggered conflicts and environmental degradation that mainly hurt the rural poor. There is increasing recognition that Sudan's governance regime is too weak and ineffective to stop the damage.

Likewise, although there are several conflict resolution institutions in Sudan, they are mainly too ineffective to deal with the complexities on the ground. In addition, many of them lack full legitimacy since they are widely seen as being political and non-neutral.

On the upside, Sudan's willingness to embrace the principles of global thinking through the adoption of international agreements is to be applauded. International conventions have had a positive influence on Sudan's domestic policies, especially those focused on environmental issues, and in a few cases the positive effects have filtered down to the community level. However, the limitations of Sudan's institutions have meant that many of these agreements have not been fully implemented down to the state or local level.

The time has come for Sudan to go beyond the narrow, piecemeal approach to environmental governance and adopt a more holistic outlook, one that recognizes the close links between governance, peacebuilding, human security and development and places the environment at the centre of all development policies.

References

REFERENCES

1. Ali, O.M. (2007). Policy and institutional reforms for an effective EIA system in Sudan. *Journal of Environmental Assessment Policy and Management*, 9 (1), 67–82. Retrieved from: <https://doi.org/10.1142/S1464333207002664>
2. Atta Elmoula, M. E. (1985). *On the Problem of Resource Management in the Sudan*. Environmental Monograph Series, Institute of Environmental Studies, University of Khartoum, Khartoum, Sudan.
3. Badi K. H., El Houri A., and Bayoumi, A. M. S. (1989). *The Forests of the Sudan*. Forests National Corporation and National Council for Research. Khartoum: Sudan
4. Dyson, M., Bergkamp, G. and Scanlon, J., (Eds.). (2008). *Flow – The essentials of environmental flows*, (2nd Edition). IUCN, Gland, Switzerland. Retrieved from: <http://www.mekonginfo.org/assets/midocs/0001809-environment-flow-the-essentials-of-environmental-flows.pdf>
5. El-Battahani, A. E. and Gadkarim, H. A. (2017). Governance and Fiscal Federalism in Sudan, 1989–2015: Exploring Political and Intergovernmental Fiscal Relations in an Unstable Polity. Number 1, Sudan Report, March 2017. CHR. Michelsen Institute (CMI), University of Bergen. Retrieved from: <https://www.cmi.no/publications/file/6189-governance-and-fiscal-federalism-in-sudan.pdf>
6. El Harizi, K., Zaki, E., Prato, B. and Shields, G. (2007). Understanding Policy Volatility in Sudan. *IFPRI Discussion Paper, 00721*, pp99. Published by International Food Policy Research Institute. USA. Retrieved from: <https://www.ifpri.org/publication/understanding-policy-volatility-sudan>
7. Elmahi, A. G. and Abdel Magid, T. D. (2002). The Role of the Private Sector, Civil Society and NGOs in the Formulation and implementation of National Forest Policies and National Forest Programmes in Sudan. Prepared as a contribution on the Sudan Forests National Corporation to the Regional Workshop held by the Food and Agriculture Organization of the United Nations (FAO), Khartoum 26–27, January 2002.
8. Esen, A. (2017). An overview of economic policy of "Injury (Damage) may not be met by injury in Islam". (La Darar Wa-La Dirar Fi'l -Islam). *International Journal of Islamic Economics and Finance Studies*. 3 (1), 40–59.
9. Food and Agriculture Organization of the United Nations (FAO) (2012). Country Programme Framework for the Republic of Sudan (2012–2016).
10. Government of Sudan (2005). The Interim National Constitution of the Republic of Sudan 2005. Retrieved from: <https://www.wipo.int/edocs/lexdocs/laws/en/sd/sd003en.pdf>
11. Government of Sudan (2012). Interim Poverty Reduction Strategy Paper (2012–2014). Retrieved from <https://www.imf.org/en/Publications/CB/Issues/2016/12/31/Sudan-Interim-Poverty-Reduction-Strategy-Paper-41025>
12. Government of Sudan (2015). The Interim National Constitution of the Republic of Sudan (Amendment) 2015. Retrieved from [https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKewihh9Hlk-tLiAhWwtYsKHacGBjAOQFjAAegQIA-hAC&url=http%3A%2F%2Fwww.track.unodc.org%2FLegalLibrary%2FLegalResources%2FSudan%2FLaws%2FConstitution%2520\(amendment\)%25202015.pdf&usg=AOvVaw2mJn2j3_L0aWISHqyPuCDL](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKewihh9Hlk-tLiAhWwtYsKHacGBjAOQFjAAegQIA-hAC&url=http%3A%2F%2Fwww.track.unodc.org%2FLegalLibrary%2FLegalResources%2FSudan%2FLaws%2FConstitution%2520(amendment)%25202015.pdf&usg=AOvVaw2mJn2j3_L0aWISHqyPuCDL)
13. Government of Sudan (2018). Voluntary National Review 2018. Implementation of Agenda 2030 and the SDGs for Peace and Development in the Sudan. Retrieved from: https://sustainabledevelopment.un.org/content/documents/19424Sudan_Voluntary_National_Review_2018_1.pdf
14. Hamad, O. E. (2017). Sudan Water Governance – laws, policies and institutions, Global Water Partnership and UNEP. Khartoum, Sudan.
15. Hope, A. and Jones, C. (2014). The impact of religious faith on attitudes to environmental issues and Carbon Capture and Storage (CCS) technologies: A mixed methods study. *Technology in Society*. Retrieved from: https://www.researchgate.net/publication/260836459_The_Impact_of_Religious_Faith_on_Attitudes_to_Environmental_Issues_and_Carbon_Capture_and_Storage_CCS_Technologies
16. Institute of Environmental Studies, University of Khartoum (2016). Environmental and Social Impact Assessment (ESIA) study for Delgo Mining Activities in Block 17 Northern State. Delgo Mining Company.
17. Intergovernmental Authority on Development (IGAD) (2012). Drought Disaster Resilience and Sustainability Initiative. Sudan Country Progress Summary Report.

18. Ministry of Finance and Economic Planning (MFEP) (2016). The Economic Exhibition. Sudan. (in Arabic).
19. Ministry of Justice (2020). Assorted Amendments Act "The Amalgamation of Environmental Councils". *Republic of Sudan Gazette*, 1901.
20. Nile Basin Initiative (NBI) (2012). Nile Basin Initiative Summary of State of the River Nile Basin 2012. Retrieved from <https://www.nilebasin.org>
21. Nile Basin Initiative (NBI) (2013). Nile Basin Initiative, Environment and Social Policy. Retrieved from: <http://nileis.nilebasin.org/system/files/23.10.13%20environmental%20and%20social%20policy.pdf>
22. Nile Basin Initiative (2020). Who we are? Retrieved from: <https://www.nilebasin.org/nbi/who-we-are>
23. Partners in Development Services (PDS) (2016). Natural Resources Management in Sudan Peace Building and Development Project (SPDP): Analysis of Legal, Policy and Institutional Framework.
24. Radio Dabanga (2018). Dinka-Ngok, Misseriya sign peace accord in Abyei. Accessed from <https://www.dabangasudan.org/en/all-news/article/dinka-ngok-misseriya-sign-peace-accord-in-abyei>
25. Shazali, S. (2006). Share the land or part the nation: the pastoral land tenure system in Sudan. Retrieved from: <https://www.sd.undp.org/content/dam/sudan/docs/Share%20The%20Land%20Or%20Part%20The%20Nation.pdf>
26. Abdel Magid, T. D. and Elsiddig, E. A. (2003). Social Forestry in the Sudan – its current status and future potential. Submitted to the XII World Forestry Congress, Québec City: Canada. Retrieved from <http://www.fao.org/3/XII/0873-C1.htm>
27. United Nations Environment Programme (UNEP) (2007a). Sudan Post Conflict Environmental Assessment. Nairobi, Kenya. Retrieved from https://postconflict.unep.ch/publications/UNEP_Sudan.pdf
28. United Nations Environment Programme (UNEP). (2007b). Global Environment Outlook 4: Environment for Development. Nairobi, Kenya. Retrieved from: <http://wedocs.unep.org/bitstream/handle/20.500.11822/7646/-Global%20Environment%20Outlook%20%204%20%28GEO-4%29-2007768.pdf?sequence=3&isAllowed=y>
29. United Nations Environment Programme (UNEP) 2012. Global Environmental Outlook 5. Nairobi, Kenya. Retrieved from: <http://www.unep.org/geo>
30. United Nations Environment Programme (UNEP) (2009). Mapping and Capacity Assessment of Civil Society Organizations (CSOS) in Darfur. Prepared for UNDP Darfur Livelihoods Programme by Partners in Development Services (PDS), Khartoum, Sudan.
31. United Nations Development Programme (UNDP) (2015). Sudan Views of Post 2015 Development Agenda. A new Sustainable Development Agenda. Retrieved from: <https://www.sd.undp.org/content/sudan/en/home/post-2015.html>
32. World Food Programme (WFP) (2019). Sudan Zero Hunger Strategic Review 2019–2030. Retrieved from: <https://www.wfp.org/operations/sd02-sudan-country-strategic-plan-2019-2023>
33. World Bank and Ministry of Finance and Economic Planning (MFEP) (2016). Sudan IPRSP Status Report 2012-2014. Retrieved from: <http://documents.worldbank.org/curated/en/980991479985933855/pdf/110503-WP-SudanFlipbookEnglish-PUBLIC.pdf>

Heavy clouds during the rainy season in Sudan. Photo credit © UNEP

3

Atmosphere

3.1 INTRODUCTION

Sudan lies at the northernmost extent of the band of rainfall created by the Inter-Tropical Convergence Zone (ITCZ), a belt of low pressure that circles the earth near the equator. The country has no extensive bodies of inland water – its moisture comes from both the ITCZ and from southerly humid maritime winds that blow from the distant Atlantic and Indian Oceans. Being a large country, Sudan has great variation in rainfall, from extremely dry conditions in the north to relatively wet conditions in the south.

The large differences in rainfall are reflected in the wide variety of livelihoods and agricultural systems across the country. Pastoral farming dominates in the north, where rainfall is minimal and the onset of the rains unpredictable. Cropping systems are more prevalent in the south where the rainy season is more reliable, longer and heavier than it is in the north. Since agriculture is mostly rain-fed, climate variability plays a major part in Sudan's economy, livelihoods and food security. The country is hot throughout the year, with temperatures in summer often exceeding 43° C. The hours of sunshine and regular wind mean that the country has great potential as a producer of renewable energy.

This chapter describes not only Sudan's climate and weather systems, but also important atmospheric issues such as air pollution and climate change. Air pollution levels are low in Sudan compared with other countries because Sudan is an extensive rural agricultural economy (UNEP 2015), with relatively few emissions from its emerging petrochemical and mining industries. One of the biggest sources of air pollution in Sudan are the dust storms, which affect areas in the east, centre and north. The *haboob*, a violent dust storm, occurs in central Sudan when the first moist southwesterly winds reach the country in May to July. The dust storm produces a yellow wall of sand and clay that can reduce visibility to zero (Khyar and Fota 2001).

3.2 CLIMATE

Sudan is arid in the north and far southwest, while the southern areas are relatively wet. The desert regions in central and northern Sudan are among the driest and sunniest places on Earth. The sunshine is uninterrupted year-round, often exceeding 4,000 hours per year, with a 91 per cent chance of cloudless skies at any time (Khyar and Fota 2001). Areas around Wadi

Halfa and along the Egyptian border often go for years or even decades without any rainfall. They are among the hottest places on Earth during the summer (between April and June), when the average daily maximum exceeds 40° C for four to six months a year and reaches 45° C in some places. Hours of sunshine vary from 11.3 hours a day in Wadi Halfa to 5.3 hours in Ed Damazin in the southeast of the country.

Temperatures across the country do not vary greatly with the seasons. The far south has uniformly high temperatures throughout the year. In Khartoum, the warmest months are May and June, when average highs are 42° C, although temperatures can reach 48° C. In Wadi Halfa, the average minimum temperature is 11° C; in Khartoum the average low is 15° C in January, though lows of 6° C have been recorded (Khyar and Fota 2001).

The most significant climatic variables are rainfall and the duration of the dry season. The duration of the dry season depends on which of two airflows predominates: the dry northeasterly winds from the Arabian Peninsula, or the moist southwesterly winds from the Congo River Basin and the Atlantic (Khyar and Fota 2001).

The dry northeasterly winds blow from January to March. There is practically no rainfall across the country during this period except for a small area in eastern Sudan by the Red Sea. The moist southwesterly winds reach southern Sudan in May, bringing some rains and thunderstorms. By July, the moist air reaches Khartoum, and in August it extends to its northern limits around Abu Hamad, although in some years the humid air may even reach the Egyptian border. The flow becomes weaker as it spreads north. In October, the dry northeasterlies begin to strengthen again in the north and by the end of December they cover the entire country. Ed Damazin, close to the border with Ethiopia, has an eight-month rainy season (April to November) and receives an average of 692 mm of rain each year; Khartoum, with a three-month rainy season (July to September), has an annual average rainfall of 120 mm (Khyar and Fota 2001).

In some years, the arrival of the southwesterly winds and rain in central Sudan is delayed, or they do not come at all. If that happens, drought follows. During the 1970s and 1980s, the southwesterly winds failed frequently, resulting in serious droughts and disastrous conditions for the Sudanese people and economy (Khyar and Fota 2001).

3.2.1 Climatic zones

Figure 3.1 shows the climatic zones of Sudan from the desert to the semi-humid, as classified in Sudan National REDD+ Programme (2017). Most of Sudan's irrigation schemes are in the dry zones, while the bulk of rain-fed agriculture lies in the semi-humid zone.

3.2.2 Rainfall

Sudan has no extensive bodies of water that contribute to evapotranspiration – the movement of moisture from the land to the atmosphere – and hence humidity is low in most places at most times. The effect of the Red Sea is limited and the River Nile, which traverses the country from south to north, is too narrow to play much of a role.

The country draws most of its moisture from the Atlantic and Indian Oceans. It is carried north on winds that are controlled by the pressure distribution over the African continent (Khyar and Fota 2001). The winds are driven by three permanent high-pressure zones: the Azores high-pressure belt off the north-western coast near the Tropic of Cancer, and the Saharan and Arabian high-pressure belts that lie south of the Equator in the vicinity of the Tropic of Capricorn. Another source of moisture is the permanent low-pressure belt known as the doldrums, which crosses the African continent around the Equator. This humid southerly wind system dominates the Saharan region during the summer. All Sudan's rainfall usually falls during the summer when these southerly winds dominate the low layers of the atmosphere.

The rainy season lasts from May to October in the southern part of the country, from June to September in the central and northern parts, and from October to January in the Red Sea coastal zone. The northward movement of the rains is partly controlled by the ITCZ, which at the beginning of the rainy season is over the extreme south of the country. From May, the ITCZ moves gradually north and reaches its northernmost position in August. During this period, most parts of the country are under the influence of the southwesterly winds that carry moisture from the Atlantic Ocean and Congo basin, and the easterlies in the mid troposphere that blow from the Indian Ocean. In September, the ITCZ moves southwards rapidly, bringing the main rainy season to an end.

The Red Sea coast has a micro-climate of its own, with a later rainy season. The main factor affecting rainfall over this area is the Red Sea trough, which develops when the Azores and Arabian high-pressure systems move closer to each other to form a convergence zone. The Red Sea trough intensifies as it interacts with the low-pressure trough of the Mediterranean Sea depression.

Due to the topographic lifting caused by the Ethiopian Plateau in the east of the country and the effect of the Azores ridge of high pressure over the west, annual rainfall generally decreases from east to the west of the country (Abdalla 2017). The isotachs – lines of equal rainfall – run from northeast to southwest over Sudan. Rainfall also decreases in a gradient from the south of the country to the north..

In summary, there are several factors that can influence the rainfall pattern in Sudan:

- ➔ The position and intensity of the ITCZ;
- ➔ The sub-tropical high-pressure systems over the Indian Ocean to the southeast and the Atlantic ocean to the southwest;
- ➔ Monsoonal wind systems around the Equator;
- ➔ The Mediterranean depressions associated with cold fronts that move eastward;
- ➔ Easterly waves (disturbances in the area close to the ITCZ which take the form of a line of thunderstorms orientated north-south and which move from east to west), and westerly waves (a polar front depression that is associated with cold and warm fronts moving from west to east); and
- ➔ The El Niño Southern Oscillation (ENSO).

An analysis of rainfall trends from 1981 to 2016 using data from the Sudan Meteorological Authority shows that the onset of the rainy season is often delayed or the rains do not come at all in some areas, resulting in drought and sometimes famine. During the 1990s, rainfall was above average in the first part of the decade and below average during the latter years. On the coast, rainfall patterns were highly variable, though the quantity did not change significantly. Figures 3.2 show how rainfall patterns in Sudan become increasingly unpredictable as one goes from south to north.



Heavy rains causing flash floods in Darfur village. Photo credit © UNAMID



A dry Hafeer due to drought. Photo credit © UNEP

Figure 3.1 Climate zones of Sudan (Sudan National REDD+ Programme 2017)

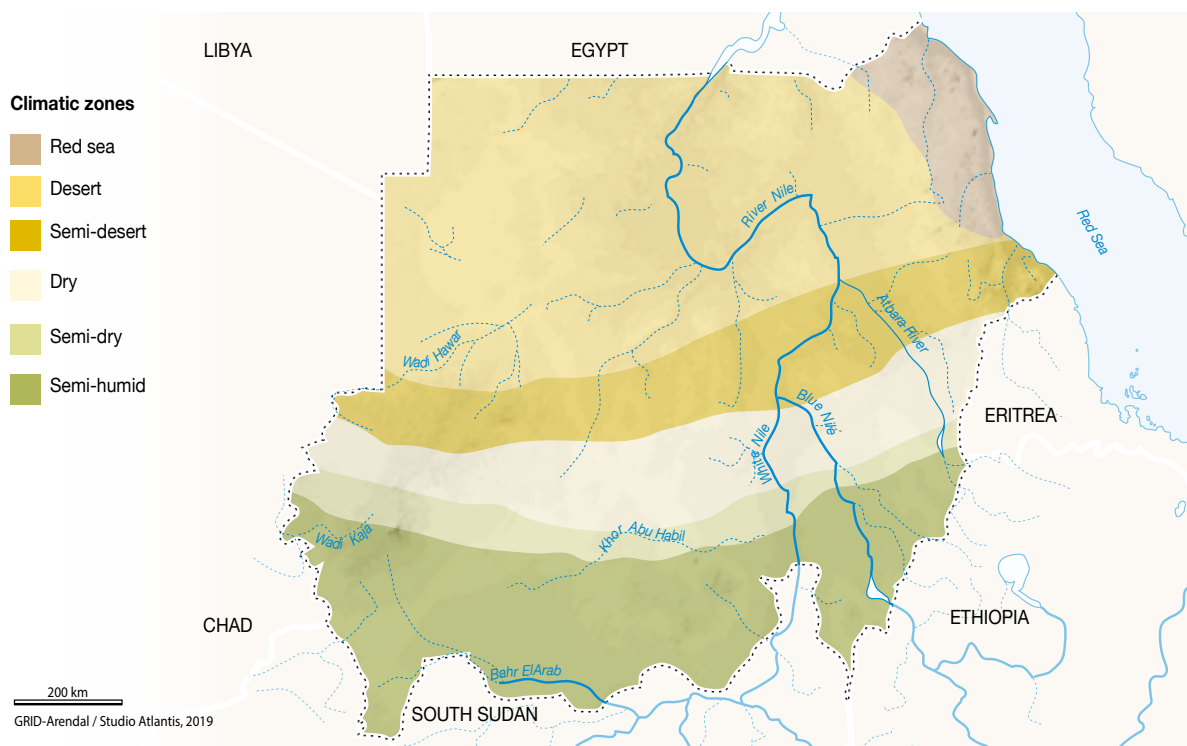
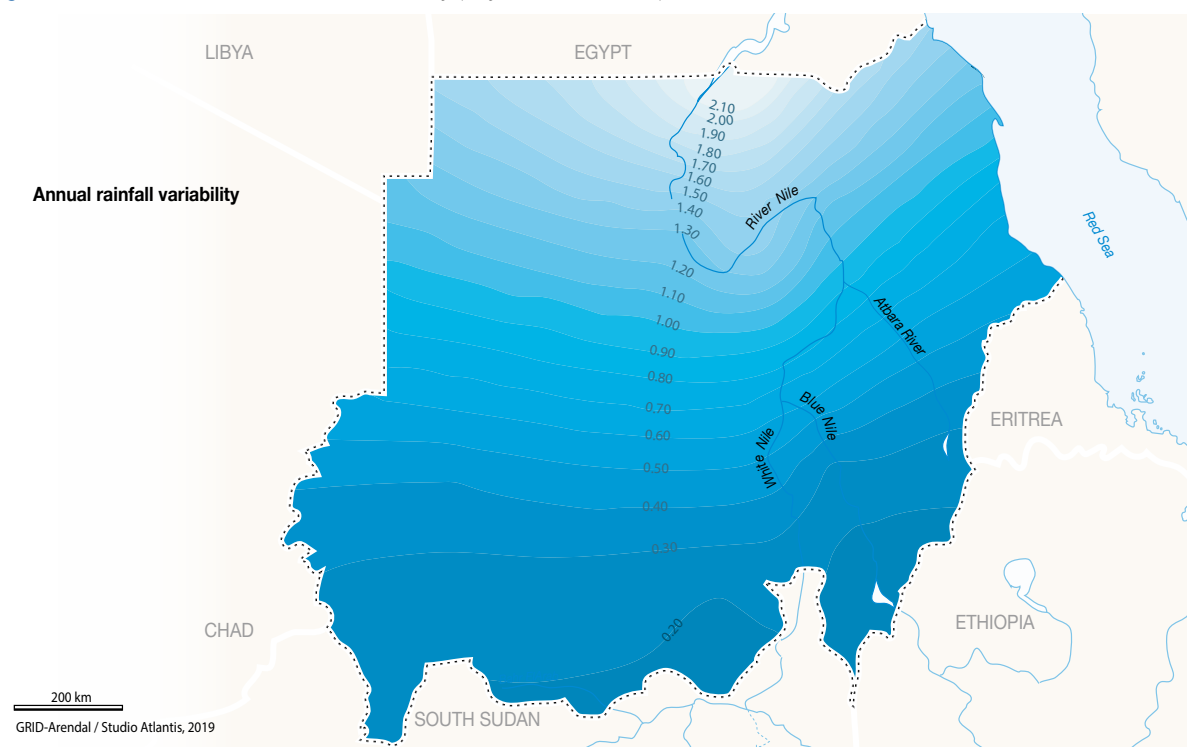


Figure 3.2 Annual rainfall coefficient of variability (Khyar and Fota 2001)



3.2.3 Temperature

Temperatures are highest at the end of the dry season due to cloudless skies and dry air. In Khartoum, the warmest months are May and June, when the average high is 42°C and temperatures can reach 48°C. Northern Sudan, with its short rainy season, is hot during the day all year round, with daily average temperatures that exceed 40°C, except in the north-west where in rare cases there is rain from the Mediterranean in January and February. Highland areas are generally cooler, and temperatures fall rapidly here after sunset. Khartoum's minimum temperature averages 15°C in January, but can drop to as low as 6°C. On the Red Sea coast, winter is pleasantly warm, with highs of around 25 to 27°C, but summers can be stifling, with a combination of heat and humidity that is hard to bear. As Figure 3.3 shows, across much of Sudan average maximum and minimum temperatures increased during the period 1980–2016.

3.2.4 Wind

Wind speeds in Sudan are sometimes so high that they cause dust and sandstorms. A violent dust storm called the *haboob* often occurs in central Sudan between May and July when the moist southwesterly flow arrives. The unstable air creates thunderstorms in the heat of the afternoon, and the downdraft from an approaching storm produces a yellow wall of sand and clay that can reduce visibility to zero (Khyar and Fota 2001).

The term 'sandstorm' is used to describe desert storms, especially in the Sahara, which in addition to fine particles that obscure visibility stir up a considerable amount of larger sand particles that travel closer to the surface. The term 'dust storm' tends to be used when finer particles are blown long distances, especially when the disturbance affects urban areas (Khyar 1998). Figure 3.4 shows average wind speeds in different stations.



Dust storm (or haboob) at North Darfur. Photo credit © UNAMID

Figure 3.3 Temperature anomalies in meteorological stations (Source: Sudan Meteorological Authority, processed by the author)

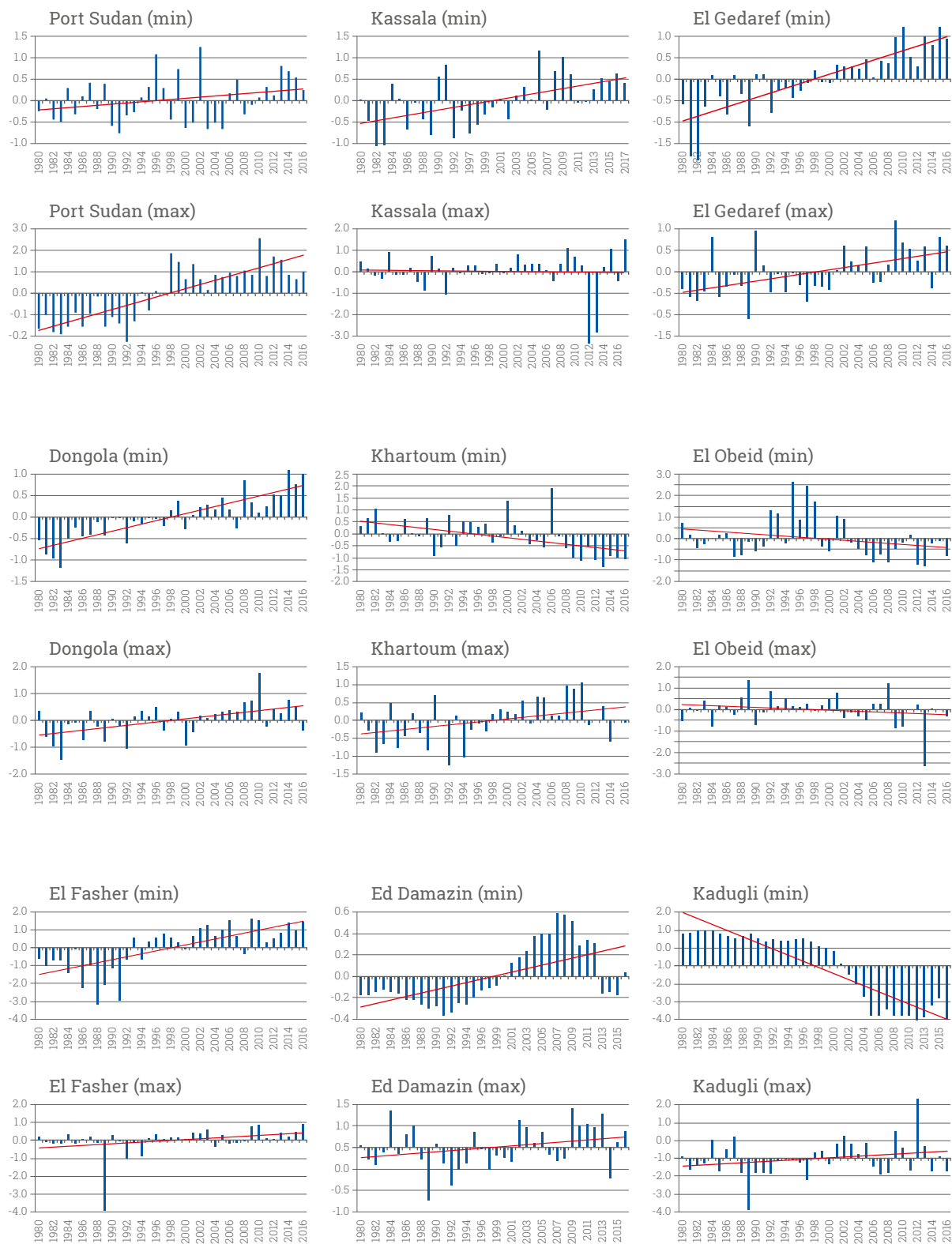
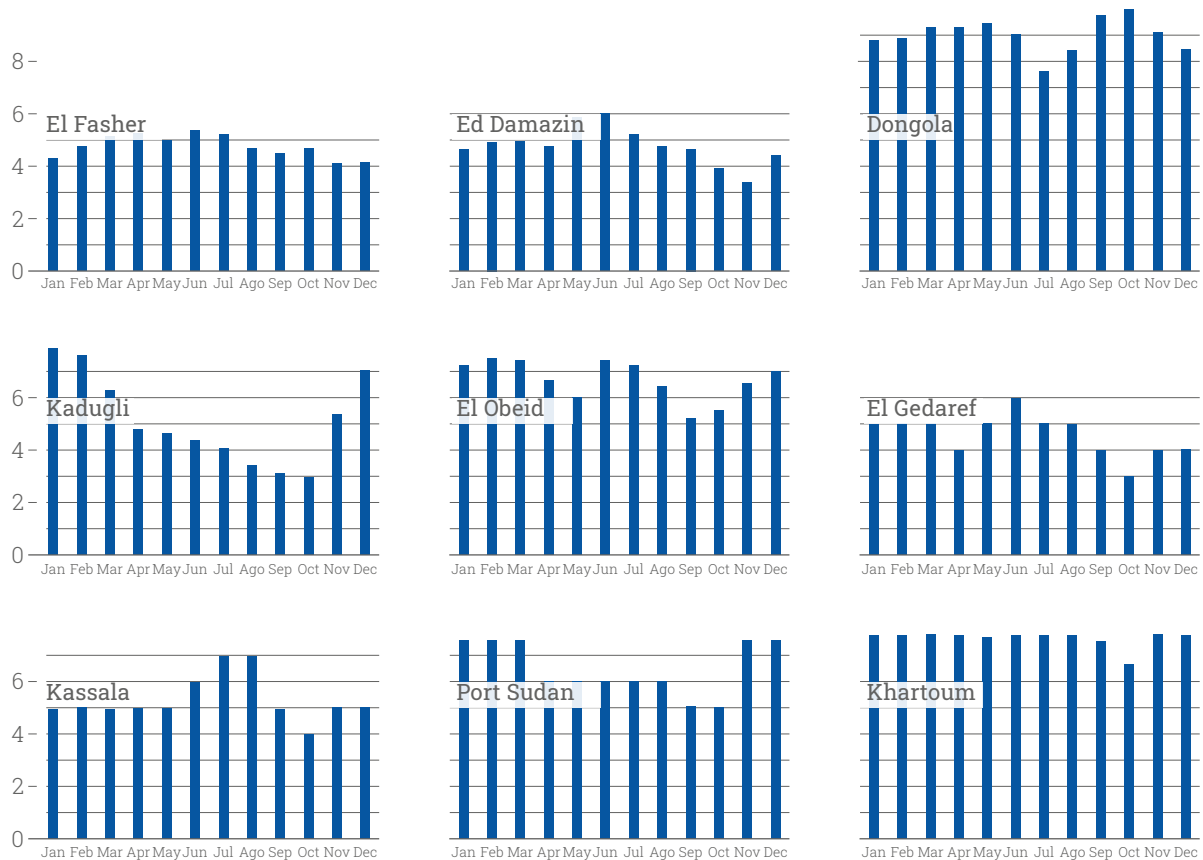


Figure 3.4 Average Wind Speeds (Source: Sudan Meteorological Authority, processed by the author)



Dust storms and sandstorms are common in arid and semi-arid regions in north and central Sudan. They arise when a cold front lifts loose sand and dust particles from the dry surface of the land and carries them as a suspension. The process erodes the soil in one place and deposits it in another.

Poor farming and grazing practices can heighten the risk of dust and sandstorms by exposing the dust and sand to the wind. The storms can seriously affect transportation, telecommunications, industrial and agricultural production, and people's lives and work. Because they remove organic matter and the nutrient-rich lightest particles, they reduce agricultural productivity, and the abrasive effect of storms damages young crop plants (UNEP, WMO, UNCCD 2016). Dust and sandstorms can have a critical effect on human health due to the deterioration in air quality, even causing deaths.

One potential advantage of Sudan's persistent winds is that they are strong and stable enough for the generation of wind power, as Figure 3.4 shows.

3.2.5 Sunshine hours

Sudan has long hours of sunshine, as shown in Figure 3.5, which means the country has the potential to generate a significant amount of solar electricity.

3.3 CLIMATE CHANGE AND VARIABILITY IN SUDAN

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (IPCC 2014 and 2018).

Evidence of climate change is clear from the 1980–2016 period, except in Khartoum, Kadugli and El Obeid where both minimum and maximum temperatures decreased. Long-term rainfall measurements recorded at nine stations show that the amount of rainfall across the country has been decreasing (Figure 3.6). Average temperature and average rainfall have both been highly variable. This data demonstrates that Sudan's long-term climate is changing.

Figure 3.5 Sunshine hours in Sudan (Source: Sudan Meteorological Authority, Processed by the author)

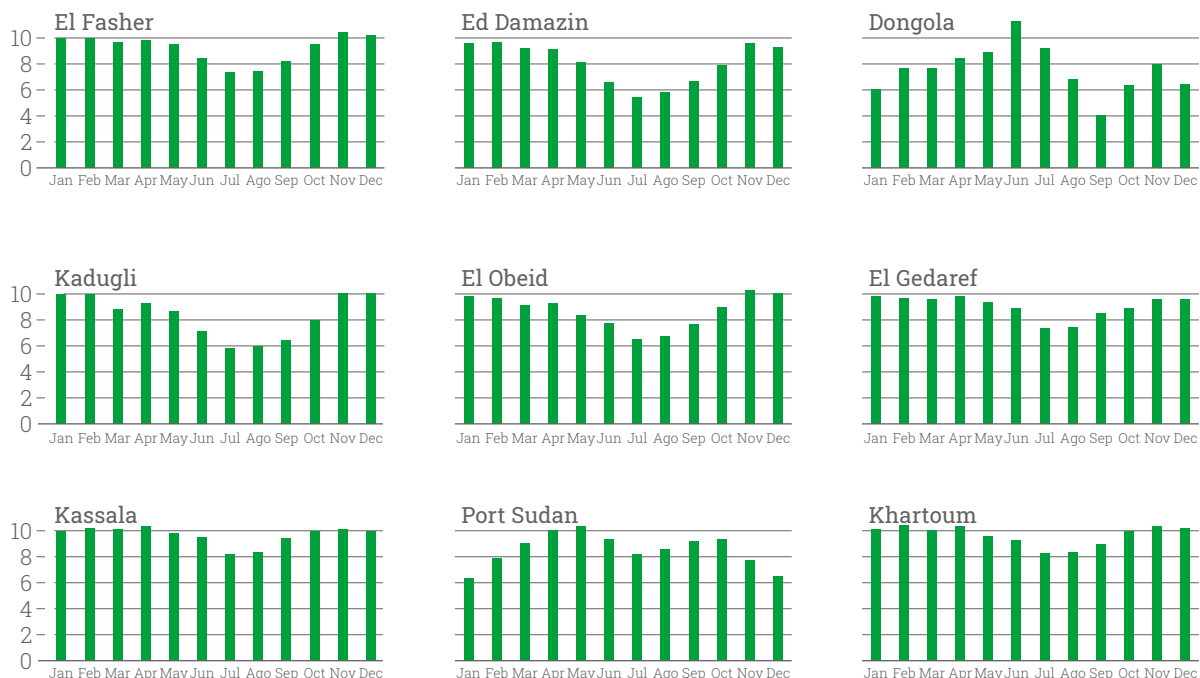
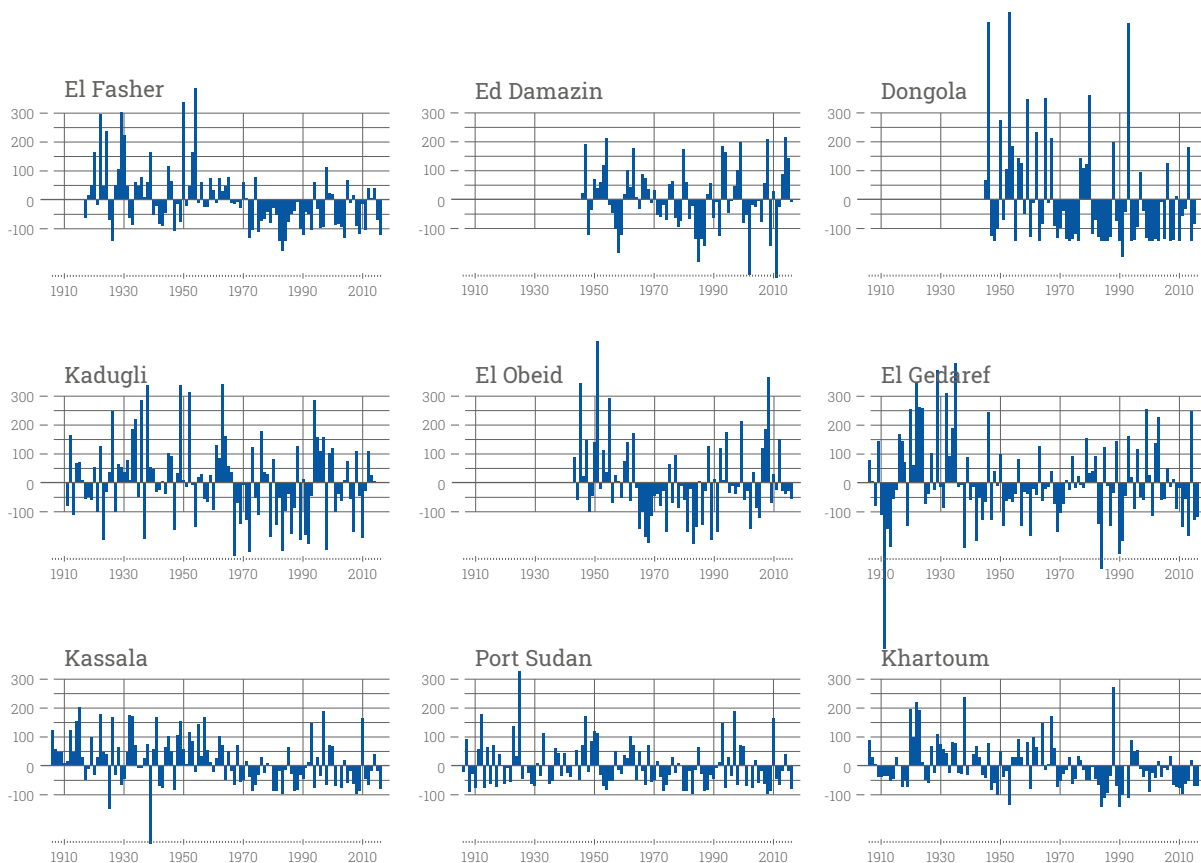


Figure 3.6 Long-term rainfall anomalies (Source: Sudan Meteorological Authority, processed by the author).



3.3.1 Climate change impacts

Sudan is highly vulnerable to the adverse impacts of climate change, particularly in the areas of agriculture, water resources and health (Zakieldeen and Elhassan 2015). The effects are already being felt in rising temperatures, reduced rainfall, an increase in the frequency of drought and floods and sea level rise (Zakieldeen and Elhassan 2015).

The Sudanese government's 2007 National Adaptation Programme of Action warns that, combined with growing socioeconomic pressures, climate change is likely to intensify the desertification of arable areas. It predicts that the agro-climatic zone will shift southward, making areas in the north increasingly unsuitable for agriculture. Crop yields for millet and sorghum are likely to decline because of decreasing rainfall and increasing variability in rainfall distribution patterns. The total area suitable for arable farming, as well as the important gum arabic belt, is expected to decrease, with serious consequences for local incomes and food security (Ministry of Environment and Physical Development 2007).

The decrease in rainfall and higher temperatures and evaporation rates will almost certainly have a negative impact on Sudan's water resources. Soil moisture is likely to decline too. Combined with an increase in water consumption due to population growth, and greater rainfall variability, these changes could result in a serious water crisis (Ministry of Environment and Physical Development 2007).

Climate change poses a direct threat to public health. Studies in Kordofan state have shown that the risk of malaria transmission could increase substantially by 2060 because of the higher temperatures (SFNC 2002). The higher temperatures could also mean that meningitis and leishmaniasis become more prevalent (Ministry of Environment and Physical Development 2007, cited by Zakieldeen and Elhassan 2015).

More generally, climate change will make it much harder for Sudan to achieve food security and sustainable development. With this in mind, the government aims to promote sustainable development by integrating climate change adaptation strategies into national policies and development plans. Its National Adaptation Plan (Ministry of Environment, Natural Resources and Physical Development 2016) identifies the following as the most significant threats to the water and agricultural sectors:

- ➔ Low and increasingly irregular and erratic rainfall regimes;
- ➔ Very high evaporation rates on open surface water bodies (hafirs, dams and irrigation canal systems);
- ➔ Increasing frequency of droughts and prolonged dry spells;
- ➔ Reduction in the length of the growing season due to increasing temperatures and undependable rainfall, resulting in lower agricultural productivity; and
- ➔ Socio-economic impacts such as food insecurity, social unrest and internal migration.

3.3.2 Adaptation and mitigation

Sudan is limited in what it can do to reduce its vulnerability to climate change, though it has launched a serious effort to switch from fossil fuels to renewable energy. Examples are pilot wind projects and replacement of diesel pumps with solar pumps in agricultural schemes in Northern State. It has also initiated a series of measures to help it adapt to climate change (Ministry of Environment and Physical Development 2007; Zakieldeen and Elhassan 2015). These measures are listed here by sector.

Agriculture:

- ➔ Crop diversification and introduction of improved drought-resistant and early maturing varieties;
- ➔ Rehabilitation of the country's meteorological stations to enhance early warning systems;
- ➔ Alternative sources of income for farmers;
- ➔ Introduction of agroforestry in areas vulnerable to climate change;
- ➔ Increase participation of women and young people in climate adaptation and environmental conservation;
- ➔ Increase the resilience of existing developmental projects against climatic change;
- ➔ Plant shelter belts, introduce trees of high economic value, rehabilitate gum arabic gardens;
- ➔ Regular surveillance of animal diseases through improved monitoring;
- ➔ Establishment of range enclosures or ranches for livestock;
- ➔ Advanced research on the impacts of climate change on rangelands;
- ➔ Joint national effort to assess the impact of climate change on natural resources;
- ➔ Sustainable management of grazing areas and rangelands;
- ➔ Improve animal productivity and select animal breeds for their resilience to climate change;
- ➔ Improve veterinary services in vulnerable areas, including mobile clinics and provision of vaccines.



Using solar energy for irrigation in North Kordofan as part of the Sudan National Adaptation Programme of Action. Photo credit © UNDP

Water:

- ➔ Integrated management of water resources to meet future needs;
- ➔ Water harvesting to help vulnerable communities;
- ➔ Establish or rehabilitate hand pumps and water supply networks in rural areas to secure drinking water supplies;
- ➔ Promote research into the impacts of climate change on the water sector;
- ➔ Establish more rain gauge stations to monitor variations in rainfall;
- ➔ Introduce a micro-credit fund to support small enterprises.

Coastal zone:

- ➔ Enhance monitoring programmes in rural and urban settings to detect biological, physical and chemical changes due to climate change;
- ➔ Improve the management of coastal zones by integrating development with ecological buffer zones and protected inland zones to accommodate salt marshes, mangroves and sea grasses;
- ➔ Raise awareness of the effects of climate change on coastal ecosystems.

Health:

- ➔ Introduction of early disease diagnosis and treatment programmes for malaria, meningitis and leishmaniasis;
- ➔ Raise public awareness of these diseases among vulnerable communities;
- ➔ Improve health services to meet the challenges of climate change;
- ➔ Increase resilience to climate change-related diseases by supporting family and school health programmes;
- ➔ Control insect-borne diseases, and diseases transmitted between humans and animals.

In the realm of mitigation, the following measures are recommended (Republic of Sudan 2013):

Energy:

- ➔ Integration of renewable energy in the power system;
- ➔ Energy efficiency;
- ➔ Electricity thermal generation using natural gas production.

Forestry:

- ➔ Afforestation and reforestation;
- ➔ National REDD+ strategy.

Waste:

- ➔ Propose collection of waste;
- ➔ Sanitary landfills;
- ➔ Adopting zero waste concept.

3.4 AIR QUALITY

Sudan has relatively clean air, though air pollution is increasingly becoming an issue of concern. Air pollutants can be gases, vapours or particulate matter. Their dispersal behaviour is affected by atmospheric conditions such as wind speed and direction, air temperature, atmospheric stability and humidity (Tiway and Colls 2010). Natural sources of air pollution include earthquakes, volcanoes, dust storms, food digestion by animals, radioactive decay within the Earth's crust, and forest and grassland wildfires. Human sources include fuel combustion for industrial and domestic purposes, other industrial processes, waste incineration, transportation and energy generation.

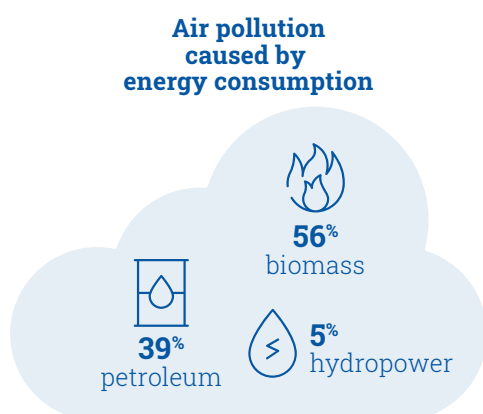
Air pollutants are classified as primary pollutants if they are directly emitted from a process (these include ash, carbon monoxide and sulfur dioxide), and as secondary pollutants if they arise from the interaction between two or more primary pollutants or the interaction between a primary pollutant and a constituent of the atmosphere (for example, ozone or peroxyacetyl nitrate) (Stern et al. 1984).

Air pollution can cause many adverse environmental effects. It can damage infrastructure (such as buildings and bridges), harm plants that are sensitive to certain chemicals, contribute to global warming via the greenhouse effect, cause acidification of water resources and obstruct visibility. It is also a threat to the health of humans and animals. Breathing in carbon monoxide can be fatal because it prevents oxygen reaching the heart and other organs (Department of Health and Human Services 2007). Nitrogen dioxide, a strong oxidant that reacts with water to form nitric acid and nitric oxide, can affect the immune system and lungs, resulting in decreased resistance to infection (Department of Health and Human Services 2007). Sulphur dioxide, if inhaled, can cause coughing, shortness of breath, sore throat and red, irritated eyes (Department of Health and Human Services 2007).

3.4.1 Air pollution

Air pollution often gets worse as a country develops. Between 2011 and 2018, Sudan's population increased from 33.98 million to 42 million and is expected to reach 57.3 million by 2030 (Government of Sudan 2019). This rapid growth, along with an influx of people into cities, has resulted in unplanned urban development, higher energy consumption, more traffic and greater industrialization, all of which cause pollution.

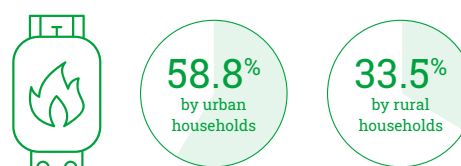
Most air pollution is caused by energy consumption. 56 per cent of Sudan's energy supply comes from biomass (wood, charcoal, agricultural residues and animal waste), 39 per cent from petroleum (gasoline, diesel and heavy oils) and 5 per cent from hydropower (Rabah et al. 2016). Brickeries utilize the silt from the Blue Nile, consume fuel wood and are a source of air pollution not far from residential areas.



The majority of Sudanese people used to depend on biomass for their domestic energy needs, especially wood and charcoal. Most household energy is used for preparing food. The process causes much smoke, soot and moisture, though this can be reduced through the use of improved stoves. A significant amount of air pollution in urban areas is caused by cooking stoves run on charcoal, wood and other biomass fuels. Of greater concern is the indoor pollution caused by inefficient stoves, which can have serious health repercussions. One positive development is that liquefied petroleum gas (LPG), which is cleaner and more efficient than biomass, is fast

becoming the most popular cooking fuel, especially in urban areas. It is easily available on the local market as one of the country's petroleum bi-products. As of 2014, LPG makes up 58.8 per cent of the energy used by urban households, compared with 33.5 per cent for rural households (Central Bureau of Statistics 2016).

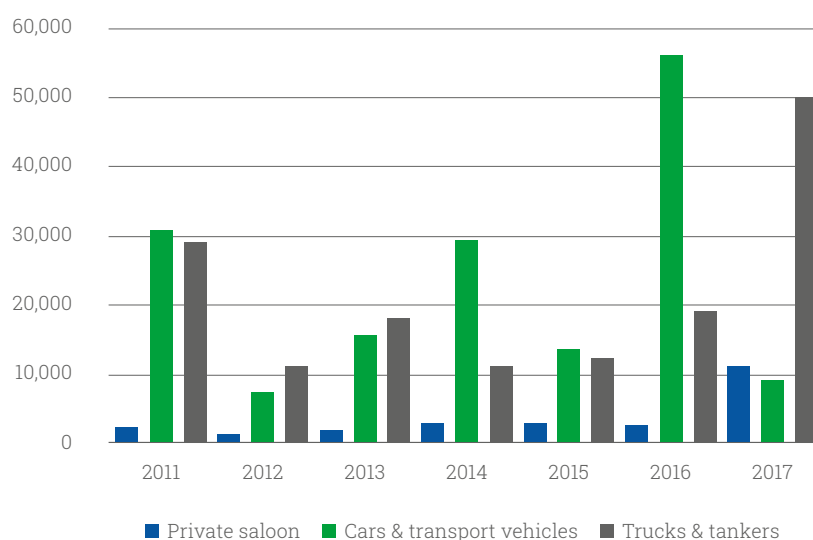
Portion of LPG in energy used in 2014



Sudan's expanding industrial sector is a cause of significant air pollution. Its most polluting industries in terms of emissions include integrated iron and steel (16 plants nationwide), thermal power plants (the main thermal plants are Um Dabakir, which uses oil, and Garri stations, which are Combined Cycle Gas Turbines), metal smelters, cement (six plants), sugar (six factories), oil refineries (three plants) and petrochemicals. These industries are mostly situated in the states of Khartoum, Gezira, River Nile, White Nile, Sennar and North Kordofan. Factories that are close to densely populated areas, such as Aljneed sugar factory near Al Hassahiesa town and the cement factories in the cities of Atbara and Rabak, create a significant health risk for a large number of people. Thermal electricity plants, which are mostly powered by fossil fuels, emit a range of pollutants including particulate matter, toxic elements, fly ash, oxides of nitrogen, sulphur dioxide, carbon monoxide and carbon dioxide.

Another source of air pollution of growing concern in Sudan is road vehicles. Recently there has been a sharp increase in the number of imported vehicles (Figure 3.7). They mainly run on petrol and diesel and are old and polluting. Two-stroke motor vehicles (rickshaws) are also increasing in number and are a concern because of their use of poorly mixed fuel and oil, and also because of how they affect the flow of traffic.

Figure 3.7 Imported vehicles 2011–2017 (Source: Custom Administration 2018)



3.4.2 Impacts of air pollution

Air pollution causes a variety of common health issues, including irritation to the eyes and respiratory system, headaches and dizziness. It can also cause more serious respiratory and lung diseases such as asthma, chronic obstructive pulmonary disease, reduced lung function, pulmonary cancer, mesothelioma, pneumonia, leukemia, birth and immune system defects, cardiovascular problems, heart disease and stroke (Department of Health and Human Services 2007). Air pollution from biomass stoves particularly affects women responsible for household activities, together with their children below the age of five. As Table 3.1 shows, respiratory diseases accounted for a large proportion of illnesses and hospital admissions in Sudan in 1998.

3.4.3 Air pollution management

Sudan has many laws that address environmental pollution, including the Environmental Health Act (2009), the Labour Act (1997) (Industrial Safety Article), the Pesticides and Pest Control Products Act (1994), and the Environment Protection Act (2001). In addition to these laws, the Sudanese Standards and Metrology Organization (SSMO) has established ambient air standards for various pollutants such as nitrogen oxides, lead and carbon monoxide (Table 3.2), as well as maximum limits for pollutants at their source of emission (Table 3.3). There are also guidelines that stipulate how far industrial areas can be sited from residential areas.



Brick making near the Blue Nile bank in Khartoum. Using fuelwood is a major cause of air pollution. Photo credit © Osman Ali

Table 3.1 Respiratory diseases in Sudan in 1998

Cases	Total diseases	<5 years	Respiratory	Asthma	Chronic obstructive pulmonary	Cardio-vascular	Acute respiratory infections in <5 y age
Total	24,471,222	6,771,957	2,507,101	28,663	88,4859	10,011	666,233
Hospital admission	404,484	222,253	6,778	4,011	31,611	4,105	4327
Mortality	12,852	3,205	185	40	455	853	137

Source: Federal Ministry of Health 1998

3 Atmosphere



Increased use of Liquefied Petroleum Gas (LPG) as an alternative for fuelwood. Photo credit © UNDP



Indoor air pollution caused by fuelwood. Photo credit © UNAMID

Table 3.2 Maximum allowable concentrations for ambient air pollutants (SSMO 2012a)

Pollutant	Symbol	Unit	Average period	Allowable concentration	Excursions
Sulphur dioxide	SO ₂	µmg/m ³	Hour	300	Three times per year during any 30 successive days
			Day	140	Once for any 12 months
			Year	40	
Carbon monoxide	CO	µmg/m ³	Hour	30	Three times per year during any 30 successive days
Total suspended particulate matter	TSP	µmg/m ³	Day	10	Three times per year during any 30 successive days
			Day	270	Three times per year during any 30 successive days
			Year	80	
Nitrogen oxides	NO _x	µmg/m ³	Hour	220	Three times per year during any 30 successive days
			Day	80	Three times per year during any 30 successive days
			Hour	50	Three times per year during any 30 successive days
Hydrogen sulphide	H ₂ S	µmg/m ³	Hour	30	Three times per year during any 30 successive days
			Day	10	Three times per year during any 30 successive days
Ozone	O ₃	µmg/m ³	Hour	130	
			Day	60	
Radon	Rn ₂₂	Bq/l		600	
Lead	Pb	µmg/m ³	Year	0.6	
Respirable particulate matter	PM ₁₀	µmg/m ³	Day	125	Three times per year during any 30 successive days
			Year	73	
Fine particulate matter	PM ₂₅	µmg/m ³	Day	10	
			Year	25	

Table 3.3 Maximum allowable concentrations for pollutants at source of emission (SSMO 2012b)

Pollutant	Unit	Maximum allowable concentration
Carbon monoxide	µmg/m ³	250
Nitrogen oxides	µmg/m ³	400
Sulphur dioxide	µmg/m ³	3.0
Sulphur trioxide	µmg/m ³	1.0
Total suspended particulate matter	µmg/m ³	50.0
Lead	µmg/m ³	20.0
Antimony and its compounds	µmg/m ³	10.0
Arsenic and its compounds	µmg/m ³	10.0
Cadmium and its compounds	µmg/m ³	3.0
Copper and its compounds	µmg/m ³	10.0
Mercury and its compounds	µmg/m ³	3.0
Nickel and its compounds	µmg/m ³	5.0
Chlorine	µmg/m ³	5.0
Hydrogen chloride	µmg/m ³	10.0
Fluorine and its compounds	µmg/m ³	5.0
Formaldehyde	µmg/m ³	6.0
Carbon	µmg/m ³	100.0
Silicon fluoride	µmg/m ³	10
Ammonia	µmg/m ³	5.0
Dioxins/ Furan	TEQ(ng)	0.1

3.5 CONCLUSION

The climate of Sudan ranges from arid in the north to tropical wet and sub-humid in the south. Desert regions in central and northern Sudan are among the driest and the sunniest places on Earth. The country has no extensive bodies of water and almost all its moisture comes from the distant Atlantic and Indian Oceans, which means that its rainfall is closely linked to sea surface temperatures. The rainy season lasts from May to October in the southern part of the country, from June to September in the central and northern parts, and from October to January in the Red Sea coastal zone.

Climate data from Sudan's nine meteorological stations shows that rainfall across the country is decreasing and becoming highly variable. Maximum and minimum temperatures have increased at all the stations except Khartoum, Kadugli and El Obeid. These changes have started to have a significant impact on Sudan's agriculture, resulting in lower crop

yields and animal productivity. Droughts are increasing in frequency, leading to food insecurity in some years. Floods are common in central and southern Sudan. The government is developing a range of strategies in response to climate change, including alternative sources of income for farmers, improved water management, disaster mitigation, and encouraging agricultural insurance schemes.

Air quality in Sudan is good except in areas close to sources of pollution such as industrial plants and factories, and in urban areas with high traffic densities. Natural air pollution occurs in the form of dust storms that affect arid and semi-arid areas in east, central and northern Sudan. The most worrying source of indoor air pollution are the biomass cooking stoves used in rural households, which can cause respiratory illnesses mainly in women and children. The country has many laws and air quality standards that address environmental pollution, though monitoring remains a challenge, and many of the laws are poorly enforced.

References

REFERENCES

1. Abdalla, K. A. (2017). Water and Climate. In A. M. Salih (Ed.). *Water Resources of the Sudan* (1st ed., pp 1–40). Water Research Center, University of Khartoum.
2. 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=W1siZiZlsljwMTYvMDUvMTgvMjEvNT-kvNTEvODg3L1N1ZGFuXzlwMTRfTUIDU19Fbmd-saXNoLnBkZiJdXQ&sha=32907fc39e6e2e6e>
3. Tiwary, A. and Colls, J. (2010). *Air Pollution: measurement, modelling, and mitigation*. (3rd ed., pp 501). Publisher: Routledge, Abingdon, UK.
4. Department of Health and Human Services (DHHS) (2007). The National Institute for Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards, DHHS Publication No. 2005-149. Retrieved from: <https://www.cdc.gov/niosh/docs/2005-149/pdfs/2005-149.pdf>
5. Government of Sudan (GoS) (2019). Sudan Central Bureau of Statistics (CBS) 2018 annual report.
6. Ministry of Environment and Physical Development (2003). Sudan's First National Communications under the United Nations Framework Convention on Climate Change. Retrieved from: https://unfccc.int/sites/default/files/resource/VOLUME1-30-MAY-03-FINAL_1.pdf
7. Intergovernmental Panel on Climate Change (IPCC) (2014). Climate Change 2014. Synthesis Report. Retrieved from: https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf
8. Intergovernmental Panel on Climate Change (IPCC) (2018). Global Warming of 1.5 oC. Retrieved from: https://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf
9. Khyar, A. and Fota, M. (2001). Rainfall Atlas for the Republic of Sudan Drought Monitoring Centre Nairobi, Kenya.
10. Ministry of Environment and Physical Development. (2007). National Adaptation Programme of Action (NAPA). Higher Council for Environment and Natural Resources (HCENR). Retrieved from: <https://unfccc.int/resource/docs/napa/sdn01.pdf>
11. Ministry of Environment, Natural Resources and Physical Development (2016). National Adaptation Plan (NAP). Higher Council for Environment and Natural Resources (HCENR). Retrieved from: <https://www4.unfccc.int/sites/NAPC/Documents%20NAP/National%20Reports/Sudan%20NAP.pdf>
12. 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*. Retrieved from: <http://dx.doi.org/10.1155/2016/5082678>
13. Republic of Sudan (2013). Sudan's Second National Communication under the United Nations Framework on Climate Change. Retrieved from: <https://unfccc.int/resource/docs/natc/sudnc2.pdf>
14. Sudan Standards and Meteorology Organization (SSMO) (2012b). SSD No. 2389/2012: Maximum allowable concentrations for pollutants at source of emissions.
15. Stern, A. C., Boubel, R. W., Turner, D. B. and Fox, D. L. (1984). *Fundamentals of Air Pollution*. Second Edition. Academic Press. New York. Retrieved from: <https://doi.org/10.1002/joc.3370050210>
16. Sudan National REDD + Programme (2017). Land use in Sudan: Study final report. Forests National Corporation. Retrieved from: <https://www.reddplussd.org/phocadownload/userupload/Final%20Landuse%20and%20REDD.pdf>
17. United Nations Environment Programme (UNEP) (2015). Air quality policies in Sudan. Retrieved from: <https://www.unenvironment.org/resources/report/air-quality-policies-sudan>
18. UNEP, WMO, UNCCD (2016). Global Assessment of Sand and Dust Storms. (Ed.) G. Shephard. United Nations Environment Programme, Nairobi. Retrieved from: https://uneplive.unep.org/redesign/media/docs/assessments/global_assessment_of_sand_and_dust_storms.pdf
19. Zakieldeen, S. A. and Elhassan, N. G. (2015). Climate Change Impacts, Vulnerability and Adaptation. *Sudan Academy of Science Journal*, 11, 217–233.

The Gezira Scheme is the largest irrigated scheme in Sudan under one administration. Photo credit © UNEP

4

Land Resources

4.1 INTRODUCTION

Sudan's land area covers 1.88 million km², 72 per cent of which is desert (FAO 2015a). Most of the desert is sparsely populated, with low-intensity pastoralism the dominant activity, though there are pockets of gold mining. The River Nile supports much of the country's irrigated agriculture. The central and southern parts of the country consist of the semi-arid Sahel belt and the humid savannah where most of the population live, and where rain-fed and irrigated agriculture are widespread. Oil is produced in the Sahel. The west of the country is dedicated to rain-fed cultivation and pastoralism; it is also where most of the country's gum arabic is produced.

Despite its growing industrialization, Sudan remains largely agrarian in its social, economic and cultural outlook. The majority of the country's 42 million population lives in rural areas and depends on crop farming and traditional pastoralism. Natural resources are the backbone of the economy: the agricultural sector accounts for approximately 30-35 per cent of the country's Gross Domestic Product (GDP) and provides a livelihood for about 65 per cent of the population (World Bank and Ministry of Agriculture 2016).

Land in Sudan is under increasing pressure from the growing population, increasing numbers of livestock, intensive arable farming, the expanding petroleum and gold-mining industries, and ecological problems caused by accelerating climate change. The secession of South Sudan reduced Sudan's land area by 25 per cent (FAO 2015b), closed off many traditional pastoral routes and led to an influx of refugees from South Sudan. Land has become a scarce resource, and competition for it has even led to conflict. It has become a political tool, too: following the loss of more than 70 per cent of the country's oil revenue to South Sudan (World Bank 2014), land is now the main commodity that the government uses to attract foreign investment.

Despite these threats, there are huge opportunities for Sudan's land resources to play an even greater role in the country's economic growth, peace and sustainable development.

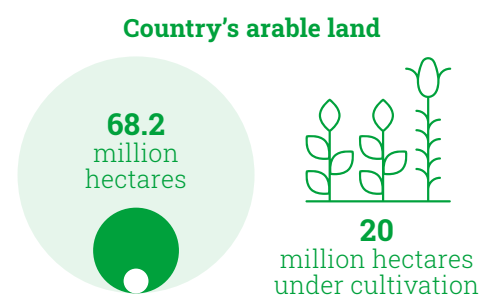
4.2 OVERVIEW OF LAND RESOURCES

Sudan is a dry land country, consisting mainly of desert or semi-desert. The 28 per cent that is not desert is in the south and comprises either low-rainfall

savannah (receiving 300 to 500 mm of rainfall per year) or rich savanna (receiving more than 500 mm of rain per year) (FAO 2015; UNEP 2012). Rainfall patterns and the duration of the rainy season are highly varied across the country. Droughts are frequent and are often followed by famines and outbreaks of disease (Teklu et al. 1991).

4.2.1 Arable Land

Sudan has around 68.2 million hectares of arable land (approximately 183.3 million feddans), which makes up about 36.2 per cent of the country (FAO 2018a). However, only around 29 per cent of this land (20.0 million ha) is cultivated. Most arable land is in the Kordofan (35.6 per cent of the country's arable cover) and Darfur (32.4 per cent) regions. There is also arable land in the states of Gedaref (6 per cent), Sennar (4.3 per cent), Blue Nile (4.1 per cent) and White Nile (4 per cent). The two main staple crops are sorghum, grown on clay soils, and millet, grown on sandy soils. Cash crops include sesame, groundnut, sunflower, kerkade (roselle), water melon and sugarcane.



4.2.2 Soils

The soils of Sudan can be divided into seven categories (FAO 2006):

- ➔ Xerosol soils of the hyper-arid area. These cover about 78 million hectares and are composed of superficial deposits of sand with bare rock debris, shifting dunes and consolidated dunes;
- ➔ Recent alluvium, which provides the basis for agriculture along the River Nile north of Khartoum, the two deltas of Baraka and Gash in East Sudan, and the beds and floodplains of the seasonal watercourses that are found in most parts of the country;

4 Land Resources

- ➔ Arenosols, which cover about 40 million hectares towards the south of the country. The arenosols are known locally as Goz (sandy dune) soil, and are the typical soils of North Kordofan State. In the Goz areas, there are patches of inter-dune soil usually of comparatively limited extent called Gardud soils. These soils are low in nutrients and organic matter, and they are highly vulnerable to erosion and free-draining. They are mixed with clay or ferruginous clay near the surface, making them firm after rainfall;
- ➔ Vertisols, found across 70 million hectares on the central clay plains. They have considerable agricultural potential;
- ➔ Ferralsols, which cover 30 million hectares of the dry sub-humid areas. They have low natural fertility, but are deep with high permeability and stable microstructure that make them less susceptible to erosion;
- ➔ Rocky soils of the Red Sea Hills and parts of the Jebel Marra mountains. They are classified as Leptosols and make up 18 million hectares. These soils are shallow, poor in nutrients, with high gravel content;
- ➔ Cambisols make up the smallest soil group in Sudan, covering 2 million hectares. The cambisols are among the most productive soils in the country. They are found in dry and moist sub-humid conditions in the Ethiopian Highlands where they are prone to water erosion.



Karkade (Roselle) crop in Al Obaied crops market, North Kordofan. Photo Credit © UNEP



Sorghum is one of the main staple crops in Sudan. Photo credit © UNEP



Typical Goz land in Kordofan region. Photo credit © Osman Ali

4 Land Resources

4.2.3 Water resources

Sudan has substantial freshwater resources – almost half the Nile River Basin lies within its borders. It also has significant but poorly developed groundwater reserves. The largest of these is the Nubian Sandstone Aquifer, which Sudan shares with Chad, Egypt and Libya. There is not yet a regional institutional arrangement for the sharing of water from this aquifer (Hamad 2019). Access to water resources in Sudan is inequitable, with wide disparity between regions. For example, over 93 per cent of household members in Northern state have access to improved water sources, compared to 27.7 per cent in Gedaref state, 32.7 in White Nile state and 33.2 per cent in Red Sea state (Fig. 4.1), while the average for Sudan is 68.0 per cent (Central Bureau of Statistics 2016). Lack of access to water is a source of great hardship especially for women and children living far from the Nile and its tributaries; it is also a cause of conflict in some parts of the country.

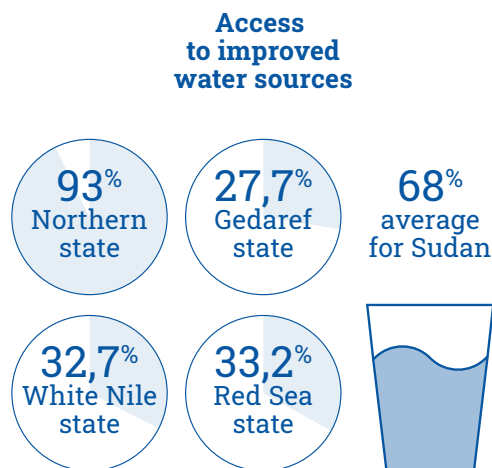
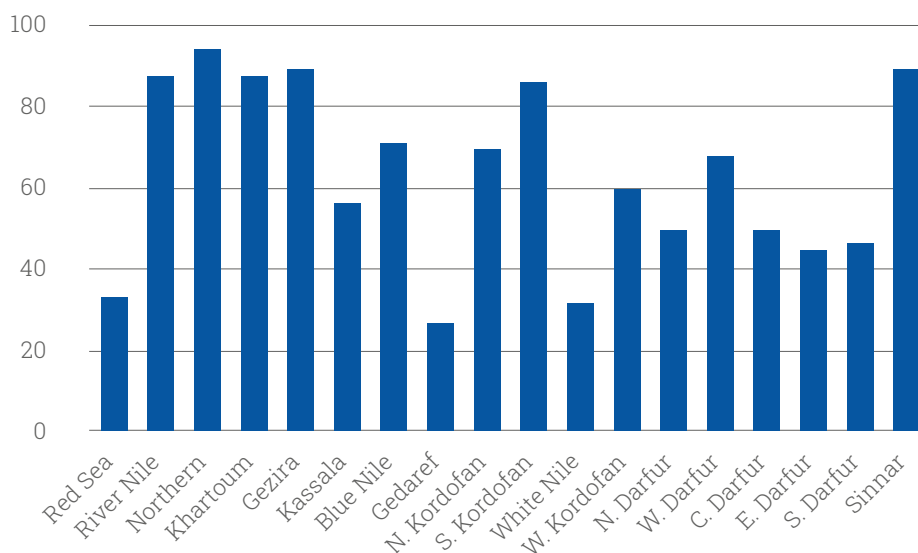


Figure 4.1 Percentage of population with access to safe drinking water, by state (Central Bureau of Statistics 2016)

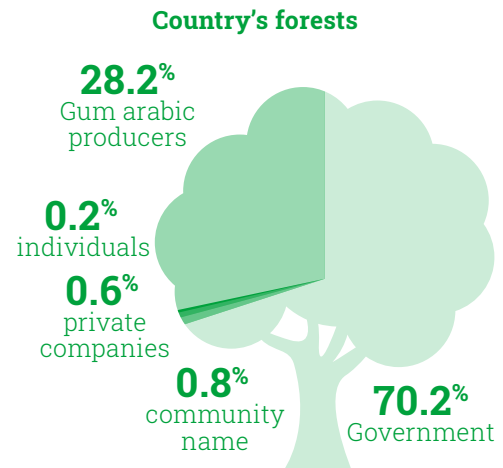


4.2.4 Forests

Data on the extent of forests and rangelands in Sudan is extremely limited and can only be extrapolated from *ad hoc* surveys. The land cover map produced by the Food and Agriculture Organization (FAO) and the United Nations Environment Programme (UNEP) in 2012 shows trees covering 10 per cent of the country. As Table 4.2 shows, South Kordofan accounts for more than a third of Sudan's total tree cover; almost 51 per cent of the state is planted with trees. The low coverage in Blue Nile, Kassala, White Nile and Gedaref states is mainly due to the vast expansion of semi-mechanized farming. Sennar state's more extensive coverage is due to Dinder National Park, the largest reserved area in the country.

Sudan has 17 million feddans or 714 km² of protected forest reserves (Gafar 2013). Most of the reserves are in West Darfur, South Darfur, Gedaref, Blue Nile and White Nile states. 70.2 per cent of the country's forests are owned by the government and managed by Forests National Corporation (Gafar 2013). Gum

arabic producers own 28.2 per cent, while 0.2 per cent are owned by individuals. Forests registered under community names and private companies represent 0.8 and 0.6 per cent respectively (Gafar 2013). Deforestation in Sudan is estimated at 2.4 per cent a year, one of the highest rates of deforestation in the world (Gafar 2013).



Forest in Kadugli, South Kordofan. Photo credit © UNEP

4 Land Resources

4.2.5 Rangelands

Rangelands make up 25.6 per cent of Sudan's total land area (FAO and UNEP 2012). There is great variability in distribution across the states: rangelands account for over 60 per cent of South Darfur state but only 0.5 per cent of Khartoum and Northern states (Table 4.1). Nearly two-thirds of the country's rangelands are found in the three states of North Darfur, North Kordofan and South Darfur (FAO and UNEP 2012).

The Range and Pasture Law 2015 recognizes and identifies four categories of rangelands: public grazing lands, private *hema*, commonly held *hema* and privately cultivated rangeland. State authorities

are responsible for the management of rangelands, in coordination with those who use them. The law gives state authorities the right to impose restrictions on grazing, and to allocate land for grazing for the benefit of the whole community. The law also prohibits closure of livestock routes (Government of Sudan 2015).

Rangelands in Sudan have been severely depleted, particularly by the expansion of farmland. In 2007, UNEP estimated that Sudan had lost between 20 and 50 per cent of its rangelands (UNEP 2007). The loss of rangelands and the deterioration in the quality and accessibility of grazing land is considered to be the root cause of conflict between pastoralists and farmers in Sudan.



Cattle grazing in AL Gazala Jawazat, East Darfur. Photo credit © UNEP

4.2.6 National parks and protected areas

National parks and other protected areas cover 8.1 per cent (150,963 km²) of the country. Most of this protected land is accounted for by three sites: Wadi Howar (100,000 km²), Radom (12,500 km²) and Dinder (10,000 km²) (UNEP 2007).

Dinder National Park, in the arid and semi-arid Sudano-Saharan zone, is one of the most important and ecologically

rich areas in Sudan (UNEP 2007). Established in 1935, the park is 70 per cent biosphere reserve and 30 per cent buffer zone (World Conservation Monitoring Centre 1993). Its most important features are a series of seasonal wetlands known locally as mayas. The wetlands are linked to the Dinder seasonal stream which rises in the Ethiopian highlands to the east (Hassaballah et al. 2016). The Dinder National Park transcends three states: Blue Nile (in the southeast part of the park), Sennar (in the north) and Gedaref (in the northeast).

4 Land Resources

Table 4.1 Rangeland areas and distribution by state in 2012 (hectares)

State name	State area	Shrubs	Herbaceous	Total (shrub + herbaceous)	% of state area	% of total (shrub + herbaceous)
Blue Nile	3,817	553	338	891	23.3	1.8
Gedaref	5,958	198	1,208	1,406	23.6	2.9
Gezira	2,713	17	335	352	13.0	0.7
Kassala	4,871	158	791	949	19.5	2.0
Khartoum	2,122	34	203	237	11.2	0.5
Northern	36,569	112	151	262	0.7	0.5
North Darfur	31,751	2,734	8,853	11,587	36.5	24.0
North Kordofan	24,056	5,776	5,136	10,912	45.3	22.7
Red Sea	21,623	1,031	579	1,610	7.4	3.3
River Nile	13,029	72	507	579	4.4	1.2
Sennar	3,924	504	400	904	23.0	1.9
South Darfur	14,163	4,722	4,035	8,757	61.8	18.2
South Kordofan	14,086	4,135	675	4,810	34.1	10.0
West Darfur	5,476	1,690	1,970	3,660	66.8	7.6
White Nile	3,799	494	802	1,296	34.1	2.7
Total	187,955	22,231	25,983	48,213	25.6	100.0

Source: Compiled and calculated from FAO and UNEP 2012

Until the 1960s, the area surrounding Dinder was relatively uninhabited. Since then, however, migration and irrational land use have resulted in development around the park, to an extent that around forty villages now exist along its boundaries (Hussien 2015). Today the park is surrounded by settlements, and there are ten villages within the boundaries of the park along the Rahad River (Hameed and Eljack 2003). In the 1980s, the expansion of mechanized farming led to vast areas of the park being appropriated for crops and grazing. Consequently, competition takes place between livestock and wild animals, which jeopardizes the survival of the wild animals (Yousif and Mohamed 2012).

Radom National Park is in South Darfur state, close to the border with the Central African Republic and bordering South Sudan (El Khidir and Ali 2018). It was designated as a biosphere reserve in 1979 and as one of UNESCO's World Network of Biosphere

Reserves in 1982 (UNESCO 2018). Encompassing 12,500 km², the park consists of savanna woodlands and forests. Recently it has suffered from a growing influx of people, including refugees, who have settled within its boundaries and exploited its resources for agriculture, honey collection, pastoralism and tree-felling for trade and charcoal (El Khidir and Ali 2018). The park has also been under pressure from the Darfur conflict since 2003, and more recently from artisanal gold mining.

Wadi Howar extends across the Darfur province of Sudan for more than 600 km. In the geological past, Wadi Howar was probably one of the most important tributaries of the Paleo Nile. It has diverse flora and outstanding geological features, including the volcanic landscape of Meidob Hills and numerous paleo lakes. The dorcas gazelle, the Barbary sheep, the North African ostrich and other wildlife are also present.

4 Land Resources

Table 4.2 Land cover by type in Sudan (hectares)¹

	AG	TCO	SCO	HCO	URB	BS	WAT	TOTAL
Blue Nile	1,275,917	1,582,755	553,158	338,253	13,413	16,248	37,209	3,816,953
Gedaref	3,458,932	598,354	197,738	1,207,604	39,799	331,314	124,163	5,957,904
Gezira	2,075,149	68,536	16,991	335,004	75,660	128,948	13,149	2,713,437
Kassala	1,077,738	401,488	157,925	791,092	23,756	2,377,681	41,544	4,871,224
Khar-toum	224,523	44,618	34,301	203,224	84,682	1,513,983	15,578	2,120,909
Northern	110,858	29,635	112,526	150,729	55,148	35,995,792	114,488	36,569,177
North Darfur	1,458,402	469,914	2,733,627	8,853,330	47,407	18,081,358	107,158	31,751,197
North Kordofan	4,571,176	2,852,632	5,776,385	5,135,514	146,862	5,188,063	385,136	24,055,768
Red Sea	30,155	458,962	1,030,880	578,602	17,522	19,479,544	27,033	21,622,699
River Nile	227,937	22,408	72,130	507,026	44,245	12,112,321	42,828	13,028,895
Sinnar	2,458,947	480,173	504,186	400,492	37,659	9,963	32,808	3,924,228
South Darfur	2,122,492	3,157,458	4,722,374	4,034,753	48,996	10,414	66,245	14,162,732
South Kordofan	1,963,585	7,174,761	4,134,598	675,395	36,182	11,999	89,235	14,085,754
West Darfur	599,674	1,120,237	1,690,251	1,969,654	17,016	9,771	69,258	5,475,861
White Nile	2,054,539	271,251	494,257	802,049	41,985	10,328	124,166	3,798,575
Grand total	23,710,025	18,733,182	22,231,327	25,982,720	730,331	95,277,727	1,290,000	187,955,312
%	12.6	10.0	11.8	13.8	0.4	50.7	0.7	100.0

Source: FAO and UNEP's 2012

¹ Hectare = 10,000 m² = 2.38 feddans

Key:

AG: Agriculture in terrestrial and aquatic/regularly flooded land

TCO: Trees closed-to-sparse in terrestrial and aquatic/regularly flooded land

SCO: Shrubs closed-to-sparse in terrestrial and aquatic/regularly flooded land

HCO: Herbaceous closed-to-sparse in terrestrial and aquatic/regularly flooded land

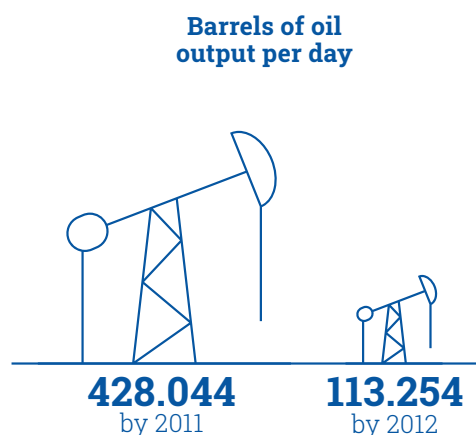
URB: Urban areas

BS: Bare rocks and soil and/or other unconsolidated material(s)

WAT: Seasonal/perennial, natural/artificial water bodies

4.2.7 Oil fields

The commercial production of oil in Sudan began in 1999 when the country made its first export (European Coalition on Oil in Sudan 2007). By 2011, oil output had reached 428,044 barrels a day, but this dropped to 113,254 barrels a day the following year after the secession of South Sudan. By 2018 it had risen to 251,800 barrels a day (Census and Economic Information Center 2018). Most of Sudan's oil fields and known reserves are in the Muglad and Melut rift basins in West Kordofan. The oil fields are linked to the country's refineries via three pipelines. The largest pipeline runs across the Misseriyya area from Heglig to Port Sudan. The others are the Petrodar pipeline which extends for 1,380 km from the Palogue oil field in the Melut Basin to Port Sudan (Pantuliano et al 2009), and the 740-kilometre El Fula pipeline that connects El Fula oil fields to the refinery in Khartoum (European Coalition on Oil in Sudan 2007). Al Rawat area, to the south of Kostî in White Nile state, has commercially viable fields, and off-shore exploration is also being pursued.



Notwithstanding the crucial role it has played in Sudan's economy, oil production is associated with a wide range of environmental and socioeconomic problems. One of the direct impacts has been the removal of forest vegetation within and around the oil fields and along the pipeline corridors. Local communities in West Kordofan state claim that the drying up of Lake Keilak is largely due to soil works and road construction that impede the water replenishment of the seasonal lake. The increased value of land around oil reserves has led to conflict over access and ownership and disputes over compensation. One example is the conflict between the Awlad

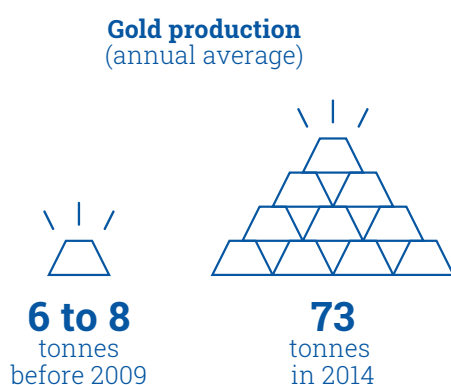


An oil field camp in West Kordofan. Credit credit © Prof. Zuhair Noreldayim

Haiban and Awlad Sirur tribes in West Kordofan in 2013, which resulted in the deaths of 130 people (El Radi 2016). Oil drilling in West Kordofan, together with the separation of South Sudan in 2011, have had an enormous impact on the livelihoods of Misseriyya pastoralists, who among other changes have been forced to switch from cattle to sheep farming because of a reduction in grazing areas (Pantuliano et al. 2009).

4.2.8 Gold mines

Gold production in Sudan increased from an annual average of 6 to 8 tonnes before 2009 to a peak of 73 tonnes in 2014 (Ministry of Finance and National Economy 2015). The primary producers are the small-scale independent artisanal miners whose output in 2014 amounted to 60 tonnes, more than six times that of the big public and private companies (Ibrahim 2015). The major deposits are in the northern desert regions of Northern and River Nile states, as well as in North Darfur (Jebel Amir area), central Butana Plains (areas around Subagh) and scattered areas in North Kordofan, South Darfur and eastern South Kordofan.



The artisanal mining sector provides employment for more than one million people in Sudan and contributes directly or indirectly to the livelihoods of more than five million (Ministry of Finance and National Economy 2015). Gold mining is becoming an important mechanism for poverty reduction. The gold sector contributes substantially to the national economy, accounting for almost one third of the total value of exports, which exceeds the contribution of the agricultural sector (Ministry of Finance and National Economy 2015). In addition, gold mining has driven growth in other sectors of the economy, especially service provision, transport and trade. The government of Sudan considers gold mining a top priority sector with enormous future potential for the national economy, especially after the loss of more than 70 per cent of oil

revenue to South Sudan (UNDP 2015a). Localities also benefit through local taxes imposed on gold businesses.

Despite its enormous economic value, Sudan's gold mining industry is poorly organized and regulated. This has had far-reaching environmental and social consequences, including the transformation of vast tracts of pastoral and agricultural lands into open pits, the loss of vegetation, oil and water pollution, and highly inflated land prices. The influx of miners from different parts of the country, as well as from neighbouring countries in West and East Africa, has led to price distortions in local economies, increased levels of crime and the proliferation of diseases. Another effect has been a severe labour shortage in other sectors, especially agriculture.

4.3 AGRICULTURE

In the 2017/2018 agricultural season, approximately 56 million feddans (23.5 million hectares) were under cultivation. As Figure 4.2 shows, there has been a steady growth in the amount of land under cultivation, making access to land one of the major drivers of local conflicts.

4.3.1 Rain-fed agriculture

In 2017/18, cereals such as dura, millet and wheat were grown on 30.7 million feddans (12.89 million hectares) out of the 56 million feddans (23.5 million hectares) under cultivation in Sudan (Ministry of Agriculture and Forests 2018). Rain-fed agriculture accounted for 29.5 million feddans (12.4 million hectares), representing 96.1 per cent of the total area under cereals (Ministry of Agriculture and Forests 2018).

Average crop yields for cereals have been steadily declining over the past 60 years, falling from around 350 kg/feddan in the late 1960s to an average of 150 kg/feddan in 2012/13, as Figure 4.3 shows (Egemi 2017). Low productivity and declining yields have become major concerns for the country's agricultural sector. An analysis of 65 years of data for all crops revealed that although the area under cultivation in Sudan has grown by 3.71 per cent a year, output has grown by only 2.53 per cent a year, while the yield per unit area has declined by 1.18 per cent a year (Ijaimi 2017).

Rain-fed agriculture contributes about 60 per cent of the country's food grain production and employs more than 60 per cent of the labour force in rural areas (Ministry of Finance and National Economy 2011). Rain-fed agriculture is Sudan's traditional farming system and

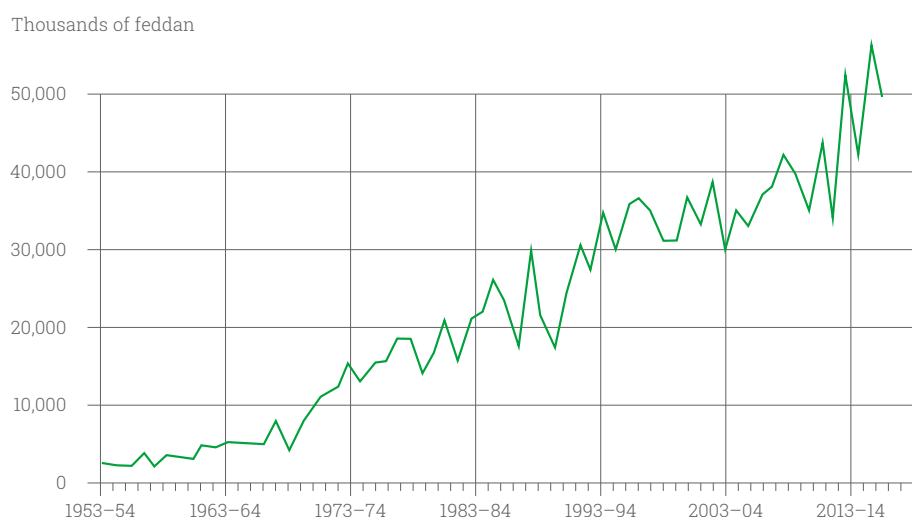
4 Land Resources

provides most of the food for rural communities. A traditional farm is a household-based system centred on the cultivation of food crops using long-established technologies such as animal-drawn ploughs and hand tools like the hoe and the digging stick. Water-lifting devices (*Ar. Shaduf*) are used to irrigate small vegetable plots. Home gardens (*Ar. Jubraka*) on small plots are widely used on the rainlands of Kordofan and Darfur to produce quick-maturing foods to provide sustenance to the household during the hungry season between cultivation and harvest.

Traditional rain-fed farming is becoming increasingly market-oriented. The introduction of tractors and other machinery has led to an increase in the number and size of cultivated plots. This has had unforeseen negative consequences, including land degradation, increased competition for land, the closure of livestock routes and an increase in local conflicts.

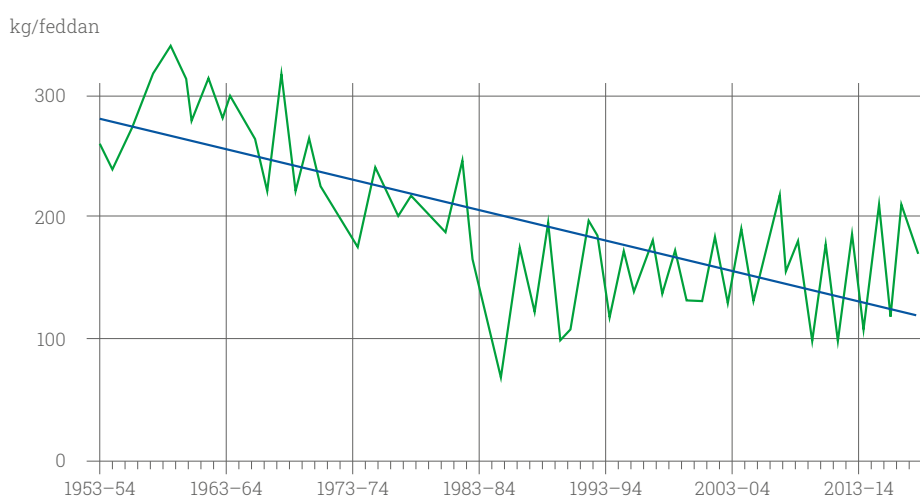
Traditional rain-fed agriculture has been neglected in Sudan. The government has invested little in research and infrastructure, and in basic social services such as education, primary health care and safe water for

Figure 4.2 Cultivated area from 1953/54 to 2017/18



Source: Compiled from data provided by Ministry of Agriculture and Forests (2018)

Figure 4.3 Crop yield in Sudan farming sector from 1953/54 to 2017/18





Traditional farm using animal-drawn' ploughs in South Darfur. Photo credit © UNEP



The Saghyia: Traditional water lifting method in Northern Sudan. Photo credit © UNEP

farming communities. This situation has been made worse by marketing monopolies and the absence of any land reform (Mohamed 2010). The lack of rights and secure access to land, along with the decline in average crop yields, are partly to blame for the proliferation of conflicts, the rapid increase in rural to urban migration, and the decision of many young people to abandon farming in favour of artisanal gold mining.

4.3.2 Mechanized farming

Mechanized farming is largely practised on the central clay of Sudan (Government of Sudan 2009). Introduced in the 1940s, mechanized farming expanded from 214,000 feddans (90,000 hectares) in 1954/55 to 17.6 million feddans (7 million hectares) in 2018 (Government of Sudan 2009). Mechanized farming takes place on farms that were legally acquired from the government through leasehold arrangements. However, a significant number of mechanized farms have no form of official approval (they are known as squatter schemes). In the late 1990s, 50 per cent of the land under cultivation in the semi-mechanized, rain-fed farming area in Gedaref state was un-demarcated, i.e. not officially delineated by the government (Government of Sudan 2009). In Sennar state, 70 per cent of mechanized farmland, amounting to some 5.4 million feddans (2.2 million hectares), is classified as belonging to squatter schemes (IFAD 2014). The government has been slow to re-demarcate the land, which has resulted in conflict between mechanised farmers and nomadic pastoralists whose animal migration routes and water points have been closed or obstructed.

Mechanized farming is an unsustainable way of managing the land. Soils become depleted of nutrients and some mechanized schemes have had to be abandoned. Yields in mechanized rain-fed areas have been decreasing by 0.6 kg/ha annually (FAO 2015c). The low productivity under mechanised and rain-fed systems has pulled Sudan's average yield closer to the yields for dry land productivity.

Land under irrigation



3.5 million hectares

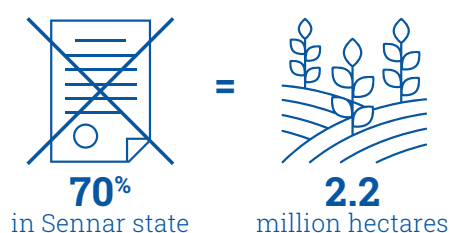
Several other factors make mechanized farming unsustainable:

- ➔ Expansion into marginal lands;
- ➔ It often involves the wholesale clearance of trees despite the legal obligation for the owner to have 10 per cent of land under tree cover;
- ➔ Absence of crop rotation;
- ➔ Monoculture practices;
- ➔ Use of machinery that cause soil compaction.

4.3.3 Irrigated agriculture

Irrigated agriculture is practised mainly in a semi-arid and arid savannah belt that stretches 1,100 km east to west across the centre of the country (Sudan National REDD+ Programme 2017). The land under irrigation, where various crops are grown, covers approximately 8.3 million feddans (3.5 million hectares) (Table 4.3).

Mechanized farmland belonging to squatter schemes



Although irrigated agriculture covers only about seven per cent of the cultivated land area in Sudan, it accounts for more than half the country's output of agricultural produce (Ijaimi 2016).



Mechanized sunflower agricultural project in Northern Sudan. Note the clearance of the original vegetation cover except for a few Balanitis (Heglig) trees. Photo credit © UNEP



Centre pivot irrigation in Nile River State. Photo credit © UNEP

Table 4.3 Major irrigated areas in Sudan

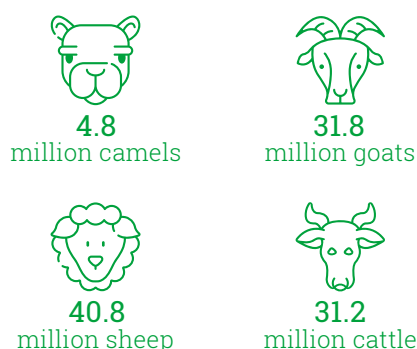
	Area (hectares)
Gezira and Managil	870,750
New Halfa	152,280
Rahad	121,500
Gash Delta	101,250
Suki	35,235
Tokar Delta	30,780
Guneid Sugar	15,795
Assalaya Sugar	14,175
Sennar Sugar	12,960
Khashm El-Girba	18,225
White Nile Sugar Company	52,200
Kenana Sugar	45,000
Aylota projects (W N, BN, NS)	1,387,000
Total	2,857,150

Source: Ministry of Agriculture and Forests 2018

4.3.4 Nomadic pastoralism

The country is home to one of the largest concentrations of traditional pastoralists in sub-Saharan Africa. An estimated 13 per cent of Sudan's population are pastoralists (Ahmed 2008). In Darfur, that figure is closer to 25 per cent, according to the 2008 Population Census.

Livestock population in 2018



Sudan's pastoralists keep an estimated 108.6 million head of livestock, including 31.2 million cattle, 40.8 million sheep, 31.8 million goats and 4.8 million camels (FAO 2018). In many cases they combine animal husbandry with subsistence cultivation, but

the animals remain pivotal to their livelihoods and their social, political and economic systems.

Camel pastoralism dominates in the desert and semi-desert in the north, and cattle herding in the savannah belt to the south. Similar to other herding groups in the African Sahel, Sudan's pastoralists adapt their livelihoods to fluctuations in resources by migrating, moving long distances between the north where they spend the wet season and the south where they spend the dry season. The banks of rivers, such as the White and Blue Niles and the Atbara River, are important dry season refuge areas. Before the secession of the South, the Baggara pastoral groups, particularly the Misseriyya and Rezeigat tribes, used to reach River Bahr Al Arab in what is now South Sudan where they would stay for approximately six months from October to April.

The landscape of Sudan is criss-crossed by a network of livestock routes some of which reach more than 1,000 km. Among the longest is a route used by the camel herders of North Darfur, which extends from Wadi Hawar to Um Dafug along the border between South Darfur state and the Central African Republic (Egeimo 2013). Since the early 1970s, frequent droughts and environmental degradation have forced camel-herding groups to move deeper into the rich savannah areas. Despite the vital role they play in the national and local



Pastoralists movement in Darfur region. Photo credit © UNEP

economies and in food security, pastoral communities in Sudan are in a constant state of crisis. They are facing many challenges, including shrinking rangelands and migration routes due to the spread of cultivation and mechanized farming; loss of value of livestock herds; the threat of spontaneous forced resettlement; and decreased resilience to drought and climate change because of degradation and lack of other natural resources (Egemi 2013). At times, they have been forced to resort to violence when competing for land and routes with sedentary farmers (i.e. farmers whose fields are not rotated). Some pastoralists have given up and moved to towns. For others, inadequate pastoral development policies, lack of secure access to land and livestock routes and limited access to education and health services, particularly among women and children, has resulted in them being marginalized from mainstream economic activities.

Despite these challenges, the expansion of the meat trade with Gulf countries and Egypt is encouraging many urban-based business people to invest in livestock breeding and farming, either via existing pastoral communities or by establishing their own livestock farms.

4.4 LAND-RELATED CHALLENGES

Land in Sudan is highly sought after. Many local conflicts stem from disagreements over the use of land for crop production, animal grazing, pastoral routes, mining or settlements. Economic activities such as gold mining often lead to the displacement of people, while expansion of agricultural land into fragile belts causes land degradation.

4.4.1 Conflict

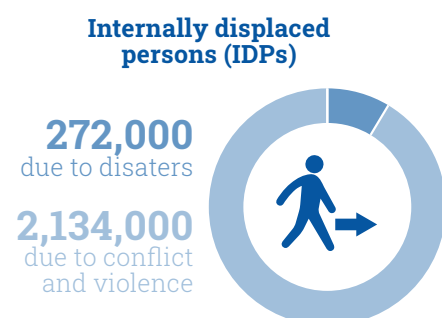
Sudan entered the twenty-first century mired in several conflicts and facing enormous security risks. Most of these conflicts are over natural resources such as land, water, grazing or forests. They are taking place in the rich agricultural areas where traditional crop farming and pastoralism are the main sources of livelihood. A conflict map produced by the United Nations Development Programme in 2015 showed that over 75 per cent of conflict incidents occur in Darfur, and 20 per cent in Kordofan (UNDP 2015a).

The conflicts are between pastoralists and sedentary farmers, or between different pastoralist communities, or between tribal groups who disagree over boundaries, mining resources or livestock routes. They range from occasional spontaneous skirmishes to large-scale violent clashes. The country's increased vulnerability to climate change is intensifying the pressure on resources and making conflict more likely.

Conflicts are often triggered by large-scale investments in projects such as dam construction, mechanized agriculture and oil exploration and drilling (Egemi 2018). This stems from the failure of the government or other parties to ensure that investments in natural resources take into account local needs and rights, and that wealth generated through these schemes yields dividends for the affected communities. For example, roads and other infrastructure that are built to support mechanized agriculture tend to have a negative impact on traditional farming communities and pastoralists, who usually get nothing in return. In such cases, conflict is often inevitable.

4.4.2 Internally displaced persons and refugees

Sudan hosts one of the largest populations of internally displaced persons (IDPs) and refugees in Africa. Although figures change frequently, some estimates indicate that there are 2,406,000 IDPs in Sudan: 2,134,000 due to conflict and violence, and 272,000 due to disasters (International Displacement Monitoring Center 2019). The vast majority of IDPs are in Darfur (88 per cent) and Kordofan (9 per cent). (Figure 4.4)



These mass movements of people have been largely triggered by a number of internal conflicts. The conflict in Jebel Marra in January 2015 between

4 Land Resources

government forces and Darfur rebels resulted in the displacement of 90,000 people to North Darfur state. An estimated 90 per cent of them were women and children. By 2016, the number had increased to 250,000 (Darfur Development and Reconstruction Agency 2016).

In 2011, the conflict between the Sudanese government and the Sudan People's Liberation Army North affected more than 300,000 people in South Kordofan state and 66,000 people in Blue Nile state (Egemi 2017) and created thousands of IDPs in both states. The number of IDPs in East Sudan is estimated at 190,000, with 60,000 of them in Kassala state and 130,000 in Red Sea state (Life and Peace Institute 2017).

In 2017, the number of refugees and asylum-seekers in the country was estimated to be more than 570,000 (UNOCHA 2018). This includes 112,283 Eritrean refugees in East Sudan and 450,000 South Sudanese refugees who have been moving into Sudan since the start of the conflict in South Sudan in December 2013 (UNOCHA 2018). Of the Eritrean refugees in East Sudan, 83,499 live in 12 camps and 28,784 in urban settlements. The United Nations Development Programme has identified six key entry points for migrants and refugees from Eritrea into East Sudan, four of which are in Kassala state (UNDP 2015b).

The movement of IDPs and refugees has far-reaching implications for Sudan. It puts additional pressure on

land and natural resources and causes severe environmental problems, including deforestation around camps, unsustainable groundwater extraction and uncontrolled growth of urban slums.

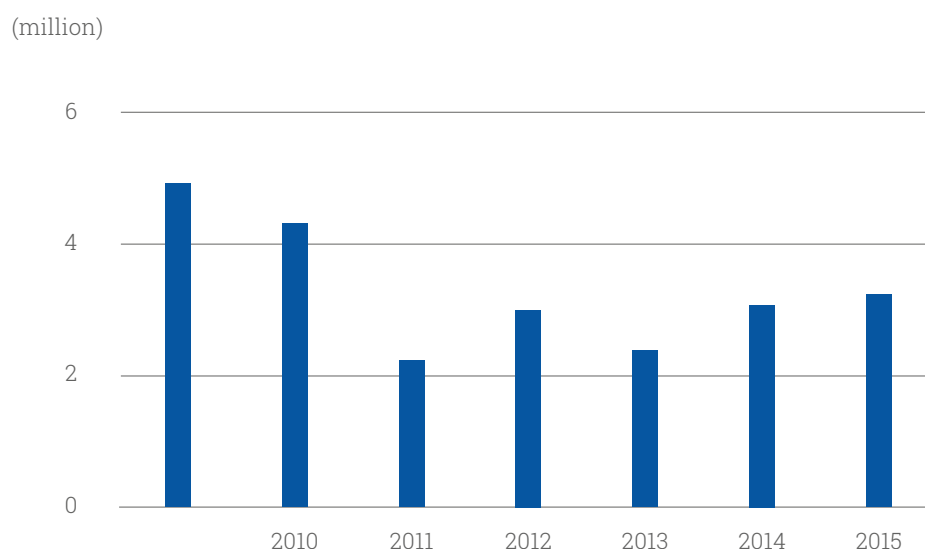
4.4.3 Returnees

The voluntary return of IDPs is a major area of alarm, especially in Darfur, since it can lead to disagreements with local farmers and residents. The following issues are of particular concern:

- ➔ Establishment of camps on lands owned by other farmers;
- ➔ Occupation of land abandoned by displaced persons;
- ➔ Possession of property by public institutions;
- ➔ Rent or sale of non-owned plots;
- ➔ Multiple allocation of the same plot by local administrations or tribal chiefs; and
- ➔ Unauthorized building on non-owned property.

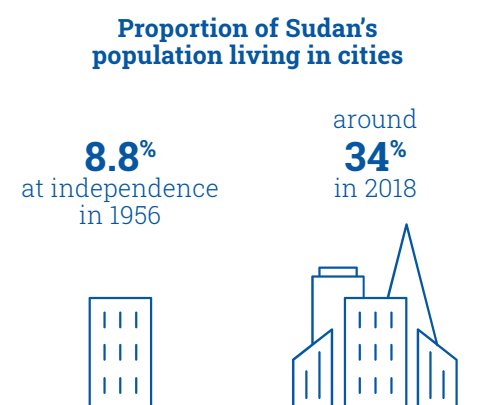
Voluntary return has accelerated significantly since 2017 due to the remarkable improvements in the security situation throughout Darfur. A recent report from 20 localities in the five Darfur states shows that the return takes place largely during the short agricultural season (FAO 2018b). It also noted that in areas abandoned by displacement since 2003, new nomadic settlements (*damras*) have emerged.

Figure 4.4 Internally Displaced People in Sudan



4.4.4 Urbanization

Rapid, disorganized and at times unauthorized urban growth (urban sprawl) has become common in Sudan. The proportion of Sudan's population living in cities increased from 8.8 per cent at independence in 1956 (Government of Sudan 1957) to around 34 per cent in 2018. Over 45 per cent of Sudan's urban population lives in Khartoum (Central Bureau of Statistics 2018) and, as Figure 4.6 illustrates, the city has absorbed an increasing proportion of the country's population, particularly since the 1980s (Abu Sin and Davies 1991; Central Bureau of Statistics 2018). Between 1955 and 2018, the capital Khartoum has significantly spatially grown as shown in Figure 4.6.



The rapid urbanization is a response to the social and economic crises caused by drought and desertification, as well as conflict and insecurity. The drought and desertification of the mid-1980s and the tragic famine that followed displaced around 1.8 million people, particularly along the southern edges of the Sahara Desert in Darfur and Kordofan (Egemi 1994). The majority of these environmental refugees went to the large urban centres, especially Khartoum, marking the onset of Sudan's rapid urban growth. The impacts of climate change intensified the problem.

Conflict and insecurity in many parts of the country, but particularly in Darfur, South Kordofan and Blue Nile, have pushed even more people to the cities. Most of the IDP camps have become part of the urban milieu. The urbanization has been accelerated by the stagnation of the rural economy after long years of drought, the urban-rural technological gap, declining agricultural yields, unfavourable terms of trade between rural and urban areas and between agricultural and processed products, and the shortage of agricultural labour as a result of young people turning to gold mining, which has resulted in higher labour costs and a reduction in farmed areas.

The rapid growth has had serious negative impacts on the urban environment, including overcrowding, a shortage of housing, a deterioration in public health and sanitation, higher land prices, the expansion of informal settlements, an increasing number of street children and more crime.

Figure 4.5 Increase in the proportion of the country's population living in Khartoum between 1955 and 2018 (compiled from Abu Sin and Davies 1991; Ali 2003; Central Bureau of Statistics 2018).

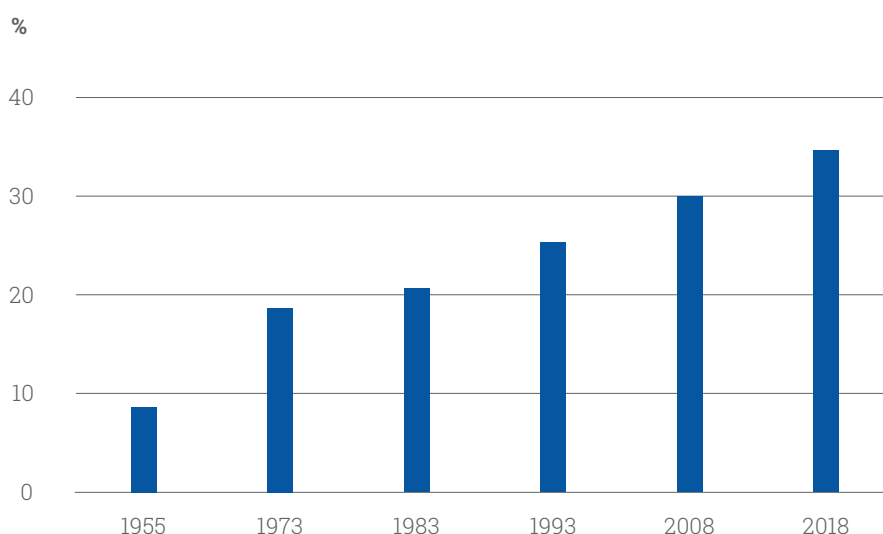
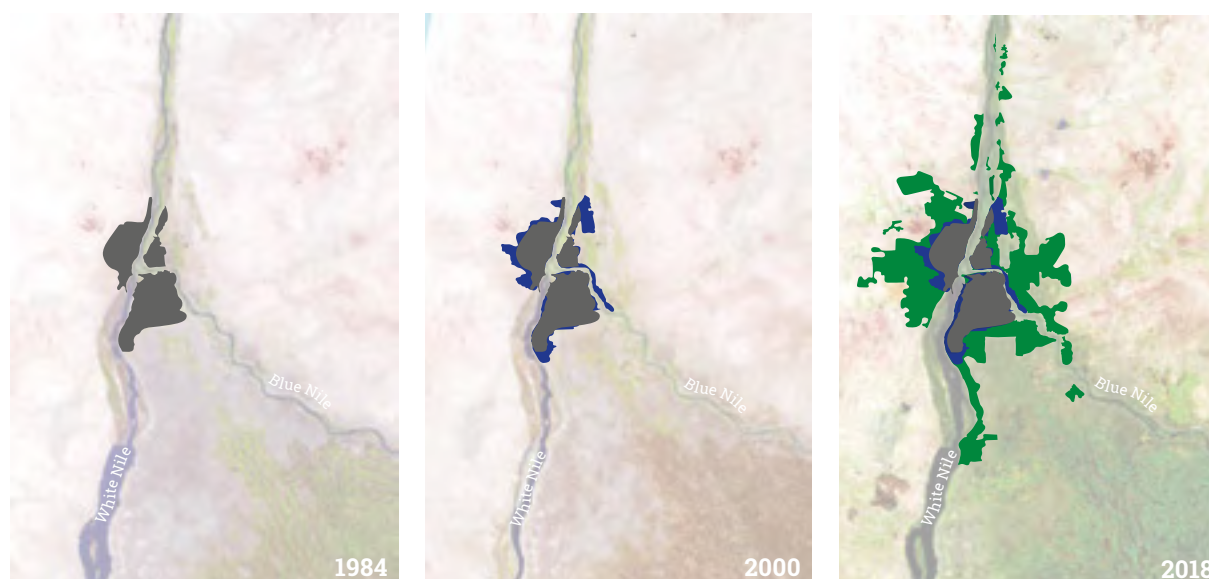


Figure 4.7 Expansion of Khartoum City between 1984 and 2018 (UNEP/GRID)



Imagery source: Sentinel and Landsat data

4.4.5 Land degradation

Despite the absence of detailed, up-to-date studies, there is a consensus among planners, decision-makers and land users that degradation is one of the major challenges facing Sudan. In 2007, a report by UNEP suggested that the boundary between desert and semi-desert had shifted southwards by 50 to 200 km since 1935 (UNEP 2007). The conflict in Darfur has caused an unprecedented destruction of environmental resources and the creation of desert-like conditions (UNEP 2007). Sudan has one of the highest rates of deforestation in developing countries, estimated at 2.4 per cent a year (Gafar 2013); between 1990 and 2005, the country lost about 11 per cent of its forest cover (Dahlberg and Slunge 2007).

Other ecosystems are also threatened: in Gedaref state, grazing land has declined from 28,250 km² (78.5 per cent of the state's area) in 1941 to 6,700 km² (18.6 per cent of the state's area) in 2002 (Babikir 2011). The situation is likely to deteriorate further. Most of Sudan's remaining semi-arid and low rainfall savannah, representing approximately 25 per cent of the country's agricultural land, is at significant risk of further degradation, according to a study by Göteborg University in Sweden (Dahlberg and Slunge 2007). It predicts that the desert boundary will continue to shift southwards due to climate change and changing rainfall patterns, leading to an estimated 20 per cent drop in food production.

Sudan's water resources are also severely degraded. Groundwater reserves are depleted and the main Nile is threatened by a combination of siltation and riverbank erosion. Except for the Jebel Aulia dam on the White Nile, all the country's reservoirs are badly silted up. Hundreds of small water sources in Sudan's deserts (oases and *wadis*) are moderately to severely degraded (UNEP 2007).

Some of the damage is human-made. A study by Sudan's Ministry of Agriculture and Forests found the mechanized farming sector to be a major cause of land degradation and biodiversity loss on the country's central clay plains due to the wholesale clearance of vegetation, water and soil erosion, monocultural farming practices and a lack of investment in soil quality (Government of Sudan 2009). Rural communities' heavy dependence on firewood and charcoal for domestic energy and income has significantly added to the problem.

Land degradation has a negative impact on food security and the incomes of the rural population. Women are made disproportionately worse off, since the scarcity of fuelwood and water adds to their workload. In conflict-affected areas land degradation remains a major cause of violence against women who are subjected to attacks and sexual violence when venturing away from their homes seeking water and fuelwood (UNEP et al. 2013). Land degradation results in a scarcity of productive land, which heightens demand and competition for natural resources and often leads to conflict.



Riverbank erosion (Haddam) south of Blue Nile. Photo credit © UNEP

4.5 LAND MANAGEMENT AND ADMINISTRATION

The management and administration of land and other natural resources in Sudan is covered by a host of policy, legal and institutional arrangements, which include laws, norms and regulations.

4.5.1 Land tenure

Sudan has two forms of land tenure arrangements: statutory and customary. Under statutory arrangements, the country has long had a legal system for land registration through which individuals, enterprises or the government can establish title to a piece of land. This is covered by the Land Settlement and Registration Ordinance of 1925. Land registrations of this type cover most of the major urban centres and land along the River Nile, while the rainlands, which form most of the country's land, are unregistered (United Kingdom, Foreign Office 1925).

In 1970, the Unregistered Land Act declared that all wasteland, forests and unregistered lands are owned by the government (Komey 2009). Before the act was passed, the government had avoided interfering with individual customary rights to unregistered land in the rainlands. The Civil Transaction Act (1984), which repealed the 1970 Unregistered Land Act, legalized elements of *Sharia* Law by recognizing rights to unregistered land (*urf*) while confirming the role of the state as landowner and manager. The Civil Transaction Act converts all non-registered land by a pen stroke into registered government land. The Act states: "No court of law is competent to receive a complaint that goes against the interest of the state." The Act maintains the basic principles of usufruct rights – the right to enjoy another person's property without abusing it. These rights recognise individual rights to land, within the tribal land ownership, which can be inherited, but with no power to remove land from the ownership of the tribe (Shazali 2002).



*Fertile land on the bank of the Blue Nile river is transformed into brick making sites causing land degradation and air pollution.
Photo credit © Osman Ali*

The Civil Transaction Act also considers the following issues that are important to securing land tenure:

- ➔ Transfer and inheritance of rights;
- ➔ Compensation for land appropriated by the state;
- ➔ Granting of land leases to cooperative bodies and communities;
- ➔ Conditions for obtaining usufruct rights;
- ➔ Possibility of registering easement rights (rights of way).

Sudan's customary land tenure arrangements derive from tribal territorial rights that were established during successive indigenous kingdoms of pre-colonial Sudan and reinforced through legislation under the British colonial administration. Customary rights ensured the collective security of the tribe within the tribal homeland. Within the customary land tenure arrangements, which still apply, security of access to land among settled communities was legitimized through membership of a village community. As well as wasteland, forests and unregistered lands,

the government owns urban land, national parks and land under irrigated agricultural schemes, which is leased to individuals or to private companies. Land used for pasture and for traditional cultivation is communally owned under customary land laws that may vary between locations but follow a similar pattern.

The coexistence of statutory and customary land laws has created a confused legislative environment. To reduce the complexity and to try to harmonize the two systems, the Sudan Comprehensive Peace Agreement in 2005 called for the creation of land commissions – a National Land Commission and one for each of South Kordofan, Blue Nile, Darfur and Eastern Sudan. Although only the Darfur Land Commission has been established, all peace agreements and their resultant institutions are under review after the political change that ended the previous regime in 2019.

Sudan's Interim National Constitution of 2005 includes provisions that relate directly to land tenure and natural resource management:

Article 186

- (1) *The regulation of land tenure, usage and exercise of rights thereon shall be a concurrent competence, exercised at the appropriate level of government.*
- (2) *Rights in land owned by the government of Sudan shall be exercised through the appropriate or designated level of government.*
- (3) *All levels of government shall institute a process to progressively develop and amend the relevant laws to incorporate customary laws, practices, local heritage and international trends and practices.*

Article 190

- (I) *Persons enjoying rights in land shall be consulted and their views shall duly be taken into account in respect of decisions to develop subterranean natural resources from the area in which they have rights. They shall share in the benefits of that development.*
- (II) *Persons enjoying rights in land are entitled to equitable compensation on just terms arising from acquisition or development of land for the extraction of subterranean natural resources from the area in respect of which they have rights.*
- (III) *The communities in whose areas development of subterranean natural resources occurs have the right to participate, through their respective states, in the negotiation of contracts for the development of those resources.*

In 2015, the Interim National Constitution was amended, and Article 186 was replaced with the following (Government of Sudan, 2015):

Article 186

- (1) *Regulation of land tenure, usage and exercise of rights thereon shall be a concurrent competence, exercised at the government level concerned, in accordance with the provisions of law.*
- (2) *The President of the Republic may, from time to time, issue presidential decrees, for defining such land, as may be used for investment purposes; and the manner of disposal of the return of investment thereof; and determine the government level concerned, for management, and exercise of rights thereon.*
- (3) *The National Legislature shall approve the National Investment Map.*

The implication of this amendment is that it gave the president powers to intervene and define lands for investment.

Unresolved issues of land rights are not only hindering investment in Sudan's natural resources and holding back their huge economic potential, they are also one of the main factors fuelling conflict throughout the country.

4.5.2 Land use policies

The lack of clear and comprehensive arrangements for land administration and management is contributing to land degradation and unsustainable land use practices. The problem is not just inadequate policies, but also the failure to implement and enforce existing regulations (Egemi 2017).

The Interim National Constitution of 2005 gives Sudan's states certain responsibilities over the administration of land and the management of natural resources. While this devolution of power is clear on paper, in practice there is confusion over the division of authority. Another challenge is that the government's Twenty-Five-Year Strategy (2007–2031) does not contain any specific policies for land and the environment under the Economic Strategy, which reflects a broader failure to integrate land issues into national development policies.

Nevertheless, the strategy does call for the sustainable management of land and contains suggestions for achieving that, including (WB/MFEP 2016):

- ➔ Optimizing land use according to its productivity;
- ➔ Implementing the national plan for land use, which includes allocating 25 per cent of the total land for grazing and forests to benefit livestock and wildlife;
- ➔ Developing Sudan's water resources by increasing storage capacity, exploiting ground water, expanding water catchments and providing drinking water for communities and livestock;
- ➔ Rehabilitating irrigation services to make water use more efficient, including the introduction of appropriate technologies to optimize water use and raise water awareness;
- ➔ Increasing the area of forest;
- ➔ Expanding exploration and exploitation of mineral resources; and
- ➔ Expanding the oil industry by introducing policies and laws protecting local and international investments from state expropriation.

4.5.3 Interim poverty reduction strategy

The Interim Poverty Reduction Strategy of 2012 includes a number of policy directives and guidelines that relate directly to land use. Table 4.4 provides a summary.

4.5.4 Investment Act (2013)

In 2013, the government eliminated the Ministry of Investment and replaced it with the High Council for Investment, as sanctioned by the Investment Encouragement Act of 2013. The Council is charged with creating an environment that attracts private investors to Sudan and that also protects their rights. It is also responsible for identifying priority areas for investment and for reviewing laws and regulations.

The 2013 Investment Encouragement Act gives the Council the authority to, among other things:

- ➔ Prepare investment plans with the relevant ministries and states;
- ➔ Approve investment requests; and
- ➔ Allocate state land for investment, in coordination with the appropriate ministries and states.

Controversially, the Act also gives the Council the power to make decisions on the designation and allocation of land for investment without consulting other parties. This denies local communities the right to have their say, and because of this and the unresolved questions of land tenure in the country the Act is seen as being a potential driver of conflict.

Table 4.4 Land-related policy measures in Sudan's Interim Poverty Reduction Strategy

Objectives	Policy Measures/Programmes
Recovery and growth of the agricultural sector	<ul style="list-style-type: none"> ➔ Reform institutions and enforce land use regulations, while providing support for research, extension and pest control. ➔ Enact land policies that provide farmers with formal and secure tenancy. ➔ Revise land policies to create stability in tenure rights for small farmers and pastoralists. ➔ Improve agricultural productivity by increasing the efficiency of management and the adoption of modern technologies. ➔ Manage water resources efficiently. ➔ Implement liberalization policies in the gum arabic sector. ➔ Increase efforts to halt and reverse desertification. ➔ Encourage private investors to play a leading role in the industry. ➔ Promote private investment in gum arabic production.
Environmental and natural resource management	<ul style="list-style-type: none"> ➔ Prepare land use maps, particularly for marginal areas, forests and food crop production. ➔ Enhance the role of community in resource management and launch environmental awareness campaigns. ➔ Enforce environmental laws and other supporting legislation. ➔ Increase the capacity of both federal and state governments to monitor and enforce land lease conditions on clearing and cultivation in areas that are vulnerable to desertification. ➔ Undertake comprehensive land reforms and secure land titles. ➔ Undertake soil and water harvesting programmes.

Source: Ministry of Finance and National Economy, *Interim Poverty Reduction Strategy*, 2010, Khartoum.

4.5.5 Institutional issues

Land administration at both the federal and state levels involves many institutions that are not closely linked. At the federal level, they include the High Council for Investment and the former ministries of Agriculture; Environment, Natural Resources and Physical Development; Justice; Tourism and Wildlife; and Water Resources, Irrigation and Electricity. At the state level, they include the *Walis* (state governors), the state Ministries of Agriculture, the Forests National Corporation, the investment commissions and the land dispossession committees. At the community level, the Native Administration also plays a role. The large number of actors leads to problems of coordination, capacity, accountability and overlapping mandates. The situation is complicated by the absence of an overarching national institution for land management and administration.

4.6 CONCLUSION

Sudan is blessed with vast natural resources that through proper management could transform society through broad-based socioeconomic development.

However, the country suffers a severe problem of land degradation, which is partly due to mismanagement. The most visible manifestations of this include declining land productivity, soil erosion, the degradation of forests and rangelands and a general loss of biodiversity. The social consequences of poor land management include accelerated rates of rural

poverty, high levels of rural-urban migration, and intensified competition and eventually conflict over land and natural resources. The poor management and administration of land has had a disastrous impact on food security and the incomes of the rural population, particularly women.

Land use across the country is changing. There is increasing demand for land from oil exploration and drilling, gold mining and large-scale mechanized domestic and regional agribusinesses. The independence of South Sudan closed off many pastoral routes and created an influx of returnees into the border region. Growing populations of both people and livestock, the rapid transformation to a market economy, and climate change are increasing the pressure on land and the livelihoods of farmers and pastoralists.

Land administration and governance in the country is at a crossroads. The policy, legal and institutional arrangements have proved inadequate to deal with the challenges of peace and stability and socioeconomic development. The lack of coordination between different administrative systems, disjointed land use policies, legislative gaps in land tenure and natural resource management, and the eroded legitimacy and authority of traditional leadership have created an environment of confusion and disputes. Lack of clarity over land use has become a major destabilizing factor in the country. Without institutional reforms, the situation will continue to impede Sudan's development, as well as the integrity of its environment.

References

REFERENCES

1. Abu Sin, M. E and Davies, H. R. J. (1991). *The future of Sudan Capital Region: A Study in Development and Change*. Khartoum University Press, Khartoum.
2. Ahmed, A. G. M. (2008). Transforming Pastoralism: A Case Study of the Rufa'a al Hoi Ethnic Group in the Blue Nile state, Sudan. Sudan Working Paper SWP 2008: 1. Chr Michelsen Institute (CMI), Bergen, Norway. Retrieved from <https://www.cmi.no/publications/file/2942-transforming-pastoralism.pdf>
3. Babiker, I. M. (1990). Drought, famine, and disaster management in Darfur, Sudan. *Famine and Food Policy Discussion Paper 4. International Food Policy Research Institute*, Washington, D.C., United States of America. Retrieved from <https://www.ifpri.org/publication/drought-famine-and-diaster-management-darfur-sudan>
4. Babiker, I. M. (2011). Mobile pastoralism and land grabbing in Sudan: Impact and responses, paper presented at the International Conference on the Future of Pastoralism, Feinstein International Centre, University of Tufts.
5. Census and Economic Information Center (CEIC) (2018). Sudan Crude Oil Production 1999–2018. Retrieved from: <https://www.ceicdata.com/en/sudan/petroleum-production-and-consumption/crude-oil-production>
6. Central Bureau of Statistics (CBS), UNICEF Sudan. (2016). Multiple Indicator Cluster Survey 2014 of Sudan, Final Report. Khartoum, Sudan: UNICEF and Central Bureau of Statistics (CBS). Retrieved from: <https://mics.unicef.org/files>
7. Central Bureau of Statistics (CBS) (2018). Estimate of Sudan Population, unpublished report.
8. Dahlberg, E. and Slunge, D. (2007). Sudan Environmental Policy Brief, Department of Economics, Göteborg University, Sweden.
9. Darfur Voluntary Return and Resettlement Commission (DVRRC) (2018). Results of the Survey and Inventory of Returnees and Return Sites in May 2018.
10. European Coalition on Oil in Sudan (ECOS). (2007). Fact Sheet II: The Economy of Sudan's Oil Industry.
11. Egemi, O. A. (1994). The political ecology of subsistence crisis in the Red Sea Hills, doctoral thesis, University of Bergen, Norway.
12. Egemi, O. (2012). Pastoralist people, their institutions and related policies. Working paper. Feinstein International Center. Tufts University. Retrieved from: <https://fic.tufts.edu/assets/Pastoralist-Peoples.pdf>
13. Egemi, O. A. (2013). Pastoralist peoples, their institutions and related policies. In Working Paper Series, Feinstein International Center, Tufts University. Retrieved from <https://fic.tufts.edu/assets/Pastoralist-Peoples.pdf>
14. Egemi, O. A. (2017). Land Use in Sudan: Study Report for Sudan National REDD+ Programme. Retrieved from: <https://www.reddplussd.org/phocadownload/userupload/Final%20Landuse%20and%20REDD.pdf>
15. Egemi, O. A. (2018). Land use transformation, rural poverty and conflict on the rain lands of Sudan. *Sudan Geographical Journal*, 1, 135–149.
16. El Khidir, S. A. and Ali, O. M. (2018). The Impact of War in Radom National Park, South Darfur state, Sudan. *Journal of Biodiversity and Endangered Species*. 6 (3), 2332–2543.
17. El Radi, G. (2016). Cost of conflict in Dar Misseriyya, workshop report, Partners in Development Services (PDS), Khartoum.
18. European Coalition on Oil in Sudan (2007). Fact Sheet II. The Economy of Sudan's Oil Industry. Retrieved from: <https://www.ecosonline.org/reports/2007/ECOSfactsheetIIOctober2007.pdf>
19. Food and Agriculture Organization of the United Nations and United Nations Environment Programme (2012). Land cover in Sudan, FAO, Sudan. Retrieved from: <http://www.fao.org/3/a-be896e.pdf>
20. Food and Agriculture Organization of the United Nations (2015a). Country Profile-Sudan. Retrieved from: <http://www.fao.org/3/i9808en/I9808EN.pdf>
21. Food and Agriculture Organization of the United Nations (2015b). Country programming Framework for Sudan. Plan of Action (2015–2019). Resilient Livelihoods for Sustainable Agriculture, Food Security and Nutrition. Retrieved from: <http://www.fao.org/3/i9808en/I9808EN.pdf>

22. Food and Agriculture Organization of the United Nations (2015c). National Investment Profile. Water got Agriculture and Energy. Sudan. Retrieved from: http://www.fao.org/fileadmin/user_upload/agwa/docs/NIP_Sudan_Final.pdf
23. Food and Agriculture Organization (2018a). FAO Food and Agriculture data. Country Profiles: Sudan. Retrieved from: <http://www.fao.org/faostat/en/#data>
24. Food and Agriculture Organization of the United Nations (2018b). Baseline and Land Resource Mapping in 20 localities in the five Darfur states, unpublished report, Khartoum
25. Gafar, A. (2013). Report to Sudan LGAF Land Governance Report, Partners in Development Services (PDS), Khartoum.
26. Government of Sudan (2009). Study of the Sustainable Development of the Semi Mechanized Farming Sector in Sudan, Ministry of Agriculture and Forests.
27. Government of Sudan (2015). Constitutional Amendment.
28. Hameed, S.M.A. and Eljack, A.O. (2003). Ramsar Information Sheet (RIS) For Dinder national Park, Sudan. Retrieved from: <https://rsis.ramsar.org/RISapp/files/RISrep/SD1461RIS.pdf>
29. Hassaballa, K., Mohamed, Y., Uhlenbrook, S. and Biro, K. (2017). Analysis of streamflow response to land use land cover changes using satellite data and hydrological modelling: case study of Dinder and Rahad tributaries of the Blue Nile (Ethiopia/Sudan). *Hydrology and Earth System Sciences Discussions*.
30. Hussien, A. E. A. (2015). Birds of Dinder National Park from 200–2011. *Poultry, Fisheries and Wildlife Sciences*. 3 (1), 1–5. Retrieved from: DOI: 10.4172/2375-446X.1000128
31. Ibrahim, M.S. (2015). *Artisanal Mining in Sudan – Opportunities, Challenges and Impacts*. Presented at the 17th Africa OILGASMINE Conference, Khartoum, Sudan. Retrieved from <https://unctad.org/meetings/en/Presentation/17OILGASMINE%20Mohamed%20Sulaiman%20Ibrahim%20S4.pdf>
32. International Displacement Monitoring Centre (IDMC) (2010). Sudan: Durable solutions elusive as southern IDPs return and Darfur remains tense. A profile of internal displacement situation. Retrieved from: www.internal-displacement.org
33. International Displacement Monitoring Centre (IDMC) (2019). Global Internal Displacement Database. Sudan: Retrieved from: <https://www.internal-displacement.org/countries/sudan>
34. Komey, G. K. (2009). Communal Land Rights, Identities and Conflicts in Sudan: The Nuba Question. Conference: The Human Rights Dimensions of Land in the Middle East and North Africa, MENA Land Forum Founding Conference, Cairo, Egypt.
35. Life and Peace Institute (LPI) (2017). Capacity assessment of civil society actors along Kassala-Eritrea border, unpublished report.
36. Ministry of Agriculture and Forests (MAF) (2018). Directorate of Agricultural Planning and Statistics Agricultural statistics 1953/54–2017/2018, Khartoum.
37. Ministry of Finance and National Economy (MFNE) (2011). Poverty Reduction Strategy Paper. Khartoum.
38. Ministry of Finance and National Economy (MFNE) (2015). Impact of traditional mining of gold on the social and economic life in Sudan and on the environment, General Directorate of International Cooperation.
39. Mohamed, I.A.W. (2010). Assessment of the role of agriculture in Sudan Economy. Munich Personal RePEc Archive. Retrieved from: <https://mpra.ub.uni-muenchen.de/id/eprint/33119>
40. Pantuliano, S. Egemi, O., Fadlalla, B. and Farah, M. (2009). Put out to pasture. War, oil and the decline of Misseriyya Humr pastoralism in Sudan. *Human Policy Group*. Overseas Development Institute, London.
41. Shazali, S. (2002). Share the land or part the nation, UNDP, Sudan Office. Retrieved from: https://www.sd.undp.org/content/sudan/en/home/library/crisis_prevention_and_recovery/share-land-part-nation.html
42. Teklu, T., von Braun, J. and Zaki, E. (1991). Drought and Famine Relationships in Sudan: Policy Implications. *International Food Policy Research Institute*. Research Report 88.
43. UNESCO (2018). Man and the Biosphere Programme Biannual Activity Report 2016–2017. Retrieved from: http://www.biosphaerenparks.at/images/pdf/180717_mab_english_fincompressed.pdf

44. United Kingdom, Foreign Office (1925). Sudan: land; Land Settlement and Registration Ordinance, 1925; Land Tax (Amendment). The National Archives Retrieved from: <https://discovery.nationalarchives.gov.uk/details/r/C9002257>
45. United Nations Development Programme (UNDP) (2015a). Eastern Sudan Mapping: Partner Interventions, Development Indicators & Migration.
46. United Nations Development Programme (UNDP) (2015b). Sudan views of post 2015 development agenda, Report.
47. United Nations Environment Programme (UNEP) (2007). Sudan Post-Conflict Environmental Assessment. Retrieved from https://postconflict.unep.ch/publications/UNEP_Sudan.pdf
48. United Nations Environment Programme (UNEP), United Nations Women, United Nations Peacebuilding Support office (UN PBSO) and United Nations Development Programme (UNDP) (2013). Women and Natural Resources: Unlocking the Peacebuilding Potential. Retrieved from https://postconflict.unep.ch/publications/UNEP_UN-Women_PBSO_UNDP_gender_NRM_peacebuilding_report.pdf
49. United Nations High Commissioner for Refugees. (2018). Global Trends. Forced Displacement in 2018. Retrieved from: <https://unhcr.org/globaltrends2018>
50. United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) (2018). Sudan 2018 Humanitarian Needs Overview. Retrieved from: <https://reliefweb.int/report/sudan/sudan-2018-humanitarian-needs-overview>
51. World Bank (WB) (2014). Republic of the Sudan Diagnostic Trade Integration Study-Update. Report No: ACS10972. Retrieved from: <http://documents.worldbank.org/curated/en/260641468188681749/pdf/97404-Replace-ment.pdf>
52. World Bank Group and Ministry of Agriculture (2016). The 2016 Enabling the Business of Agriculture Report. Retrieved from: <http://worldbank.org/en/newa/press-release/2016/05/16>
53. World Bank (WB) and Ministry of Finance and Economic Planning (MFEP) (2016). The Sudan Interim Poverty Reduction Strategy Paper Status Report: A Joint World Bank Group and Sudan's Ministry of Finance and Economic Planning Assessment (2012–2014). Accessed on 16 April 2020 from <http://documents.worldbank.org/curated/en/980991479985933855/pdf/110503-WP-SudanFlipbookEnglish-PUBLIC.pdf>
54. World Conservation Monitoring Centre (WCMC). (1993). Assessing the conservation status of the world's tropical forest. Summary of the WCMC Tropical Management Areas Assessment Project.
55. Yousif, E.A. and Mohamed, F.A. (2012). Trends of poaching, Livestock Trespassing, Fishing and Resource Collection from 1986-2010 in Dinder National Park, Sudan. *Journal of Life Science and Biomedicine*. 2(4): 105–110. Retrieved from: <http://jlsb.science-line.com>

5

Water Resources

5 Water Resources

5.1 INTRODUCTION

Sudan's water resources include rivers, seasonal streams, lakes, ponds and groundwater aquifers. The country also borders the Red Sea with a continental coastline about 853 km long, including embayments and inlets (FAO 2019). Water resources contribute to the country's development through domestic use, irrigation, industrial use, power generation, fisheries and recreation. They also constitute a mosaic of aquatic ecosystems that play a fundamental role in shaping Sudan's distinctive climatic and ecological zones.

Around 75 per cent of Sudan's land area lies within the Nile River Basin, which represents 44 per cent of the Nile Basin's total area (FAO 2017a). Sudan shares several transboundary aquifers with its neighbours, such as the Nubian Sandstone Aquifer, used by Sudan, Egypt, Libya and Chad, and the Um Ruwaba Aquifer, shared with South Sudan. Sudan's inland waters are affected by seasonal flows, rainfall variability, siltation, floods, riverbank erosion and pollution. The country's marine and coastal resources play an increasingly important role in the economy and attract a considerable number of tourists, though they are under threat from pollution, unregulated economic development and climate change.

Sudan is classified as a water-scarce country. Competition for water has been a source of conflict, but it can also be an opportunity for collaboration and stabilization. The sensitive management of water resources is seen as a way of achieving stability and sustainable development in Sudan. With efficient institutions and appropriate legislation, water resources could play a significant role in improving the economy, society and the environment.

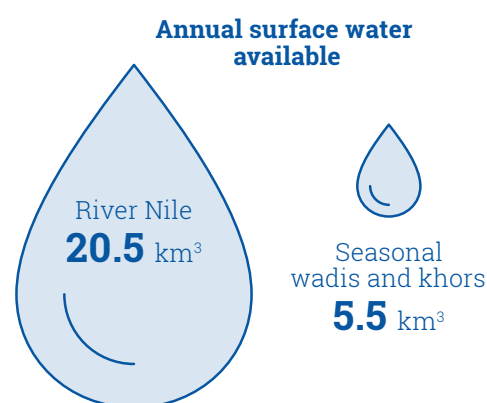
5.2 WATER AVAILABILITY

Rainfall is a major source of fresh water despite the low amounts the country receives and the high evapotranspiration rates. The estimated annual rainfall in Sudan is about 440 billion cubic metres (Adam and Abdo 2017). In the north, from Khartoum to the border with Egypt, the rainy season is short and rain falls in isolated showers. Annual rainfall in this region varies from almost zero in the far north to about 120 mm in the Khartoum area (Abdalla 2017). All over the country, evapotranspiration rates exceed rainfall, resulting in rainwater deficiency for most of the year. Rainfall exceeds evapotranspiration only in August, September and part of October, when the

runoff fills seasonal streams and recharges aquifers (Adam and Abdo 2017). Due to deforestation, runoff water is often loaded with silt and debris, which causes erosion of the catchment area (Abdalla 2017). Although the southernmost parts of the country receive more rain than the north, even the wettest areas get no more than 800 mm a year (Abdalla 2017).

The Nile provides 73 per cent of Sudan's annual fresh water (Hamad 2015). Most of this water comes from Ethiopia and passes from Sudan into Egypt as part of the provisions of the Nile Water Agreement of 1959 between Egypt and Sudan (Governments of Sudan and Egypt 1959). The Nile flow inside Sudan includes the Blue Nile and its tributaries the Dinder and the Rahad, the White Nile, the Atbara River and the seasonal streams flowing into these. More than half of Sudan's population lives along the Nile River on what amounts to 15 per cent of the country's land area (Hamad 2015).

The estimated annual total surface water that Sudan can use is 26 km³. This includes the water that Sudan is permitted to take from the Nile, which amounts to 18.5 km³ a year as measured at Aswan in southern Egypt (equivalent to 20.5 km³ in the centre of Sudan before the transportation loss due to evaporation and seepage), as stipulated in the 1959 Nile Water Agreement. It also includes the flow from streams unconnected to the Nile (5.5 km³) (Adam and Abdo 2017).



5.2.1 Nile River System

The Nile is the most prominent geographical feature in Sudan, cutting through the plains of the country from the south and east to the centre and north before heading into Egypt. Ten other countries share the Nile: Burundi, Democratic Republic of the Congo, Egypt, Eritrea (observer status), Ethiopia, Kenya, Rwanda, South Sudan, Tanzania and Uganda.

* km³ = BCM

5 Water Resources

Three main tributaries of the Nile unite in Sudan. The Blue Nile and the White Nile meet at the capital Khartoum, while the Atbara River joins the main Nile at Atbara town 320 km north of Khartoum. There are two seasonal tributaries of the Blue Nile which originate in Ethiopia: the Dinder and the Rahad. After this, the main Nile continues as a single artery through the Sahara Desert to Egypt (Permanent Joint Technical Committee 1960). The sum of the average annual flow of the Nile tributaries when they enter Sudan is estimated at 97 km³ a year. The tributaries of the Nile are shown in Table 5.1.

Some 13 per cent of the water flowing into the Nile in Sudan is lost to evaporation through central Sudan and the Sahara Desert. Around 10 km³ a year evaporates from the Nuba/Nassir Lake of the High Aswan Dam. According to the Nile Water Agreement, Sudan is allowed to abstract up to 18.5 km³ a year from the Nile, which represents 21 per cent of the Nile's flow as measured at the Sudan-Egypt border (Hamad 2015). Egypt is allowed to extract 55.5 km³ a year (Governments of Sudan and Egypt 1959).

Sudan's abstraction from the Nile, measured in central Sudan, ranged from a low of 13.3 km³ in 1986/87 to a high of 16.5 km³ in 2004/05 (Hamad 2015) – equivalent to 12.1 km³ and 14.3 km³ respectively as measured at Aswan, Egypt. The main reason for the difference is the variation in rainfall in Sudan's irrigated areas and the Ethiopian plateau.

The storage capacity available in Sudan's Nile reservoirs has been continuously decreasing due to siltation and debris accumulation. Except for the Jebel Aulia dam on the White Nile, all the other reservoirs built on rivers coming from the Ethiopian Plateau have lost a considerable volume of storage capacity. The reservoirs of Roseires dam, Khashm El-Girba dam and Sennar dam have lost more than half of their design capacity (Ahmed 2017). Even Merowe dam, which was commissioned in 2009, has lost about 1.7 per cent of its design capacity. However, the heightening of the Roseires dam in 2013 has raised its storage capacity from 3.35 to 5.8 km³, while the construction of the Upper Atbara and Setit Dam Complex has added another 3.6 km³ (Ahmed 2017).

Figure 5.1 Water courses and drainage systems in Sudan (GRID-Arendal)

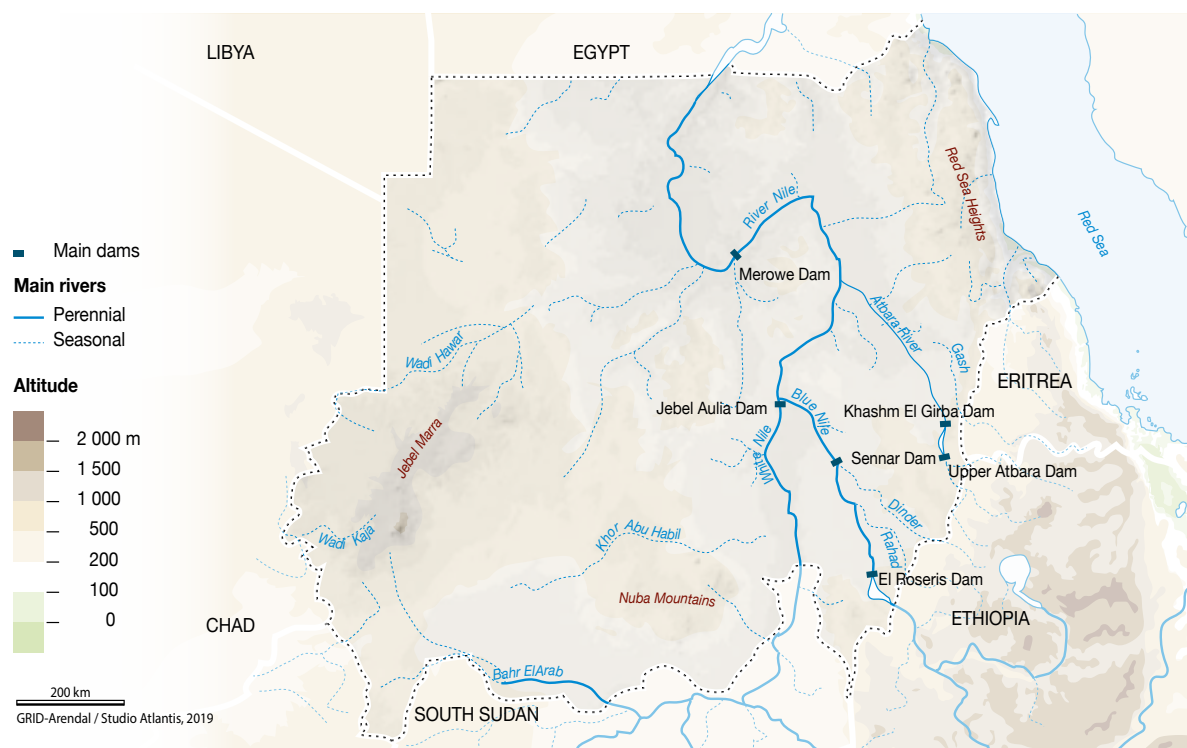


Table 5.1 Characteristics of the Average Annual Flow of the Nile Tributaries

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

Source: Hamad 2015



The Blue Nile embracing Tuti Island meets the White Nile at Khartoum forming the Mogran (confluence). Photo credit © UNEP

5.2.2 Seasonal *wadis* and *khors*

There are four major seasonal streams, also known as *wadis* or *khors*, in Sudan. These are Gash and Baraka, which are shared with Eritrea, and Azum and Hawar, which are shared with Chad. Other relatively smaller seasonal streams include Khor Abu Habil, Wadi El Mugaddam, Wadi Kaja, Wadi Nyala, Alawataib and Alhawad. Most of these wadis flow across more than one state, and there are others that Sudan shares with South Sudan and Central African Republic. The average annual flow of the seasonal streams is around 5.5 km³ (Adam and Abdo 2017). However, this varies considerably from one year to another due to the variable rainfall. The streams tend to flow for a few days or hours during the period from July to October, and are usually dry for the rest of the year. Most of these seasonal streams are not monitored regularly.

5.2.3 Groundwater

The sedimentary Nubian Sandstone and Umm Ruwaba formations are the main aquifers in Sudan. They extend to depths ranging from 40 to 400 m, and have total dissolved solids ranging from 100 to 2000 ppm (Abdo and Salih 2012). The Nubian Sandstone aquifer, which holds fossil water that has been there for thousands of years, is shared by Sudan, Chad, Egypt and Libya. There is not yet a regional institutional arrangement for the sharing of water from this aquifer.

Figure 5.2 shows the main aquifers in Sudan. The basement aquifers have proved to be an important source of groundwater, supporting large settlements and humanitarian services, especially in war-affected areas.

Table 5.2 Groundwater Storage, Recharge and Abstraction in Sudan (millions of cubic metres)

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

Source: (Adam and Abdo 2017)



A seasonal water course (Wadi Shagra), North Darfur, during the rainy season. Photo credit © Albert Gonzalez Farran

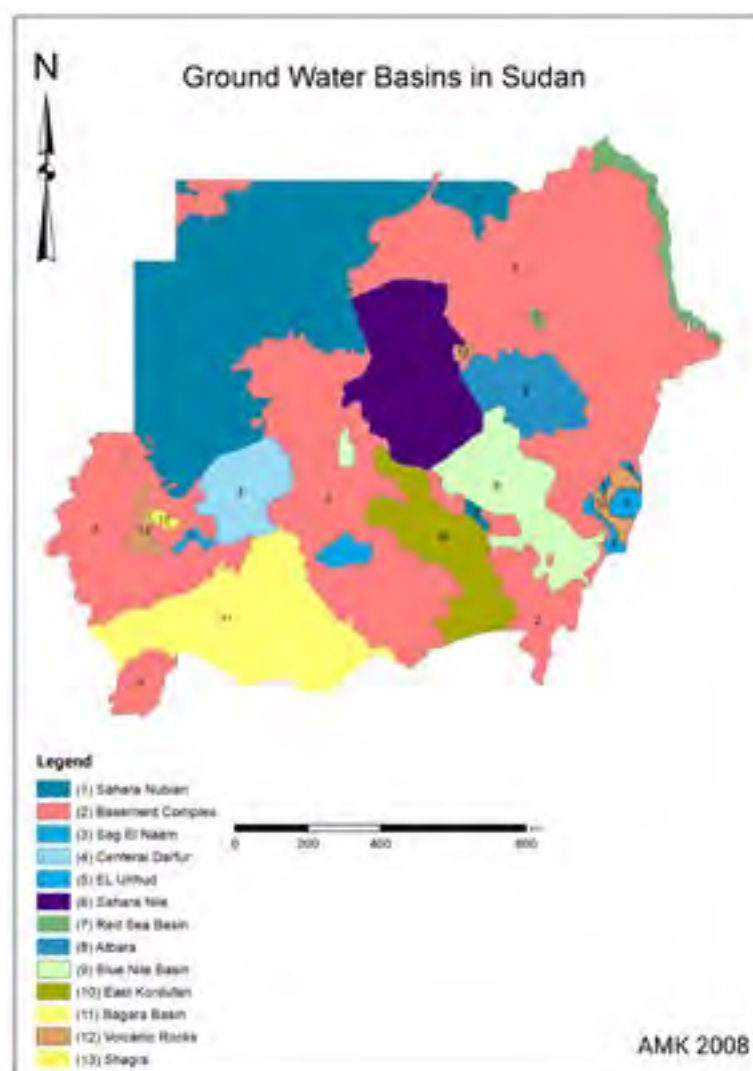
5 Water Resources

Groundwater reserves in Sudan are not measured systematically due to low funding and shifting institutional responsibility between ministries. Although the annual recharge of the country's aquifers has not been assessed accurately, it is estimated at 2 km³, while annual abstraction is estimated at 1 km³ (Adam and Abdo 2017). As can be seen from Table 5.2, the amount of water removed each year is less than 0.2 per cent of the total amount stored in the aquifers. Most stored groundwater is ancient and non-renewable, so great care should be taken in abstracting it to ensure it does not become depleted.

Groundwater management in Sudan is facing the following main challenges:

- ➔ Poor, unreliable and limited information on water resources, exacerbated by a lack of monitoring systems;
- ➔ Lack of comprehensive plans on which development and utilization of water can be based;
- ➔ Weak and fragmented legislative arrangements, and low capacity of the relevant institutions;
- ➔ Poor public awareness on water use, the economic value of groundwater and its susceptibility to depletion and pollution;
- ➔ No integration between surface and groundwater, despite the presence of both resources in many areas;
- ➔ High cost of extraction by conventional diesel-operated pumps especially in deep aquifers, along with limited use of solar and wind energy.

Figure 5.2 Groundwater Resources in Sudan (Adam and Abdo 2017). Redesigned by UNEP



5.2.4 Marine waters

The Red Sea and the Gulf of Aden together make up a globally significant marine ecosystem linked to the Indian Ocean. It is renowned for its unique and beautiful marine and coastal environments and species richness, which includes many species found nowhere else on Earth (Gladstone 2006).

Figure 5.3 The Sudanese coastal zone with main cities (Reworked by GRID-Arendal)



The Sudanese continental coastline of the Red Sea is about 853 km long, including bays and inlets, extending from 18° N at the Eritrean border to 22° N at the Egyptian border (FAO 2019). It lies within the desert and semi-desert subzones, receiving an average annual rainfall of 111 mm. It has a wide but shallow coastal plain, which is very dry (Abdel Salam 2006). Numerous freshwater streams drain into the sea from the Red Sea hills, but there is no permanent water flow into the lower reaches of the coastal plain. The largest seasonal stream, Khor Baraka, sometimes reaches the sea via the vast Tokar Delta.

The Sudanese Red Sea coast has three distinct depth zones: the shallow reef-studded shelves less than

50 m deep, the deep shelves 500 to 1,000 m deep, and the central trench more than 1,000 m deep, reaching a maximum of 3,000 m off the city of Port Sudan (Krupp et al. 1994). On most of the Sudanese Red Sea coast the water is clear. Surface temperatures range between 26.2° C and 30.5° C, and salinity is high, reaching 39 to 41 per cent (Krupp et al. 1994). From May to October, surface currents flow in a southerly direction, and for the rest of the year they flow northwards. The maximum tidal range is about 55 cm (Krupp et al. 1994). The surface sea temperature is highest during summer and autumn and lowest during winter, with a seasonal variation of approximately 6° C.

Numerous islands are scattered along the coast, the majority of which have no fresh water or vegetation, though some of them host mangrove stands and various salt-tolerant plants. The dominant coastal features are silty beaches, rocky headlands and salt marshes, commonly bordered by mangroves. Sea-grass beds are frequently found in the shallow waters of the *marsas* and in lagoons between the coast and the fringing reef. Most of the coast is bordered by discontinuous fringing reefs close to the shore which are separated by deep channels from a barrier reef. The Sudanese coast has the most diverse coral reefs of the Red Sea, including Sanganeb Marine National Park, the only atoll.

5.2.5 Lakes

Natural lakes are another major source of fresh water in Sudan. The country's major lakes include Lake Kundi, which lies 10 km north of Bahr el Arab in southern Darfur; Lake Abyad in Southern Kordofan; Lake Keilak, 200 km north of the junction of Bahr el Arab and Bahr el Ghazal; and Turdat el Rahad Lake in Kordofan (Green et al. 1984; Ministry of Environment, Forestry and Physical Development 2014). The lakes provide habitat for many fish and aquatic plants.

The country has a number of saline lakes, including the Dariba crater lakes, which lie in the volcanic caldera of Jebel Marra in western Sudan (Green et al. 1979; Ministry of Environment, Forestry and Physical Development 2014); the Malha (salty) lake, in the Medoub in Northern Darfur; and several oases such as Nikheila, Natroon and Saleema in the north of the country (Ministry of Environment, Forestry and Physical Development 2014).



Turdāt El Rahad: A natural freshwater lake in North Kordofan. Photo credit © Osman Ali



The inner Dariba crater lake of Marra Mountains, Darfur, within the outer crater. Photo credit © Hammy07 at en.wikipedia

The Nile and its tributaries host several artificial reservoirs. Among these are Sennar and Roseires on the Blue Nile; Jebel Aulia on the White Nile; Khasham el Girba and the Upper Atbara and Setit Complex on the River Atbara; Merowe in the Northern region; and Lake Nubia on the Sudanese-Egyptian border, part of the High Aswan Dam reservoir (Ministry of Environment, Forestry and Physical Development 2014).

Seasonal water bodies form when rainwater flows into natural depressions, *haffirs* (artificial ground reservoirs designed to catch water), and road burrow pits. Extensive pools called *mayas* are found in the Dinder National Park, including Ras Amir, Greissa and Fersh El Nieam (Ministry of Environment, Natural Resources and Physical Development 2016).

5.2.6 Non-conventional water

Non-conventional water is derived from the desalination of seawater or the recycling of treated waste-water. Sudan currently has five desalination plants available in Port Sudan, where 0.02 million m³ are produced per day (Farah 2010). In Khartoum, water from sewage treatment plants is used to irrigate plantations on the outskirts of the city (Adam and Abdo 2017).

5.3 USES OF WATER IN SUDAN

Sudan depends heavily on the Nile for drinking water, irrigation, hydropower generation, river transport and recreation. Other major sources of drinking water include groundwater reserves and *wadis* or *khors*, which are exploited for both people and livestock.

5.3.1 Irrigated agriculture

The area of land irrigated by the Nile or its tributaries varies considerably from year to year depending on the distribution of rainfall and the level of flooding. Table 5.3 shows Sudan's existing irrigation schemes, while Table 5.4 shows future schemes that could be irrigated from the Nile system. Irrigated agriculture accounts for 96.2 per cent of the total water allocated to the country by the 1959 Nile Water Agreement (FAO 2015).

Some of the new irrigation schemes are made possible by the increase in water storage brought about by the construction of Merowe dam, the heightening of Roseires dam and the construction of the Upper Atbara and Setit Dam Complex (the hydraulic installations are already in place either on the dam or downstream of it). The regulated flow of the Blue Nile and possibly the Main Nile will allow Sudan to draw even more water throughout the year for use in its new irrigated areas. The new schemes are likely to use the remaining unused portion of Sudan's quota from the Nile.

5.3.2 Domestic and industrial use

The increase in population and urbanization are placing ever greater demands on Sudan's water resources. Unfortunately, water supply, sanitation and water resource development have all been hampered by a lack of clear policies, insufficient and fragmented information, weak institutions and poor coordination.

The municipal domestic sector accounts for about 3.5 per cent of the water used in Sudan (FAO 2015). Industry – mainly oil production, sugar manufacturing, food processing and construction – accounts for 0.3 per cent, but this is increasing (FAO 2015). Domestic water and sanitation coverage is low and lagging behind population growth. 70 per cent of the urban population and 63.5 per cent of the rural population have access to safe drinking water; while access to safe drinking water sanitation services averages 39.5% (57% in urban areas and 22% in rural areas) (Central Bureau of Statistics and UNICEF 2016).

40 per cent of the basic education schools in Sudan have to endure water shortages and inadequate sanitation facilities (Ministry of Water Resources, Irrigation and Electricity 2016). Sudan established its drinking water safety strategic framework in 2017 (Ministry of Water Resources, Irrigation and Electricity and Federal Ministry of Health 2017).

5 Water Resources

Table 5.3 Areas of irrigated schemes in Sudan

Scheme	Cropped		Equipped	
	Feddans	Ha	Feddans	Ha
Blue Nile System	2,165,840	909,653	3,140,895	1,319,176
Abu Naama	10,000	4,200	30,000	12,600
Pumps u/s Sennar	135,000	56,700	180,000	75,600
Hurga and Nour-el-deen	22,270	9,353	100,000	42,000
Genaid (Sugar)	40,000	16,800	53,333	22,400
Seleit	15,000	6,300	30,000	12,600
Small Private Pumps Schemes	178,570	74,999	238,095	100,000
Waha (Blue Nile)	22,500	9,450	30,000	12,600
Gezira – Managil	1,400,000	588,000	2,016,000	846,720
Rahad I	235,000	98,700	300,000	126,000
Suki Scheme	67,500	28,350	90,000	37,800
NW Sennar Sugar	35,000	14,700	53,466	22,456
Haddaf /Wad Al Faddul	15,000	6,300	20,000	8,400
White Nile System	189,080	79,414	333,950	140,259
Kenana Sugar Scheme	71,400	29,988	95,200	39,984
Kenana – mixed crop	11,250	4,725	15,000	6,300
Asalaya (sugar)	35,000	14,700	43,750	18,375
White Nile Pumps	71,430	30,001	180,000	75,600
Atbara System	210,000	88,200	500,000	210,000
New Halfa	180,000	75,600	462,500	194,250
New Halfa Sugar	30,000	12,600	37,500	15,750
Main Nile System	170,000	71,400	226,670	95,201
Merowe – Dongola	75,000	31,500	100,000	42,000
Hasanab – Merowe	20,000	8,400	26,670	11,201
Khartoum – Hasanab	75,000	31,500	100,000	42,000
Total	2,485,840	2,485,840	2,485,840	2,485,840

Source: Updated from Hamad 2015

*These are areas equipped and ready to be cropped (land prepared and canals dug)

Table 5.4 Areas of planned irrigated schemes

Scheme	Cropped Areas (F)	Developed Areas (F)	Crops
Public Pump Schemes	150,000	550,000	Various
Private Pump Schemes	150,000	400,000	Sugar and others
Rahad Scheme	160,000	300,000	Cotton, groundnuts, sorghum
Es Suki Scheme	60,000	90,000	Cotton, groundnuts, sorghum
El Guneid Scheme	60,000	80,000	Sugar, cotton, groundnuts
New Halfa Scheme	180,000	450,000	Sugar, cotton, groundnuts
Gezira Scheme	1,200,000	2,200,000	Cotton, groundnuts, sorghum
Kenana Sugar Scheme	80,000	100,000	Sugars
NW Sennar Scheme	10,000	17,000	Sugar
Abu Naama Scheme	8,000	30,000	Kenaf
Seleit and others	15,000	40,000	Mainly livestock

5.3.3 Hydropower generation

Generating electricity from hydropower costs 2 to 4 cents per kilowatt-hour (kWh), compared with about 4 cents per kWh from coal plants and about 15 cents per kWh from oil (Sharfi and Murdis 2017).

New infrastructure for hydropower continues to be developed in Sudan, subject to environmental impact assessments. Recently, the following projects have been completed:

- ➔ The Merowe dam, which started generating in 2009, has a capacity of 1,250 MW, doubling Sudan's hydropower generation capacity (Dams Implementation Unit 2018). The Merowe dam has a storage capacity of 12.5 km³;
- ➔ The heightening of Roseires dam by ten meters was completed in 2012, increasing the dam's water storage volume by 4 km³ (Hamad 2015; Dams Implementation Unit 2018). Since it was not accompanied by a new irrigation scheme, most of the added storage went into increasing Roseires hydropower generation by about 26 per cent. Excess water flows into the Merowe dam, increasing its output by 6 per cent (Hamad 2015; Dams Implementation Unit 2018);
- ➔ Construction of the Upper Atbara and Setit Dam Complex was completed in 2016, with four turbines of 80 MW each giving a total of 320 MW (Dams Implementation Unit 2018).

Although not in Sudan, the Grand Ethiopian Renaissance Dam will greatly influence water flows and electricity generation in Sudan and beyond. Moreover, the hydropower plant at the Grand Ethiopian Renaissance Dam could supply an additional 1,000 MW of electricity to Sudan's national grid, and this could be expanded to 3,000 MW in the future. This electricity corridor may even extend to Egypt, since Sudan and Egypt have agreed to connect their grids (Egypt Independent 2020). The Declaration of Principles signed by the leaders of Egypt, Ethiopia and Sudan in 2015 stated: "Downstream countries will be given priority to purchase energy generated by the Grand Ethiopian Renaissance Dam".

When the Grand Ethiopian Renaissance Dam is operational, it is expected to regulate the flow of the Blue Nile and the main Nile, lowering the flood peaks by about two meters and increasing the low summer flow by about two meters, thus creating a more constant year-round flow. This should increase the electricity generation at Roseires by about 28 per cent (Hamad 2017). If the turbines at Roseires are upgraded to 400 MW from the present 280 MW, which is likely, the regulated flow caused by the Grand Ethiopian Renaissance Dam would lead to an increase of more than 40 per cent in electricity generation (Hamad 2017). The regulated flow will also increase power generation from Merowe dam by about 10 per cent and would increase power generation at Sennar Dam as well.



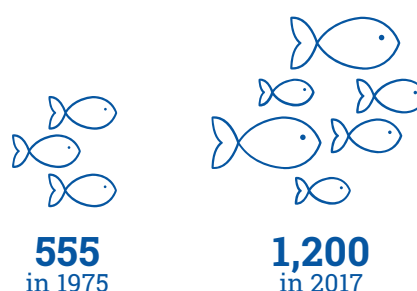
Merowe hydropower dam in Northern Sudan with a capacity of 1250 MW under hydropower generation. Photo credit © Osman Ali

5.4 COASTAL AND MARINE RESOURCES AND THEIR ECONOMIC IMPORTANCE

Sudan has 9,800 km² of continental shelf in the Red Sea that can be exploited for fishing and other activities. The Red Sea houses tremendous and diverse living and non-living resources. The living resources include fish, molluscs, mother-of-pearl oysters, shrimps and other crustaceans, lobsters, crabs, echinoderms such as sea cucumbers, turtles, corals, seabirds, mangroves, sea grasses and sea-weeds. Non-living resources include salt, desalinated water, minerals, gypsum, petroleum and natural gas, in addition to services such as harbour access, navigation, and maritime and tourism activities.

Commercial fish production increased significantly from 555 tonnes in 1975 to around 1,200 tonnes in 2017. There are some 800 km² of flat seabed suitable for trawling off the southern coast of Port Sudan, mainly in the Tokar Delta and Gulf of Agig areas (Ministry of Agriculture, Red Sea State 2017). Trawling produces between 500 and 800 tonnes of fish a year.

Commercial fish production (in tonnes)



Purse-seine fishing, which uses a net strung between two boats and mainly takes place in the north, produces 1,300 tonnes a year; the maximum sustainable yield for this method is estimated at 2,300 tonnes (Ministry of Agriculture, Red Sea State 2017). The major commercial activity on the Sudanese Red Sea coast is maritime transport. In 2015, 1,699 vessels called at Port Sudan harbour (Sea Ports



The Red Sea is rich in marine fauna such as fish, sharks and turtles. Photo credit © SUDIA

Corporation Report 2017). Passenger ferries link Suakin with Jeddah, with an average of two ships a day arriving at Suakin. Imports and exports through Sudanese ports amounted to about 10.4 million tonnes in 2015 (Sea Ports Corporation Annual Report 2017).

The Red Sea state has great potential for tourism. The main activity is scuba diving, and Sudan has several of the best diving sites in the Red Sea. There are also beaches and opportunities for a variety of water sports, recreational areas in the Red Sea hills, and a number of historical and archaeological sites, with the old town of Suakin offering many attractions for visitors.

5.4.1 Marine protected areas

Sanganeb and Dugonab Marine Protected Areas (MPAs) were declared marine national parks in 1990 and 2005 respectively and World Heritage Sites in 2016. They form the nucleus of a national network representing the different habitats and biodiversity of the Sudanese coastal and marine environments and a strong base for ecotourism (Ali 2016).

Sanganeb Marine National Park is designed to protect a unique geological structure in which steep slopes rise more than 800 m from the sea floor. It is the only widely recognized atoll in the Red Sea with pristine living reefs and populations of reef fauna, including commercially important fish stocks (Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden and Global Environment Fund (PERSGA/GEF) 2004. It lies approximately 30 km northeast of Port Sudan city in the central Red Sea. The atoll is entirely submerged; the only part of Sanganeb Marine National Park that is visible above



Sanganeb Marine National Park: the only coral atoll in the Red Sea. Photo credit © SUDIA

the sea surface is the magnificent Sanganeb lighthouse and the few buildings that surround it. These features, along with the site's growing reputation as one of the best diving destinations in the world, make Sanganeb Marine National Park an excellent candidate for protection.

The Dugonab Bay and Mukkawar Island Marine National Park lies on the western shore of the north-central Red Sea. The southern boundary of the MPA is located approximately 120 km north of Port Sudan. It extends almost 70 km northwards and includes reefs, islands and all other marine habitats along this stretch of the coast. The MPA contains an enormous diversity of habitats, many still in very good condition, and a variety of species including populations of several endangered flagship species. Among the highlights are extensive and diverse sea grass beds, a regionally important population of dugong, import-

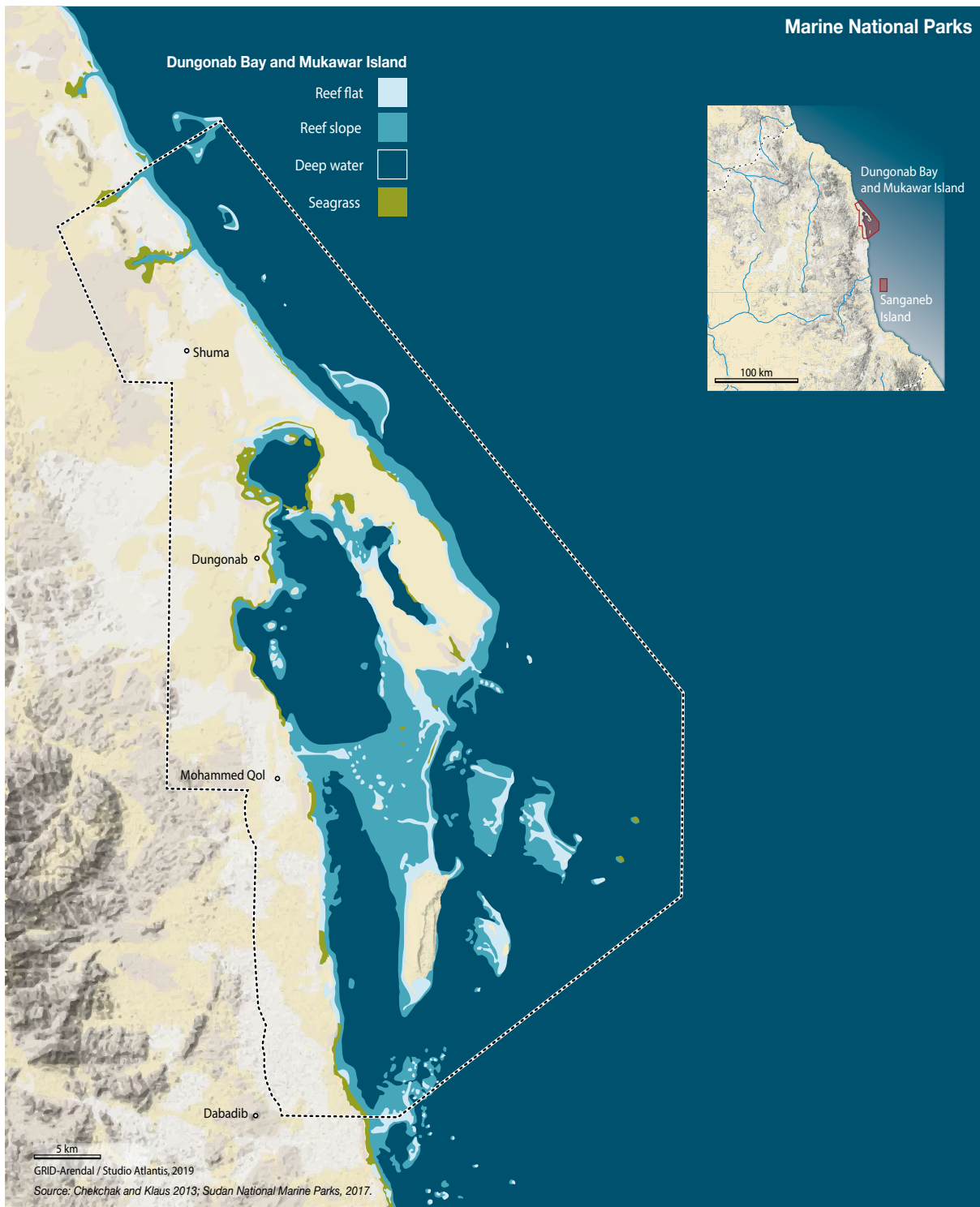
ant nesting areas for marine turtles and seabirds, and seasonal groupings of whale sharks and manta rays that are unique in the Western Indian Ocean region (PERSGA/GEF 2004).

5.4.2 Coastal tourism

There are two main types of tourism in the Red Sea: recreational tourism, which is mainly scuba diving and snorkeling, and fishing.

Most international tourism revolves around the diving industry. The number of dive vessels operating out of Port Sudan increased from eight in 2000 to 13 in 2014. These include eight European-owned boats permanently stationed in Sudan. There are also seven Egyptian boats that visit Sudan on an occasional basis throughout the diving season (Chekchak 2014).

Figure 5.4 Sanganeb Atoll and Dungonab Bay and Mukkawar Island Marine National Parks





Port Sudan is an important seaport for Sudan imports and exports. Photo credit © UNEP

The diving season lasts from the end of September to June. The main draw for tourists is the opportunity to view sharks on the offshore reefs. Tourists live aboard dive boats that offer one- or two-week tours to Sanganeb, Sha'ab Rumi and the Umbria wreck. The boats can take up to 225 clients a week or 8,000 to 9,000 tourists a year. The cost varies between \$1,600 and \$2,500 per client per week, and the industry's total income ranges between \$15 and 17 million per year if the boats are operating at full capacity. Most clients come from Europe, particularly the United Kingdom, Germany, Austria, Italy, France and Spain, but there are increasing numbers from Eastern Europe and Russia (Chekchak 2014).

5.4.3 Navigation

The Red Sea ports at Port Sudan, Sawakin (Osman Digna) and Bashayer Alkhair are used for sea transport for various purposes. Sawakin port is expected to be rehabilitated through an agreement between Sudan and Qatar. The rehabilitation of these ports would bring enormous benefits for Sudan as transit ports for the African and international markets.

5.5 THREATS AND CHALLENGES TO WATER RESOURCES

Sudan faces many water-related challenges ranging from water scarcity and safe drinking water to inadequate sanitation and water pollution. The major threats to the country's water resources include rapid population growth, urbanization, changing lifestyles and consumption patterns, and competing demands from agriculture, industry and energy. There are also unpredictable risks from climate change and environmental degradation, as well as growing tension over scarce water resources that flow across administrative boundaries.

5.5.1 Water stress

Sudan faces a scarcity of water due to the changing climate, increasing demand especially from a growing urban population, and the degradation of watersheds, catchment areas and other sources. Water scarcity threatens food security, energy generation and social cohesion, and can sometimes result in conflict.



Fetching water is a problem in many rural areas in Sudan. Photo credit © UNEP

Currently the country's annual per capita water availability is about 700 m³ based on the Falkenmark Water Stress Indicator, significantly below the "water scarcity margin" of 1000 m³ per capita (White 2012). The demand for water is bound to increase as urbanization and rural development grow. The options for increasing supply are limited. Harvesting all the water from the seasonal *wadis* is practically impossible since their flow comes suddenly, is short-lived and is heavily loaded with silt and debris. Moreover, pollution makes some water sources unsuitable for human consumption. The water in the country's aquifers is mostly of fossil origin, non-renewable and too expensive to extract.

Recently, the government has allowed an increasing number of foreign agricultural companies to acquire land in Sudan and to irrigate it, thus diverting water from other uses and adding to the country's water stress. One study estimated that between 2004 and 2008, these "land grabs" amounted to four million hectares (Elhadary and Obeng-Odoom 2012). The principal investors are from Saudi Arabia, United Arab Emirates, Egypt, Syria, China, Jordan, Morocco and South Korea. The investors utilize the valuable land and water and export the crops and fodder they produce.

5.5.2 Safe drinking water, sanitation and hygiene

Lack of safe water, inadequate sanitation and poor hygiene are among the most important underlying causes of child mortality and morbidity in Sudan, mainly because of diarrhoeal diseases. 40 per cent of schools in Sudan lack water and sanitation facilities (Ministry of Water Resources, Irrigation and Electricity 2016). In 2017, among the ten leading diseases for children under 5, 14 per cent of cases were diarrhoea and gastroenteritis, and 17 per cent were malaria. 8.1 per cent of those with diarrhoea and gastroenteritis died, and 5.9 per cent of those with malaria (Ministry of Federal Health 2017).

The provision of safe, adequate and sustainable drinking water is threatened by Sudan's rapid industrialization, which has caused extensive pollution. Some of the worst-hit areas are around Khartoum, where the uncontrolled discharge of industrial effluents from tanning, food processing and textiles has caused extensive damage (Banaga 2018). Contaminated water sources combined with poor hygiene practices cause water-borne diseases such as diarrhoea, bilharzia, malaria and cholera.



Water supply contamination is a common phenomenon in water points. Photo credit © UNEP

The following are some of the other threats to Sudan's water supplies from industry:

- ➔ Effluent from sugar and soap factories and tanneries is dumped in surface watercourses without treatment;
- ➔ Wastewater from oil fields is dumped into watercourses or transported in flood water;
- ➔ Traditional and industrial mining of gold uses mercury which pollutes surface water and percolates to shallow groundwater, as reported by local authorities in Darfur, Blue Nile and Northern States (Ibrahim 2015);
- ➔ The uncontrolled use of chemicals and the extensive aerial spraying of pesticides on agricultural land (UNEP 2012): in many parts of Sudan, especially in the Gezira area, irrigation canals are also a source of drinking water.

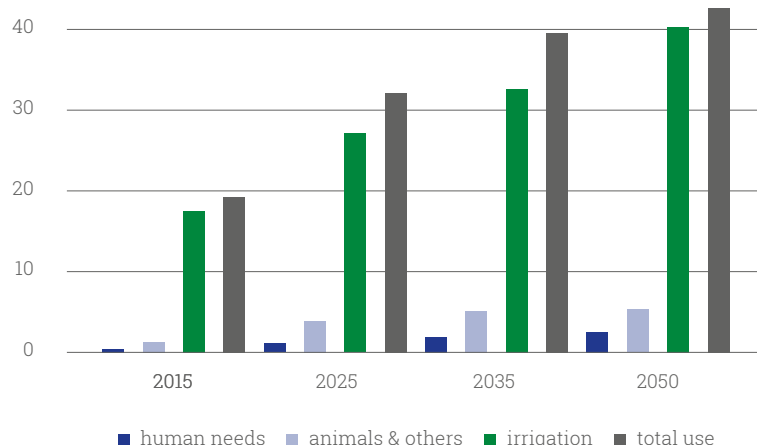
Researchers have been experimenting with ways to reduce the impact of industrial pollution on the environment. For example, one project in Heglig oil fields involves planting reed beds with *Phragmites australis* (Hagahmed et al. 2014) in areas where wastewater from the oil fields has been dumped. As they grow, the reeds biodegrade the hydrocarbons in the water. However, in the absence of appropriate legislation, such treatments are rarely used.

5.5.3 Water supply and demand imbalance

One of the challenges for Sudan's authorities is that many of the country's natural water supplies fluctuate throughout the year. For example, the flow of the Blue Nile and Atbara rivers follows the rainfall pattern over the Ethiopian highlands. These river systems have two distinct flow periods: the flood period from July to October and the low flow or dry season from December to June. The daily flow of the Blue Nile fluctuates between 10 million m³ per day in April to more than 500 million m³ per day in August (FAO 2016). The Atbara River used to be virtually dry from January to June before the construction of Tekezi hydropower dam in Ethiopia. Today the dam ensures a constant flow of at least 5 million m³ per day throughout the dry season (DIU 2018).

Most of Sudan's extracted water is used in agriculture. One issue is that because of the high daily temperatures, Sudan's agricultural lands are affected by evapotranspiration, which causes the loss of 1700 to 3000 mm of water per year, increasing from south to north (Abdalla 2017). This means that a hectare of a

Figure 5.5 Annual water demand projection (km³)



Source: Updated from SNPW 2000 and Hamad 2002

seasonal crop in central Sudan requires 12,000 m³ of water a year. Climate change presents an additional risk. An increase in average temperatures between 1.5°C and 2.5°C in most of the northern states is expected towards 2050 and the demand for agriculture might increase two to three-fold compared to the year 2000 (Abdelaty and Babiker 2013). The situation could be exacerbated by increasing demand for water from other sectors, such as households, livestock and industry. Figure 5.5 shows some annual water use projections up to 2050.

The seasonal nature of Sudan's water supplies was a main reason for building dams on the Nile and Atbara rivers to store water after the peak of the flood. The stored water is used for irrigation and hydropower generation during the long dry season from December to June. The limited storage capacity of the dams, which is being continuously decreased by siltation, could still provide a source for more irrigated land. It is estimated that about 1.72 million ha is equipped for full control irrigation (modern and traditional irrigation) while about 1.3 million ha is equipped for spate irrigation (FAO 2017b). The total area of farmland in Sudan that could potentially be irrigated is many times that amount, which means that future irrigation projects will need to find water elsewhere. As stated by Ahmed (2017), the water demand for new proposed projects up to 2032, such as the Rahad II and Atbara River projects, is estimated to be 7.3 km³.

5.5.4 Climate change and extreme climatic events

An environmental and climate change assessment study for Sudan was conducted by the International Fund for Agricultural Development in 2011. Nine meteorological stations were selected and data were collected for different starting years (1900–1937) up to 2011 (Abdelaty and Babiker 2013). The study found that the overall trend has been an increase in average temperatures in Sudan, ranging from 0.6 °C in El Obeid to 2.1 °C in Khartoum (Abdelaty and Babiker 2013). The total annual temperature is projected to increase by between 1.5°C and 2.5°C by 2050.

From 1970 to 2011, rainfall declined by between 10 and 20 per cent across the western and southwestern states. Future projections up to 2050 estimate a change in rainfall ranging from a reduction of 9 per cent to an increase of 9 per cent (Abdelaty and Babiker 2013). The frequency of extreme climatic events is expected to increase (Abdelaty and Babiker 2013). According to another study using different climate change scenarios, the entire Nile basin is expected to experience increases in precipitation early in the century (period I, 2010–2039), followed by decreases later in the century (periods II, 2040–2069, and III, 2070–2099), with the exception of the eastern-most Ethiopian highlands where summer precipitation is projected to increase in the period 2080–2100 (Beyene et al. 2006).

5 Water Resources

If temperatures continue to rise in the northern states, some indigenous plants, insects and small animals may be lost forever. Sub-tropical plants requiring wet or moist conditions may shift further south (Abdelaty and Babiker 2013). Crop yields are likely to fluctuate more with a significant downward shift in the long-term average. The World Bank has estimated that a 1°C increase in temperature could cause a loss in agricultural production of 10 per cent (Abdelaty and Babiker 2013). This could mean a decrease in production of up to 25 per cent in the northern states by 2050.

In 2016, Sudan published its climate change National Adaptation Plan (NAP), which was produced by a large number of institutions headed by the Higher Council for Environment and Natural Resources (Ministry of Environment, Natural Resources and Physical Development 2016). The NAP's key recommendations are focused on capacity building in human resources, institutions, methodologies, technology and equipment, and information and networking.

5.5.5 Coastal zone vulnerability and adaptation to climate change

Sudan's coastline faces several major hazards relating to climate change, including sea level rise, increased seawater temperature, salinity changes, intensified storm surges, more frequent droughts and more frequent flash floods.

Local sea level rise is already happening in the Red Sea. A review of limited data from the Permanent Service for Mean Sea Level for Port Sudan area shows that there has been a gradual increase in sea level of between 10 and 20 cm during the past century (Ministry of Environment, Forestry and Physical Development 2013), though because of a lack of data it is unclear how much of this is due to local subsidence. Future sea level rise is likely to have a significant impact on Sudan's coastline and poses a threat to both natural systems and coastal development plans.

One of the most vulnerable areas is the Tokar Delta. Further sea level rise would cause salt water to move inland and to enter aquifers, affecting agriculture and coastal communities. The impact on salt marsh and mangrove habitats would mean a loss of biodiversity and feeding grounds for many resident and migratory seabirds. The retreating shoreline would cause erosion of sand on the upper part of the beach, increasing the turbidity of the seawater, and as a result light conditions would be too low for coral and other benthic organisms to photosynthesize.

Coral reefs near Port Sudan and Suakin ports have already been damaged by shipping, construction and dredging activities (Hassan et al. 2002). Remarkably, a recent survey found that Sanganeb Marine National Park and Dungonab Bay and Mukkawar Island Marine National Park were among the few coral reef sites to have escaped bleaching caused by heat stress as a result of global warming (UNESCO 2017).

Figure 5.6 Mean sea surface temperature (°C) in the Red Sea between January 2011 and December 2017 (NOAA 2017).

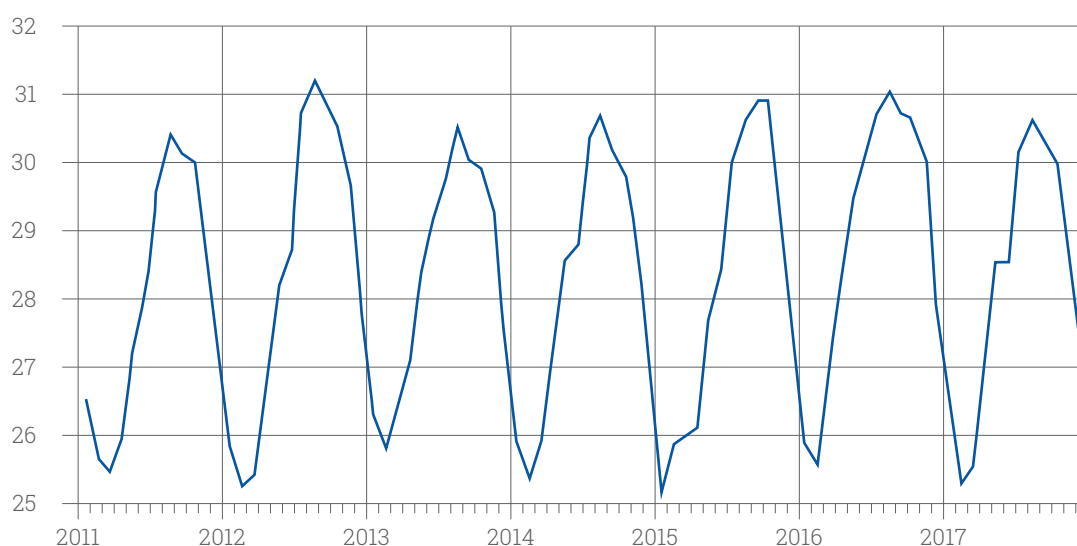
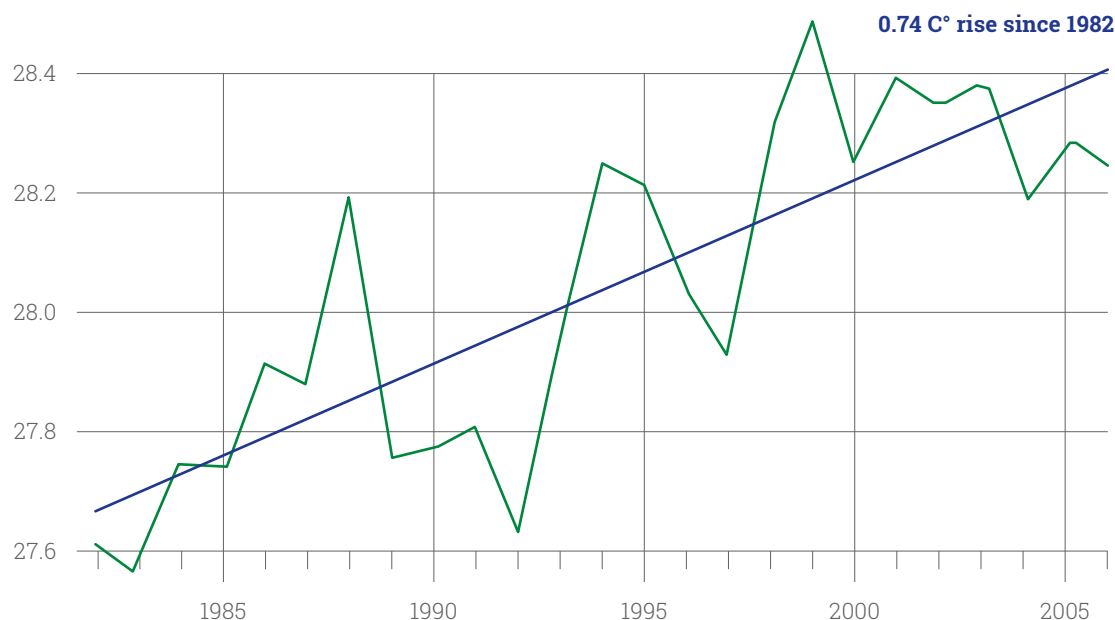


Figure 5.7 Red Sea annual mean sea surface temperature (°C) between 1982 and 2006 (Shermen et al. 2007)



5.5.6 Catchment degradation, floods and droughts

Droughts and floods disturb the hydrological regime through which water cycles between the land and the atmosphere, which in turn affects ecosystems. Persistent drought leaves the soil dry, loose and prone to erosion. It also lowers the groundwater table and reduces the flow from groundwater sources during the dry season.

Drought causes social disruption too, causing malnutrition and disease, forcing people to migrate and increasing conflict over resources. The extent of human and animal suffering during the years of drought in the mid-eighties is well known. In 1984, the flow of the Nile was 60 per cent of its long-term average and among the lowest recorded in 100 years, second only to that of 1913. Rainfall was less than 40 per cent of the average in most regions of Sudan. The drought made it impossible to plant the wheat crop in Gezira state in the winter of 1984' (Permanent Joint Technical Committee, Annual Reports 1960–2014).

Floods cause a different set of problems. During a flood period, the Blue Nile and Atbara Rivers carry a lot of silt. Soil and debris are eroded from the Ethiopian highlands and carried into Sudan, causing siltation of reservoirs and irrigation canals. This reduces the storage capacity of reservoirs and the carrying capacity of irrigation canals, and causes blockages in pumping systems.

The erosion of river banks is another problem, especially along the main Nile north of Merowe where mature date palms and fruit trees are uprooted into the river. However, the partial regulation of flow downstream of Merowe dam has helped to limit riverbank erosion to some extent, and the operation of the Grand Ethiopian Renaissance Dam may reduce these adverse effects even further.

Floods are both a blessing and a curse. On the one hand, they renew the fertility of floodplains and relieve farmers of the need to irrigate their crops that season. On the other hand, they damage hydraulic infrastructure, buildings, animals and, sometimes, human livelihoods. The floods in 2013, 2014 and 2017 not only damaged homes and livelihoods, but also exposed communities to water-borne diseases (Abdo 2017). As a result, in a number of areas in Khartoum and Omdurman the healthcare system was stretched beyond its capacity (Abdo 2017). Table 5.5 shows the impact of the 2014 flash floods on some of Sudan's states. The 2020 flood in Sudan was the highest in record. The floods, which were caused by the Nile flood and/or rainfall flash floods, have affected all states with Khartoum the worst. 770,000 people were affected, 103 deaths and 38,000 homes destroyed. The Blue Nile level at Khartoum reached 17.65 m on 6 September, the highest since the country started measuring in 1912.



River Nile flood in Wad Ramli district, Khartoum state, 2019. Photo credit © UNEP

Table 5.5 Impact of flash floods of 2014 on the states in Sudan

Affected States	Human Losses		Houses Damaged	
	Injured	Death	Completely	Partially
West Darfur	0	0	836	119
Gezira	4	5	844	1,020
Northern	41	3	352	1,049
North Kordofan	0	0	1,253	1,762
Sennar	0	0	1,004	1,217
South Kordofan	0	0	344	2,114
White Nile	0	0	1,291	1,816
River Nile	35	2	1,116	2,140
Kassala	0	0	3,750	822
Khartoum	0	4	3,468	1,925
Total	80	14	14,258	13,984

Source: Sudanese Red Crescent Society 2014

5.6 THREATS AND PRESSURE ON MARINE RESOURCES

The Sudanese Red Sea has, to some extent, escaped the widespread degradation that is evident in many other large areas of reef within the Red Sea and globally. However, this situation is changing rapidly. Ali (2016) reported a number of serious and rapidly growing threats, including:

- ➔ Rapid and very substantial coastal population growth.
- ➔ Rapid urban expansion especially in Port Sudan; this is environmentally unsustainable because of insufficient urban planning, poor provision of public services and lack of infrastructure to accommodate the growing population.
- ➔ Increase in off-shore oil and gas exploration and oil extraction.
- ➔ Increased ship traffic and the associated risks, such as navigational hazards and oil spills.
- ➔ Unsustainable construction activities such as dredging.
- ➔ Unsustainable fisheries, including both artisanal reef fisheries and the growing industrial-scale fisheries.
- ➔ The spread of tourism southwards from Egypt to central and southern parts of the Red Sea.

The combination of increasing human impacts and global-scale disturbances such as sea level rise pose a serious threat to the ecology of coral reefs and the biological communities that depend on them.

5.7 INSTITUTIONAL AND POLICY ARRANGEMENTS

The key institution for water resources management at the federal level in Sudan is the Ministry of Water Resources, Irrigation and Electricity. It sets the national water resources policies, develops and monitors water resources projects, and promotes water management including irrigation and drainage. The National Water Resources Council was created in 1995 as a result of the Water Resources Act of 1995.

Three of the most recent pieces of regulation concerning water resources are the Exploitation of Groundwater (Licensing) Regulation (2016), Irrigation and Drainage Licenses Regulations (2016), and Surface Water Regulations (2016).

Until recently, two other ministries were also involved in water management: the Ministry of Agriculture and the Ministry of Environment, Natural Resources and Physical Development. The former still exists while the latter was replaced in 2018 by the National Council for Environment, and in April 2020 a new Higher Council for Environment and Natural Resources was established.

Following the decentralization of governance in Sudan in 1997, the states and in some cases the localities started building their own institutions for managing water resources within their areas, or for managing resources that are shared by more than one state. In general, state-level institutions are not well equipped to manage water resources, partly due to low funding and a lack of clarity over roles (Ministry of Environment and Physical Development 2008).

5.8 TRANSBOUNDARY WATER RESOURCES

In February 1999, the then nine countries of the Nile Basin signed the Nile Basin Initiative (NBI). The NBI is a transitional arrangement for the sharing of the Nile waters. It is due to be replaced by a Cooperative Framework Agreement once negotiations for this have been finalized and a permanent institution is created. The Cooperative Framework Agreement was signed in 2010 by five countries – Ethiopia, Kenya, Uganda, Rwanda and Tanzania. Burundi signed in 2011. However, Egypt and Sudan have not signed because it does not recognize their water rights as laid out in their 1959 Nile Water Agreement. The Democratic Republic of the Congo and South Sudan have also not yet signed it. The Cooperative Framework Agreement would give deciding power over large hydraulic projects to a commission representing all the signatories. It is currently on hold due to the position of Egypt and Sudan (NBI 2012).

A significant landmark in transboundary water management is the 1997 UN Convention on the Law of the Non-Navigational Uses of International Watercourses (United Nations 2014). So far, Sudan, Egypt and Ethiopia have not ratified this Convention.

Many of Sudan's non-Nile streams are shared with neighbouring countries. For example, Gash (or Mereb, as it is called in Eritrea) and Baraka originate in Eritrea. Azum and Kaja originate in Sudan and are shared with Chad. Sudan shares seven transboundary aquifers with neighbouring countries including the Nubian

Sandstone aquifer system, with no legal agreement to cover these shared resources. The Nubian Sandstone aquifer is the largest groundwater aquifer in the regions is shared between Sudan, Chad, Egypt and Libya. There is a permanent joint committee, and in 2013 the four countries signed a Regional Strategic Plan for NSAS.

In 2015, the then-leaders of Egypt, Ethiopia and Sudan made an important move towards closer cooperation on water resources when they signed the Declaration of Principles (DoP) on the Grand Ethiopian Renaissance Dam. The DoP establishes a solid base for working together and sharing the costs and benefits of the Nile's resources. The main principles in the declaration are (State Information Service 2017):

- ➔ Principles of Cooperation;
- ➔ Principle of Development, Regional Integration and Sustainability;
- ➔ Principle Not to Cause Significant Harm;
- ➔ Principle of Equitable and Reasonable Utilization;
- ➔ Principle to Cooperate on the First Filling and Operation of the Dam;
- ➔ Principle of Confidence Building;
- ➔ Principle of Exchange of Information and Data;
- ➔ Principle of Dam Safety;
- ➔ Principle of Sovereignty and Territorial Integrity;
- ➔ Principle of Peaceful Settlement of Disputes

5.9 OPPORTUNITIES FOR SUSTAINABLE WATER RESOURCES DEVELOPMENT

About 14 of the UN's 17 Sustainable Development Goals (SDGs) are related to water, sanitation and hygiene. Sudan's Water, Sanitation and Hygiene Policy, known as WASH (Ministry of Water Resources, Irrigation and Electricity 2018), commits the country to achieving these goals by 2030. The policy, yet to be endorsed and implemented, will set the government on the path of improving the management and protection of water resources, with due consideration to certain globally accepted principles such as decentralization, gender balance, community participation and sustainability in the face of climate change. This will help improve the living conditions and health of the people of Sudan and the country's economic growth.

5.9.1 Water harvesting and the Zero Attash (Thirst) programme

Lack of access to safe water and competition for limited water resources is hindering socio-economic development and environmental conservation in rural areas away from the Nile and has helped fuel conflict in some areas. This situation led to the Zero Attash or Thirst programme, a presidential initiative started in 2016 that aims to ensure that everyone in the rural areas of Sudan is within 500 metres of a reliable water supply by the year 2020. A major part of this programme is to enhance Sudan's water harvesting technologies. The programme has not yet achieved its targets. The Dams Implementation Unit has produced a water atlas for Sudan as an inventory and guide for its water harvesting projects.

Water harvesting involves collecting rainwater during the rainy season (July–September) and storing it for use during the dry period (December–June). Small dams and embankments are built to divert water into storage areas and to recharge groundwater supplies. The water storage capacity of the constructed facilities ranges from 1 to 20 million m³ (DIU 2019).

5.9.2 Integrated Water Resource Management

Since 2005, Sudan has committed to implement Integrated Water Resources Management (IWRM) in order to promote the sustainable and equitable management of water resources. Japan International Cooperation Agency (JICA) is involved in Sudan – via the Ministry of Irrigation and Water Resources – in a project to enhance the practice of IWRM. Two outputs have resulted from the project: water balance analysis; and identification of issues on water resources management (JICA 2017).

Many good practices and case studies of IWRM can be found in Sudan. UNEP has collected and diagnosed more than 30 such case studies, out of which six case studies from different parts of Sudan were selected for presentation (UNEP 2020). They cover wide geographical locations; various ecological zones and a range of water uses. They include:

- ➔ Wadi El Ku Catchment Management Project, Darfur;
- ➔ National Adaptation Programme for Action: Climate Change Adaptation Project;
- ➔ Butana Integrated Rural Development Project;
- ➔ Rural Water for Sudan.



Water dam in Malit locality, North Darfur. Photo credit © UNEP

5.9.3 Cooperative approach to water resources management

Regional cooperation is essential to allow countries to make the most of their shared water resources. Without cooperation, it is difficult for them to regulate rivers against floods and droughts, to manage groundwater reserves and protect watersheds and wetlands. Special attention should be given to shared aquifers that sustain life in remote areas away from the Nile. The sustainable management of transboundary, non-renewable resources such as the Nubian Sandstone aquifer requires all countries to refrain from over-extraction. The signed protocol between the four countries sharing the Nubian Sandstone aquifer should focus on promoting regional cooperation, networking and monitoring.

There are several other opportunities for regional cooperation in water resource management, such as the development of the electricity corridor between Ethiopia and Sudan, and the Grand Ethiopian Renaissance Dam. As a joint project for transboundary water supply, storage, irrigation, hydropower generation, navigation, flood and drought mitigation and sustainable management, it is hoped that the dam will be an example of best practice for the rest of the Nile Basin countries.

5.10 CONCLUSION

Water resources play a fundamental role in shaping Sudan's distinctive climatic and ecological zones, and also the diverse livelihoods of its people.

Sudan's inland waters are affected by many factors including seasonality of rainfall, siltation, floods, riverbank erosion and pollution. Its marine and coastal resources support a growing number of economic and livelihood possibilities, while the marine protected areas play important roles as sites of international heritage, as tourist destinations, and in preserving and replenishing biotic resources.

Sudan is classified as a water-stressed country, and its water resources are under increasing threat from pollution, unregulated economic development and

climate change. Although they have been a source of conflict where there is competition for their use, if properly managed they could also be a basis for collaboration, stability and sustainable development.

The major challenges for Sudan's water management include weak institutions, poor enforcement of laws and regulations, a lack of cooperation with neighbouring countries and climate change. The failure to address these challenges is putting pressure on the lives of the Sudanese people and hindering development. There is an urgent need for Sudan to adopt an ecosystem-based approach to the management of its inland and marine water resources, and to integrate sustainable development policies throughout its institutions.

References

REFERENCES

1. Abdalla K. A. (2017). Water and Climate. In A. M. Salih (Ed.). *Water Resources of the Sudan* (1st ed., pp. 1–40). Water Research Center, University of Khartoum, Sudan.
2. Abdelaty, M. and Babiker A. (2013). Sudan Environmental and Climate Change Assessment, IFAD's Country Strategic Opportunities Programme 2013-2017. Retrieved from: <https://operations.ifad.org/documents/654016/2344574/Sudan+-+Environmental+and+climate+change+assessment/b71854bc-a1f2-40c8-998a-ed7ac7866c46>
3. Abdel Salam, M. Y. (2006). Marine and Coastal Environmental Conservation in Sudan: The role of marine protected areas. Workshop on the Post-Conflict National Plan for Environmental management Sudan. Khartoum, Sudan.
4. Abdo, G. M. (2017). Water Related Disasters (floods and droughts) In A. M. Salih (Ed.). *Water Resources of the Sudan* (1st ed., pp. 82–91). Water Research Center, University of Khartoum, Sudan,
5. Abdo, G. and Salih, A. (2012). Challenges Facing Groundwater Management in Sudan, Paper presented at the Annual Conference of Post-graduate Studies and Scientific Research, 17–20 February 2012, Khartoum, Sudan.
6. Adam, A. M. and Abdo, G. M. (2017). Water and hydrology (Surface and Groundwater), In A. M. Salih (Ed.). *Water Resources of the Sudan* (1st ed., pp. 41–81). Water Research Center, University of Khartoum, Sudan.
7. Adam, A. M. (2017). Sudan Estimated Water Demands. Paper presented at the plenary session of the 5th Nile Basin Development Forum in Kigali, Rwanda.
8. Ahmed, H. E. (2017). Water for Human Needs and Livestock Requirements. In A. M. Salih (Ed.). *Water Resources of the Sudan* (1st ed., pp. 266–289). Water Research Center, University of Khartoum, Sudan.
9. Ahmed, S. E. (2014). Changing Produced Water from Nuisance into a Resource using Natural Reeds, Ministry of Oil and Gas, Sudan.
10. Ali, M. E. (2016). Policy Assessment on Biodiversity and Ecosystem Management. Higher Council for Environment and Natural Resources, Khartoum, Sudan.
11. Banaga, S.E. (2018). Khartoum State Master Plan for the Sewerage Networks and the Sewage Treatment Plants.
12. Beyene, T., Lettenmaier, D. P. and Kabat, P. (2006). Hydrologic Impacts of Climate Change on the Nile River Basin: Implications of the 2007 IPCC Scenarios. *Climatic Change*, 100 (3), 433-461. Retrieved from: DOI: 10.1007/s10584-009-9693-0
13. Borji, T.T. (2013). *Sedimentation and sustainability of hydropower reservoirs: Case of Grand Ethiopian Renaissance Dam in the Blue Nile River in Ethiopia*. (Master of Science thesis in Hydropower Development. Norwegian University of Science and Technology, Trondheim, Norway).
14. Chekchak, T. (2014). (Ed.). Towards a Sustainable Future for the Red Sea Coast in Sudan. Part 2: Socio Economic and Governance Survey. Cousteau Society. Retrieved from: <http://sudan-marineparks.info/wp-content/uploads/2016/04/ICZM-reportsudan-RSS-socioeco.pdf>
15. Dams Implementation Unit (2018). Glimpses on Sudan Dams (in Arabic) Retrieved from: <https://www.facebook.com/DAMSINSUDAN>
16. Dams Implementation Unit (2019). The state of the implementation of the water harvesting projects, Dams Implementation Unit report (in Arabic).
17. Egypt Independent (2020). Egypt Sudan run electricity linkage project at a voltage of 220 KV. Retrieved from: <https://egyptindependent.com/egypt-sudan-run-electric-linkage-project-at-a-voltage-of-220-kv>
18. Elhadary, Y. and Obeng-Odoom, F. (2012). Conventions, changes, and contradictions in land governance in Africa: The story of land grabbing in north Sudan and Ghana. *Africa Today*, 59 (2), 59–78.
19. Food and Agriculture Organization of the United Nations (2008). Fishery country profile – Sudan. Retrieved from: <http://www.fao.org/fishery/facp/SDN/en>
20. Food and Agriculture Organization of the United Nations (2015). AQUASTAT Information System on Water and Agriculture. Sudan Country Profile Retrieved from: http://www.fao.org/nr/water/aquastat/countries_regions/SDN/index.stm
21. Food and Agriculture Organization of the United Nations. 2016. AQUASTAT. Water resources Sudan. Retrieved from: http://www.fao.org/nr/water/aquastat/countries_regions/Profile_segments/SDN-WR_eng.stm
22. Food and Agriculture Organization of the United Nations (2017a). AQUASTAT Information System on Water and Agriculture. Sudan Country Profile.

23. Food and Agriculture Organization of the United Nations (2017b). AQUASTAT. Country Profile- Sudan. Retrieved from: http://www.fao.org/nr/water/aquastat/countries_regions/SDN/index.stm
24. 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>
25. Farah, O. M. (2010). Marine and coastal resources (living and non-living), threats, priority actions and abatements. National Workshop on Marine Science Curriculum, UNESCO Chair of Marine Science, Port Sudan, Sudan.
26. Gladstone, W. (2006). State of the Environment Reporting in the Red Sea and Gulf of Aden. In W. Gladstone (Ed.). State of the Marine Environment. Report for the Red Sea and Gulf of Aden 2006. Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA).
27. 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>
28. Green, J., Moghraby, A. I. and Ali, O. M. (1984). A Faunastic Reconnaissance of Lakes Kundi and Keilak, Western Sudan. *Hydrobiologia*, 110, 33–44.
29. Green, J., Moghraby, A. I. and Ali, O. M. (1979). Biological observations on the Crater Lakes of J. Marra, Sudan. *Journal of Zoology (London)*, 189, 493–502.
30. Hagahmed, D.E.D., Gasmelseed, G.A. and Ahmed, S.E. (2014). Multiple loops control of oil biodegradation in constructed wetland. *Journal of Applied and Industrial Sciences*, 2 (1), 5-13.
31. Hamad, O. E. (2015). Strategic water resources analysis – the consolidated data report for Sudan, Submitted to the Nile Basin Initiative Secretariat (NBI SEC), Entebbe, Uganda.
32. Hamad, O. E. (2017). Sudan Water Governance – laws, policies and institutions, Global Water Partnership and the United Nations Environment Programme, Khartoum, Sudan.
33. Hassan, M., Kotb, M. M. and Al-Sofyani, A. (2002). Status of Coral Reefs in the Red Sea – Gulf of Aden. In C. Wilkinson (Ed.). *Status of Coral Reefs of the World*. (pp.45-53). Publisher: Australian Institute of Marine Science, Townsville, Queensland, Australia.
34. Ibrahim, M.S. (2015). *Artisanal Mining in Sudan – Opportunities, Challenges and Impacts*. Presented at the 17th Africa OILGASMINE Conference, Khartoum, Sudan. Retrieved from <https://unctad.org/meetings/en/Presentation/17OILGASMINE%20Mohamed%20Sulaiman%20Ibrahim%20S4.pdf>
35. Japan International Cooperation Agency (JICA) (2017). The Project for Enhancement of Integrated Water Resources Management in the Republic of the Sudan. Retrieved from: https://www.jica.go.jp/project/sudan/009/materials/ku57pq000028p35u-att/briefnote_ph1_en_201710.pdf
36. Ministry of Agriculture, Red Sea State (2017). Marine Fisheries Administration Annual Report, Port Sudan, Sudan.
37. Ministry of Environment, Natural Resources and Physical Development (2016). National Adaptation Plan (NAP). Retrieved from: <https://www4.unfccc.int/sites/NAPC/Documents%20NAP/National%20Reports/Sudan%20NAP.pdf>
38. Ministry of Environment and Physical Development (2008). National Capacity Self-assessment: report and action plan. Khartoum, Sudan. UNDP and Global Environmental Facility.
39. Ministry of Environment, Forestry and Physical Development (2013). Stocktaking and National Biodiversity Targets Setting Report. Khartoum, Sudan.
40. Ministry of Environment, Forestry and Physical Development (2014). Sudan Fifth National Report to the Convention on Biological Diversity (CBD). Khartoum, Sudan. Retrieved from: <https://www.cbd.int/doc/world/sd/sd-nr-05-en.pdf>
41. Ministry of Environment, Forestry and Physical Development (2015). National Biodiversity Strategy and Action Plan 2015–2020. Khartoum, Sudan.
42. Ministry of Federal Health (MFH) (2017). Annual Health Statistical Report. Sudan.
43. Ministry of Water Resources and Electricity (1999). Sudan National Water Policy (SNWP).
44. Republic of Sudan (2011). Water, Sanitation and Hygiene Sector – National Strategic Plan (2012–2016). Supported by UNICEF. Retrieved from: <http://washinschoolsmapping.com/wengine/wp-content/uploads/2015/10/sudan-khartoumstrategicplan.pdf>
45. Ministry of Water Resources, Irrigation and Electricity (2016). Assessment and review of the WASH sector national and state strategic plans for the period 2012–2015. Drinking Water and Sanitation Unit (DWSU) DWSU and UNICEF's WASH Programme.

46. Ministry of Water Resources, Irrigation and Electricity and Ministry of Federal Health (2017). Sudan Drinking Water Safety Strategic Framework. Retrieved from: <https://www.humanitarianresponse.info/files/2019/07/Sudan-Drinking-Water-Safety-Strategic-Framework-%28SDWSSF%29-2017.PDF>
47. Ministry of Water Resources, Irrigation and Electricity (2018). Sudan Water, Sanitation and Hygiene (WASH) Policy – Report by Newtech Consulting Group, Khartoum.
48. National Oceanic and Atmospheric Administration (NOAA) (2017). Global Climate Report. Retrieved from: <https://www.esrl.noaa.gov>
49. Nile Basin Initiative (NBI) (2012). State of the Nile River Basin Report 2012.
50. Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA) and Global Environment Fund (GEF) (2004). Dungonab Bay – Mukawwar Island Proposed Marine Protected Area: Site-Specific Master Plan with Management Guidelines. PERSGA, Jeddah.
51. Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA) (2010). The Status of Coral Reefs in the Red Sea and Gulf of Aden: 2009. PERSGA Technical Series Number 16, PERSGA, Jeddah.
52. Sea Ports Corporation (2017). Annual Report. Port Sudan, Sudan.
53. Sharfi, E. M. and Murdis, M. (2017). Water and Energy Nexus. In A. M. Salih (Ed.). *Water Resources of the Sudan* (1st ed., pp. 177–265). Water Research Center, University of Khartoum, Sudan.
54. Sherman, K., Belki, I., O'Reilly, J. and Hyde, K. (2007). Variability of large marine ecosystems in response to global climate change. *International Council for the Exploration of the Sea Council Meeting documents*. Retrieved from: <http://www.ices.dk/sites/pub/CM%20Documents/CM-2007/D/D2007.pdf>
55. State Information Service (2017). Agreement on Declaration of Principles between Egypt, Ethiopia and Sudan on the GERDP. Retrieved from: <https://sis.gov.eg/Story/121609/Agreement-on-Declaration-of-Principles-between-Egypt%2C-Ethiopia-and-Sudan-on-the-GERDP?lang=en-us>
56. Sudanese Red Crescent Society (SRCS) (2014). Sudan: flash floods, the International Federation of Red Cross and Red Crescent Society, IFRC flash flood info bulletin, the Sudanese Red Crescent Society. Accessed on 24/4/2020 from: www.ifrc.org
57. Thiel, H., Pfannkuche, O., Theeg, R. and Schriever, G. (1987). Benthic metabolism and standing stock in the central and northern Red Sea" *Marine Ecology* 8, (1), 1–20. Retrieved from: <https://doi.org/10.1111/j.1439-0485.1987.tb00171.x>
58. United Nations Environment Programme (UNEP) (2007). Sudan Post-Conflict Environmental Assessment. Nairobi, Kenya. Retrieved from: https://postconflict.unep.ch/publications/UNEP_Sudan.pdf
59. United Nations Environment Programme (UNEP) (2012). Environmental governance in Sudan: An expert review. Nairobi, Kenya. Retrieved from: <https://www.unenvironment.org/news-and-stories/story/new-report-environmental-governance-sudan-expert-review>
60. United Nations Environment Programme (UNEP) (2016). Some, for all, forever. Emerging development of Integrated Water Resources Management in non-Nile Sudan. Retrieved from: https://wedocs.unep.org/bitstream/handle/20.500.11822/22505/UNEP%20Sudan_IWRM_Some_for_all_forever_2016.pdf?sequence=1&isAllowed=y
61. United Nations Environment Programme (UNEP) (2016). Disasters and Conflicts. Retrieved from <http://www.unep.org/explore-topics/disasters-conflicts>
62. United Nations (UN) (2014). Convention on the Law of the Non-Navigational Uses of International Watercourses. Retrieved from: https://legal.un.org/ilc/texts/instruments/English/conventions/8_3_1997.pdf
63. United Nations Environment Programme (UNEP) (2020). Integrated Water Resource Management – Good Practices in Sudan. Retrieved from: <https://www.unenvironment.org/resources/report/integrated-water-resources-management-good-practices-sudan>
64. Zaroug, M. A. H., Eltahir, E. A. and Giorgi, F. (2014). Droughts and floods over the upper catchment of the Blue Nile and their connections to the timing of El Nino and La Nino events. *Hydrology and Earth System Sciences* 18, 1239-1249. <https://www.hydrol-earth-syst-sci.net/18/1239/2014>

6

Biodiversity

6 Biodiversity

6.1 INTRODUCTION

Sudan is blessed with a rich variety of ecosystems of national and global importance. They include forests, arid and semi-arid rangelands, and a wide variety of natural and artificial wetlands, from rain pools to crater lakes, and from riverine to marine habitats. These ecosystems are home to a great diversity of fauna and flora, including terrestrial and aquatic flowering plants, seaweeds, mammals, birds, freshwater and marine fish, coral reefs and a wide array of amphibians, reptiles, insects, phytoplankton, algae, zooplankton, mollusks and fungi. Much of this wildlife is protected through a network of national parks and game reserves.

Sudan's natural ecosystems are among its greatest assets. Apart from their cultural and aesthetic value, they provide important services, particularly to rural communities. Forests provide habitats for wildlife, supply timber and many non-wood forest products including gum, honey, building materials, fuelwood, charcoal, fodder, dyes, tannins and game food. Vegetation cover serves many useful functions such as the stabilization of sand dunes in the semi-desert region, improvement of soil fertility and flood control. Wetland services include water supply, fisheries, agriculture, nutrient retention in flood plains, transport, recreation and tourism opportunities; they are also essential habitats for fish and migratory birds, and support many invertebrate insect fauna and other organisms. Coral reefs that extend along the Red Sea coast provide fish as well as other benefits such as ecotourism. Rangelands support livestock husbandry, one of the biggest economic activities in Sudan.

Despite this richness, Sudan's biological resources face several challenges. Management is weak due to a poor understanding of the value of biodiversity; competing claims on the land have led to overex-

ploitation of resources and the destruction and fragmentation of habitats, exacerbating deforestation and pollution. Climate change is likely to make the situation worse.

The loss of biodiversity is not just a tragedy for the environment. It can also have a negative impact on people's health through the loss of ecosystem services and the depletion of raw materials and food resources. The loss of income from wildlife and nature-based tourism can have a significant impact on livelihoods. Conserving the country's biodiversity is crucial for its future prosperity.

6.2 ECOSYSTEMS AND HABITATS

The country is divided into five ecological zones defined by the amount and pattern of rainfall and by the dominant vegetation type. Average annual rainfall varies considerably across the country, from almost nil in the desert of the north to more than 800 mm in the south (Mohamed et al. 2014).

With the secession of South Sudan in 2011, the flood region with its equatorial forests has been lost and what is left of the high rainfall savannah zone constitutes less than 4 per cent of Sudan.

Harrison and Jackson (1958) and Kheir Al Seid (2016) described Sudan's major ecosystems as follows:

Desert

Desert areas have sandy soils and vegetation that germinates only after rare rain showers. There are some shrubs around waterways. Pastures are found on the fringes of seasonal valleys and around some oases. The desert covers Northern, River Nile, Red Sea, Kassala, North Kordofan and Darfur states.



Sinai agama (*Pseudotrapelus sinaitus*) in Agri Village, North Sudan. Photo credit © Anaconda 2014

Semi-desert

These areas have sandy soils with grass and shrubs interspersed with trees. The vegetation varies according to rainfall and soil type. *Acacia tortilis* and *Maerua crassifolia* grow in the eastern clay plains, and *Acacia mellifera* and *Commiphora africana* in the sandy soil of the west (Abdel Magid and Badi 2008). The semi-desert of western Sudan is home to pastoral and semi-pastoral communities. Traditional, mechanized and irrigated agriculture are practised in some areas.

Many wild animal species that used to be found in the desert and semi-desert areas of northern Sudan, such as Addax (*Addax nasomaculatus*), Beisaoryx (*Oryx besa*), Bongo (*Boocerus euryceros*), Dama gazelle (*Gazella dama*), Scimitar-horned oryx (*Oryx dammah*) and Capeeland (*Taurotragus oryx*), have become locally extinct. There are still Dorcas gazelle (*Gazella Dorcas*), small mammals such as foxes, wild cats and fennec, and reptiles in the semi-desert. The wadis in the deserts of River Nile state and Northern state are home to various types of snakes and lizards (Wildlife Conservation General Administration and Wildlife Research Centre 2014; Abdelhameed et al. 2017).

Savannah grasslands

This zone is characterized by mixed herbaceous non-woody vegetation including scattered trees and shrubs. Savannah grasslands occur at transition zones between semi-desert and forests where rainfall is too marginal for some tree species. Savannas have sufficient soil water to support a closed herbaceous plant canopy that is lacking in deserts.

Savannas are classified as either low-rainfall or high-rainfall. Low-rainfall savannas are again classified according to whether they occur in clay soil or sandy soil. Low-rainfall clay savannas cover most of eastern and central Sudan and the central plains of Sennar, Blue Nile and Gedaref states. Typical vegetation consists of trees, shrubs, weeds and grasses. Low-rainfall sandy savannas are found in west Sudan in areas such as the stabilized sand dune (Goz) areas of North Kordofan, North Darfur and the northern parts of South Darfur, as well as in the west of White Nile state. Most livestock, rain-fed and irrigated agricultural projects, as well as the gum belt, are situated in low-rainfall savanna.



The inflorescence of the thorny shrub *Dichrostachys cinerea* (Kadad) in West Kordofan. Photo credit © Osman Ali



A natural pasture in high rainfall savannah in Kordofan. Photo credit © Osman Ali

High-rainfall savannas, defined as receiving 800 mm or more annual rainfall, are dominated by perennial broad-leaved trees. They are mostly found in western and southern parts of Sudan. They are good for pasture, and are dominated by the Baggara tribes during summer periods.

Mountain vegetation

Sudan's mountain areas include the Nuba Mountains, the Jebel Marra and the Red Sea hills. These regions are characterized by a rich diversity of trees and plants. The gallery forests of the Jebel Marra plateau contain 932 species of flowering plants, 32 species of ferns and 295 bird species (Al Hadi 2015). The Medob Mountains of North Darfur are believed to host Dorcas gazelle, hares, wild cats, foxes, fennec and many different types of snakes and lizards (Ayoub 2017).

A survey of the Nuba Mountains in Kordofan by the Wildlife Research Centre (WRC) and the Wildlife Conservation General Administration (WCGA) during 2008-2010 revealed healthy populations of warthog (*Phacochoerus aethiopicus*), Dorcas gazelles and ostrich (*Struthio camelus*). Jebel Al Dair in North Kordofan, part of the Nuba Mountains, is home to a distinctive set of fauna and flora that includes 112 plant species, 96 of which are medicinal or aromatic plants. 22 species of large and small mammals are also found there, the most prominent of which are the Greater Kudu (*Tragelaphus strepsiceros*) and the Rock hyrax (*Procavia capensis*), both of them endangered. There are also six species of snakes and lizards and 17 species of indigenous and migratory birds (Abdelhameed et al. 2013).



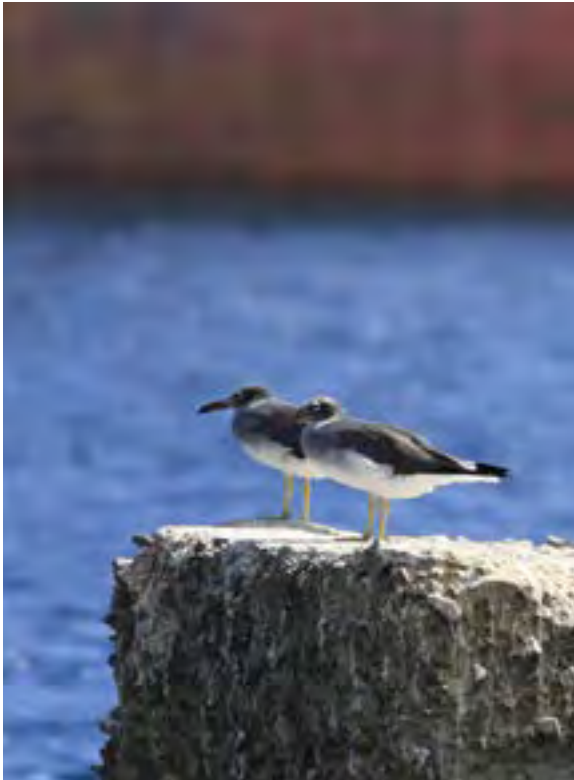
The Dugong (*Dugong dugon*) is a marine mammal spotted in the Sudanese coast and threatened by fishing nets. Photo credit © SUDIA

Marine and coastal habitats

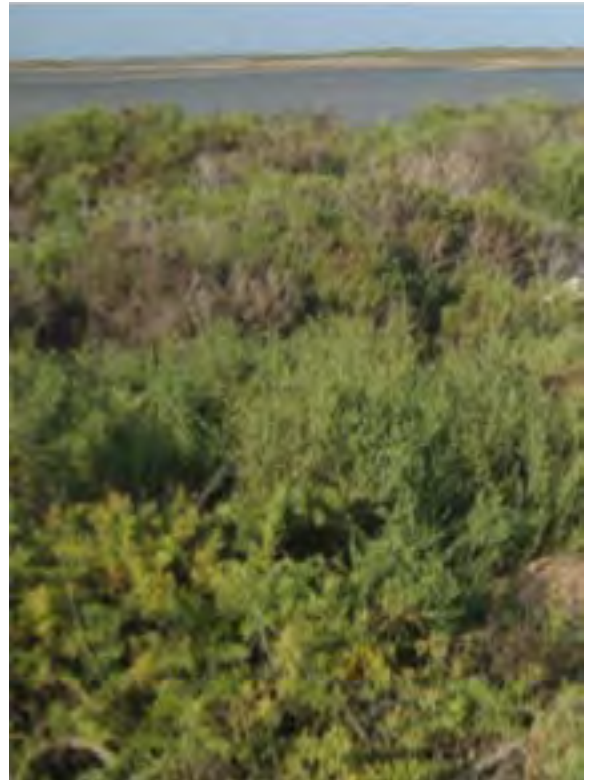
The Sudanese continental Red Sea coastline is about 853 km long, including embayments and inlets (FAO 2019). Its features include mud flats, salt marshes, sand or gravel substrates, numerous islands, silty beaches, coastal plains, lagoons, sheltered bays (marsas), barrier reefs, fringing reefs and one oceanic atoll (Sanganeb). Vegetation in these areas is sparse, consisting of scattered halophytes and grasses, and mangrove forests on the coast.

The following is a selection of the mammals, birds, fish and plants found on the Sudanese Red Sea coast:

- ➔ The Dugong (*Dugong dugon*). Around 4,000 dugongs live in the Red Sea. The animal is regularly spotted on the Sudanese coast, though they are threatened by fishing nets (Antonio 2017);
- ➔ 114 species of seaweed live in the intertidal areas of the coast, according to a 2016 survey (Osman and Mohamed 2016). Seaweed habitats in Sudanese waters are in good condition, with no reports of alien species, though some have been damaged by dredging and other development;
- ➔ The Sudanese coast is home to 10 of the 11 species of sea grasses that are known to live in the Red Sea (Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden and Global Environment Fund (PERSGA/GEF) 2004). They inhabit shallow water environments such as marsas and lagoons;
- ➔ Cetaceans include the Pilot whale and several species of dolphin, including the common, bottle-nose and humpback dolphin (Abu-Gideiri 1997);
- ➔ 23 shark species live off the Sudanese coast, as well as three batoid cartilaginous species commonly known as rays: the silky reef shark (*Carcharhinus faciformis*), the silvertip shark (*Carcharhinus albimarginatus*) and the white tip reef shark (*Triaenodon besous*) (Antonio 2017);
- ➔ Numerous seabirds nest on the coast, the most common of which is the Lesser Crested Tern (*Thalasseus bengalensis*);
- ➔ Wild mother of pearl oysters (*Pinctada margaritifera*) and trochus shells (*Trochus dentatus*) are found in the shallow coastal waters; these are caught for food;



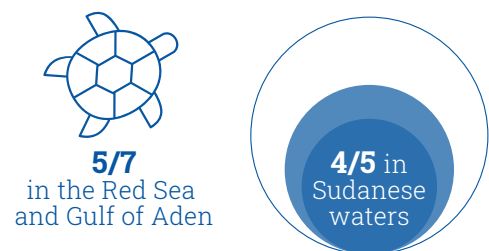
Sea gulls in the Red Sea coast. Photo credit © Awad Siddeg



Suaeda monica (Adleeb) is a typical shrub in the Sudanese Red Sea coast. Photo credit © Osman Ali

- ➔ Crustaceans are abundant. The Sudanese coast has eight species of shrimp (Antonio 2017), including large-scale species known as Jambo, the most famous of which is the *Penaeus semi-sulcatus*. The main shrimp areas are the southern regions such as Tala Islands, Marsi Asht and Marsi Antabib (Alhaj et al. 2013);
- ➔ Five of the world's seven species of sea turtle are found in the Red Sea and Gulf of Aden, and four of them have been recorded in Sudanese waters: *Chelonia mydas* (green sea turtle), *Caretta caretta* (loggerhead sea turtle), *Eretmochelys imbricata* (hawksbill turtle) and *Dermochelys coriacea* (leatherback turtle) (Antonio 2017 and UNEP CMS 2019). Turtles are threatened by maritime shipping, net fishing, marine pollution and the destruction of critical habitats by trawlers (Antonio 2017);

Sea turtle species



- ➔ Sudan's coral reefs are known for their cleanliness, lack of pollution and relatively low level of human activity. There are three main types of reef here: party (Tarafya) reefs, impedance (Alhagizya) reefs, and cyclone reefs (on the island of Sanganeb). These reefs are home to numerous fish, including 44 species of sharks. The most important coral environments for their biodiversity are Sanganeb, Shub Al Rumi, Al-Suwaidi and Luqa.

6.3 FOREST BIODIVERSITY

Sudan's forests grow in a range of habitats, from high-rainfall savannah to the tropical southern mountains. Forest reserves cover about 15.7 million feddans (6.6 million hectares) and are scattered across several different states and ecological zones. Irrigated forests, which account for around 8,000 feddans (3,360 hectares), are found in Gezira, Blue Nile, Kassala and Kordofan states. The most widely planted exotic tree species is *Eucalyptus microtheca*, which is tolerant of heat, drought and other environmental stresses (Abdel Magid 1995; Armitage 1985).

The only tree species that has adapted successfully to the flood basins of the Nile rivers is *Acacia nilotica*, which thrives in conditions of regular flooding. The natural forests of *A. nilotica* along the Nile and its tributaries were declared protected reserves early in the 20th century. The conversion of the natural forests of *A. nilotica* into plantations started in 1935 when sawmills were operated for the production of railway sleepers. Al'ain forest reserve in North Kordofan and other natural plantations in South Kordofan are dominated by *Acacia nilotica* trees.

Mountain forests are found in Jebel Marra, the Nuba Mountains, Jebel Al Dair and the Arkwait Mountains. Jebel Marra forests cover 1,410 feddans (592.2 hectares). Some of the most endangered tree species are found in the Arkwait Mountains. For example, the species *Dracaena ombet* is found only in Arkwait. The Red Sea Hills contain mostly *Acacia* species. Al Angasana hills are dominated by broad-leaved trees (Nimir 1983; WCGA 2018).

Sudan's mangrove forests, especially *Avicennia marina*, are distributed along the Red Sea coast from Mohammed Qol, north of Port Sudan, to Shabarango-Gafud, south of Suakin (PERSGA/GEF 2004) (Figure 6.1). They cover 0.782 km² (Antonio 2017). Mangrove lagoons and channels are an important habitat for birds, animals and marine organisms including fish, crustaceans and molluscs, as well as micro-organisms such as animal plankton and vegetable phytoplankton (Alhaj et al. 2013; Antonio 2017).

Mangroves (*Crimea spp*) are located in three main areas: at the southern tip of the Dungonab peninsula, at the southern tip of the island of Mukkawar, and on the mainland coast of Anchoval Anchorage.

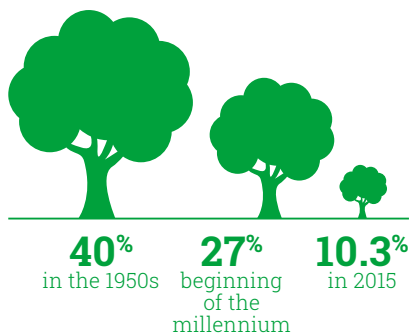


A riverine forest of Sunt trees (*Acacia nilotica*) in Khartoum State is seasonally inundated during the river flood.
Photo credit © Awad Siddeg

6.3.1 Threats to forests

Sudan's forests 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, and then to 10.3 per cent by 2015, according to the FAO Global Forest Resources Inventory (1990–2015). The annual loss in 2015 was estimated at 855,000 feddans (35.91 square kilometres). This was mainly due to the expansion of agriculture and the growing demand for energy. In the 1990s, 70 to 81 per cent of Sudan's energy needs came from firewood (Forests National Corporation 1995), and this has not changed much. Several species are under threat either due to lack of natural regeneration or the human activities (Table 6.1)

Forest coverage



The following represent the main threats to Sudan's forests:

Main threats to Sudan's forests



Disease



Climate change



Human activities



Overgrazing



Fire



Mining and industry

Disease

An epidemic of Surt (*Acacia nilotica*) dieback is affecting many riverine forests along the Nile and its tributaries. Termites are a serious problem in Eucalyptus plantations, while seed borer affects the natural regeneration of species like *Acacia*, *Balanites aegyptiaca* and several species of *Combretum*.

Climate change

The majority of Sudan's ecosystems are vulnerable to the changes in temperature and precipitation brought by climate change.



The Dragon tree (*Dracaena ombet*) endangered tree species are found in the Arkwait Mountains in the Red Sea. Photo credit © Awad Siddeg



Mangrove population (*Avicennia marina*) in the Red Sea coast. Photo credit © Awad Siddeg

Human activities

More than 70 per cent of Sudan's population lives in rural areas (Mahgoub 2014). Rural communities depend greatly on natural resources such as forests. This dependency has increased with the decline in agricultural productivity and the growth in population. Human activities such as grazing, cultivation, tree felling, poaching and fire tend to reduce the nutritional quality of forage and increase the risk of extinction for some species. Civil wars and tribal conflicts (with the resultant refugees and internally displaced people) result in further biodiversity losses (Mahgoub 2014). A recent study stated that the rapid increase in human and animal populations and the resulting demand for land and energy are one of the main underlying causes of deforestation and rangeland depletion (Hassan and Tag 2018).

Overgrazing

Grazing that allows an appreciable amount of natural regeneration is not considered harmful to forests (Hassan and Tag 2018). Overgrazing happens when the animal population exceeds the potential of the resource. Trees suffer further damage when grass and herbage are scarce and seeds and pods are shaken from the trees for use as animal feed.

Figure 6.1 Location of mangrove stands along the Sudanese Red Sea coast (Antonio 2017).



Table 6.1 Sudan's tree species under threat

Species	Degree of Threat	Source of threat
<i>Balanites aegyptiaca</i>	Medium	Lack of natural regeneration
<i>Adansonia digitata</i>	High	Lack of natural regeneration
<i>Hyphaene thebiaca</i>	High	Lack of natural regeneration
<i>Borassus athiopum</i>	High	Expansion of agriculture
<i>Diospyrus mespiliformis</i>	High	Expansion of agriculture
<i>Tamarindus indica</i>	Medium	Expansion of agriculture
<i>Pterocarpus lucens</i>	High	Expansion of agriculture
<i>Cordia africana</i>	High	Expansion of agriculture
<i>Pseudosedrel akotshyi</i>	High	Expansion of agriculture
<i>Oxytenanthera abyssinica</i>	High	Over-felling
<i>Albizia aylmeri</i>	High	Over-felling
<i>Grewia tenax</i>	Medium	Over-exploitation
<i>Khaya senegalensis</i>	High	Over-exploitation
<i>Acacia seyal</i>	Medium	Expansion of agriculture
<i>Acacia mellifera</i>	Medium	Expansion of agriculture
<i>Acacia polycantha</i>	Medium	Expansion of agriculture
<i>Acacia seyal var. fistula</i>	Medium	Expansion of agriculture
<i>Acacia sieberiana</i>	Medium	Expansion of agriculture
<i>Faidherbia albida</i>	Medium	Expansion of agriculture
<i>Terminalia laxiflora</i>	High	Over-felling
<i>Terminalia brownie</i>	High	Over-felling
<i>Medemia argun</i>	High	Gold mining
<i>Avicennia marina</i>	Affected at various levels	Camel grazing

Source: Abdel Magid et al. 2015; Ministry of Agriculture and Forestry 2015

¹ Hectare = 10,000 m² = 2.38 feddans

Fire

Fire is a serious problem in several forest areas in Sudan. Grass fire in plantations of *Acacia senegal* causes a reduction in yields of gum arabic, an important export commodity; two successive years of fire results in the total destruction of the trees. Fires are destructive for trees if they are fierce or if the dry season is unusually dry; in this case the grassland advances and the forest retreats. If the fire is less intense or the dry season is shorter than normal, the forest has a chance to regain lost ground (Badi and Abdel Magid 2017). The area of burn has been increasing in recent years, as shown in Table 6.2.

Mining and industry

The petroleum industry and gold mining are responsible for the large-scale clearance of forests during exploration and for the construction of infrastructure such as pipelines, roads and settlement camps. As Table 6.3 shows, the construction of pipelines has resulted in the clearance of more than 542,000 hectares (more than 129,000 feddans) of forests in five states (Abdel Magid et al. 2015). Table 6.4 shows the large-scale impact of oil exploration and road construction on forests.



The use of biomass for energy is a major cause of deforestation. Photo credit © UNEP

Table 6.2 Annual burned area of forest, woodland and range ecosystems in Sudan, 2010–2015

Fire season	Burned area / ha
2010–2011	1,075,974.8
2011–2012	1,049,790.7
2012–2013	1,076,363.9
2013–2014	1,087,602.0
2014–2015	1,090,119.7

Source: Hassan and Tag 2018

6 Biodiversity

Table 6.3 Impact of pipelines on tree cover in different states

State	Area removed (feddans)	Area removed (hectares)
West Kordofan	1,286,513	540,335
South Kordofan	133	55.7
North Kordofan	89	37.4
White Nile	4,798	2,015
Khartoum	48	20.2
Total	1,291,581	542,463

Source: Abdel Magid et al. 2015

Table 6.4 Impact of exploration and road construction on forest cover in some states

State	Activity	Area removed (feddans)	Area removed (hectares)
Sennar	Exploration	12,200	5,124
River Nile	Exploration	9.1	3.8
Western Kordofan	Road construction	1,286,513	540,335

Source: Abdel Magid et al. 2015



The Baobab tree (*Adansonia digitata*) is an endangered tree in Sudan due to lack of natural regeneration. Photo credit © Zuhair Noor Eldayim



The Argun palm (*Medemia argun*): An endemic critically endangered tree in the eastern desert of Sudan due to isolated population and recently mining activities. Photo credit © Osman Ali



Construction of roads and other infrastructures are major causes of deforestation. Photo credit © Osman Ali

6.3.2 Forest protection measures

Decision-makers and the public in Sudan have long undervalued the contribution of forests to socio-economic development and environmental protection (Abdelnour and Abdel Magid 1997; Elsiddig and Abdel Magid 2008). However in 2017, the government put forward a plan to reduce the pressure on forests from agriculture and industry, slow the rate of deforestation, protect forest ecosystems while also protecting rural livelihoods, and reduce the threat of climate change (Forest National Conservation 2017). This will be achieved by:

- ➔ Monitoring the state of – and risks to – forest;
- ➔ Facilitating forest reserving procedures to ensure that at least 20 per cent of Sudan's forest area is reserved forest;
- ➔ Increasing planted area by natural and artificial regeneration in reserved forests;
- ➔ Encouraging communities and the private sector to produce non-wood forest products such as fruits, gum and honey, and regulating the markets to meet the increasing demand for these products;
- ➔ Expanding the production of gum arabic to 500,000 tonnes per year by 2019 and increasing the export of gum arabic to at least 200,000 tonnes per year;
- ➔ Promoting scientific and technical research in forestry to support forest-related industries such as furniture, construction, pulp and paper, food, fodder, glue, medicine and aromatic resources;
- ➔ Promotion of sustainable fuelwood production, consumption and usage;
- ➔ Use of alternative sources of energy such as LPG, solar and wind.



Non-wood forest products (Honey, and Gum Arabic). Photo credit © UNEP



In El Obeid Crop Market, North Kordofan, the collected gum arabic is repacked for export. Photo credit © World Bank

Table 6.5 Afforestation activities (1999–2015)

No	Year	Seeds/ tonne	Seedlings/ million	Plantation per “000” feddans				Total area
				Official	Community	Schemes (5% and 10%)	Sub-total (community +5% and 10%)	
1.	2002	77	5.1	50.485	128.5	42.675	171.18	221.66
2.	2003	53	4.2	24.4	10.5	7.301	17.80	42.20
3.	2004 ¹	57	2.7	29.764	12.3	1.200	13.50	43.26
4.	2005	66	2.4	28.9	13.634	2.531	16.17	45.07
5.	2006	92	2.7	30.9	108.14	0.940	109.08	139.98
6.	2007	150	6.3	75.473	24.995	9.462	34.46	109.93
7.	2008 ²	191	5.7	104.245	66.560	2.000	68.56	172.81
8.	2009	143	6.6	59.039	72.213	10.450	82.66	141.70
9.	2010	147.7	5.8	55.629	214.198	1.0	215.20	270.83
10.	2011	161.12	6.87	68.01	287.557	2.587	290.14	358.15
11.	2012	98	7.2	106.267	96.3	3.500	99.80	206.07
12.	2013	215	6.391	64.1	89.4	0.500	89.90	154.00
13.	2014	150	7.5	75.5	161	9.000	170.00	245.50
14.	2015	142	7.385	73	152	13.820	165.82	238.82
15.	2016	178.3	6.94	119.93	482.6	15.140	497.74	617.67
16.	2017	226.1	7.1	162.64	429.626	13.42	443.05	605.69
Total		2,147.2	83.786	1,128.28	2,349.52	135.53	2,485.05	3,613.33

Source: Abdoun 2020

6.4 CONSERVATION OF FOREST GENETIC RESOURCES

The conservation of forest resources is enshrined in national and state laws, including the conservation of genetic diversity at the ecosystem and species levels. Most forest genetic resources are conserved in national parks, forest reserves, natural stands and plantations (Warrag et al. 2002). There is a special focus on endangered species, including *Balanites aegyptiaca*, *Commiphora africana*, *Dablergia melanoxylon*, *Hyphaene thebaica*, *Salvadora persica*, *Sclerocarya birrea* and *Sterculia setigera*.

Acacia senegal is one of Sudan’s most important tree species because of its use in the production of gum arabic. Its seed has been the focus of a major genetic conservation effort, with local knowledge being used to select consistently high-yielding and healthy trees in the wild and in plantations (Warrag et al. 2002). Care is also needed towards other gum-producing trees such as *Acacia seyal*, *Sterculia setigera* and *Boswellia papyrifera*.

Sudan's forest reserves, which are owned by the government, cover each of the country's five ecological zones. They are surveyed, demarcated, mapped and registered in the Sudan Gazette (the official government periodical publication for legal news and notes). As well as conservation of forest resources, the objective of forest reserves is sustainable management, based on the understanding that felling programmes should take place inside reserves because their protective status allows regeneration and reforestation. The felling of endangered tree species inside protected areas is prohibited. As well as *in situ* conservation, genetic material from Sudan's forests is stored off-site in conditions that will allow for future regeneration. The Forest Research Centre is coordinating research on the storage of tree seeds.

Sudan boosted its forest conservation efforts in 2012 by initiating the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation, known as REDD+. As well as reducing carbon emissions from forests, the programme is aimed at improving conservation and the sustainable management of forests.

6.5 WILDLIFE RESOURCES AND PROTECTED AREAS

Wildlife is largely confined to national parks and some pockets of habitat scattered throughout the country. The wildlife census conducted in Dinder National Park in 2010 by the WRC noted that the population of large wildlife species is declining rapidly, with some species becoming rare (Abdelhameed 2015) (Table 6.6).

6.5.1 Protected areas in Sudan

With the secession of South Sudan in 2011, the protected areas in Sudan were reduced to nine national parks, two game reserves and three game/bird sanctuaries (Abdelhameed et al, 2008). The country has two marine protected areas, Sanganeb Marine National Park and Dungonab Bay and Mukkawar Island Marine National Park. Both were declared world heritage sites in 2016 (United Nations Education, Science and Culture Organization (UNESCO) 2016). Three of the protected areas are part of the UNESCO World Network of Biosphere Reserves: Dinder (declared by UNESCO in 1979), Radom (1982) and Jebel Al Dair (2017) (WCGA 2018).

Protected areas



The terrestrial and marine protected areas covered 1.3 per cent of Sudan's area in 2010. While there was a marginal increase to 1.7 per cent as of 2016 (World Bank 2017), this was largely due to the reduction in the country's land area following South Sudan's independence. Two of the most recently established national parks are Jebel Al Dair (created in 2010) and Al Gazalla (2015) (Abdelhameed et al. 2017). A new marine park, Sha'ab Rumi, has been proposed. Table 6.8 shows some of Sudan's protected areas and the ecological regions they are found in.

Some of the protected areas were specifically designated for the protection of threatened animals. For example, Al Sabaloga, Arkawit and Sinkat game reserves were established to protect the Barbary sheep (Nimir 1995; WCGA 2018). Others provide protection for water catchment areas of Sudan and its neighbouring countries. These include Dinder National Park on the Sudan-Ethiopian border, which covers the Blue Nile River catchment, and Radom National Park on the border with the Central African Republic, which covers the Bahar Al Arab River catchment area (Man and the Biosphere 2017).

Table 6.6 The status of wild animals

Extinct	Endangered and/or vulnerable	Rare and not frequently seen
Addax (<i>Addax maculates</i>)	Tiang (<i>Damaliscus Korrigum</i>)	Nubian ibex (<i>Capra ibex Nuniana</i>)
African Ass (<i>Equus africanus</i>)	Giraffe (<i>Giraffa camelopardalis</i>)	Mangalla gazelle (<i>Gazella albenetata</i>)
Dama gazelle (<i>Gazelle dama</i>)	Black-backed jackal (<i>Canis Adustus</i>)	Grant's gazelle (<i>Gazella granti</i>)
Rhim gazelle (<i>Gazella leptoceros</i>)	Wild dog (<i>Lycaon pictus</i>)	Roan antelope (<i>Hippotragus equines</i>)
Beisa Oryx (<i>Oryx beisa</i>)	Greater kudu (<i>Tragelaphus strepsiceros</i>)	Giant Forest hog (<i>Hylochoerus meinethageni</i>)
Cheetah (<i>Acinonyx jubatus</i>)	Nubian ibex (<i>Capra nubiana</i>)	Crest porcupine (<i>Hystrix spp</i>)
Scimitar-horned Oryx (<i>Oryx dammah</i>)	Arabian bustard (<i>Ardeotis arabs</i>)	White-earned kob (<i>Kobus leucotis</i>)
Colobus monkey (<i>Colobus abyssinicus</i>)	Great bustard (<i>Ardeotis kori</i>)	Elephant (<i>Loxodonta africana</i>)
Tora hartebeest (<i>Alcelaphus Buselaphus</i>)	Leopard (<i>Panthera pardus</i>)	Pangolin (<i>Manisspp</i>)
Bongo (<i>Boocerus euryceros</i>)	African lion (<i>Pantheraleo</i>)	Klipspringer (<i>Oreotragus oreotragus</i>)
Yellow-backed duiker (<i>Cephalophus sylvicultor</i>)	Africa Elephant (<i>Loxodonta africana</i>)	Leopard (<i>Panthera pardus</i>)
Cape eland (<i>Tauratragus oryx</i>)	Red-fronted gazelle (<i>Gazella rufifrons</i>)	Civet (<i>Viverra civetta</i>)
	Barbary sheep (<i>Ammotragus lervia</i>)	
	Somemmerring's gazelle (<i>Gazalla soemmerringi</i>)	
	Hippopotamus (<i>Hippopotamus amphibius</i>)	
	Tora hartebeest (<i>Alcelaphus buselaphus tora</i>)	
	Cape buffalo (<i>Syncerus caffer</i>)	
	Lesser kestrel (<i>Falco naumanni</i>)	
	Green turtle (<i>Cheko niamydas</i>)	
	Dugong (<i>Dugong dugon</i>)	

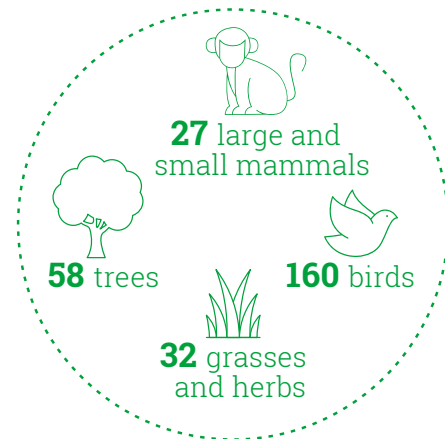
Source: Abdelhameed 2015

6.5.2 Dinder and Radom National Parks

Dinder National Park is in the low-rainfall savannah ecological zone. It has three ecosystems: Acacia seyal–Balanites woodland, riverine and *mayas* (meadows) (Hakim et al 1978; Abdel Hameed et al. 1997). The Acacia seyal-Balanites woodland ecosystem consists mainly of Talih (*Acacia seyal*), Habeel (*Combretum spp.*) and Higlieig (*Balanites aegyptiaca*). The riverine ecosystem along the banks of the Dinder and Rahad rivers consists of multilayered forests dominated by Dom (*Hyphaene thebaica*), Abu Gawi (*Gardenia lutea*), Kuk (*Acacia sieberiana*), Aradieeb (*Tamarindus indica*), Jomez (*Ficus sycomorus*) and Sidir (*Ziziphus spina-christi*). The riverine areas also have perennial and annual grasses and different species of forb (a herbaceous flowering plant). *Mayas* wetlands form an important ecological zone in the arid and semiarid Sodano–Saharan region in Dinder and Rahad basins. They are the most unique feature of the Dinder National Park and one of its three major ecosystems. According to the Dinder National Park authority, the Dinder and Rahad river ecosystems inside the park contain more than 40 *mayas*. They are the main source of food and water

for wildlife (herbivores), especially during the dry season which extends from November to June (Hassaballah et al. 2016). Dinder National Park hosts 27 large and small mammal species, 58 tree species, 32 grasses and herb species and 160 bird species (Higher Council for Environment and Natural Resources and WCGA 2004).

Dinder National Park (number of species)



Water bucks (*Kobus ellipsiprymnus*) in Dinder National Park. Photo credit © Awad Siddeg

Table 6.7 Protected areas in the different ecological zones

Ecological zone	Name of protected area	Type of protected area	Area size (hectares)
Arid	Wadi Hower (2002)	National park	10,000,000
	Al Gazalla (2015)	National park	30,000
	Jebel Hasania (2003)	National park	10,000,000
	Jebel Al Dair (2010)	National park	31,546
Semi-arid-terrestrial	Toker (1939)	Game reserve	630,000
	Al Sabaloga (1946)	Game reserve	160,000
	Arkawit – Sinkat (1939)	Game sanctuary	12,000
	Arkawit (1939)	Game sanctuary	82,000
Semi-desert-marine	Sanganeb (1990)	National park	1,740
	Dongunab (2002)	National park	2,800
Riverine ecosystem wetland	Jebel Bawzer Sunt Forest reserve (1939)	Bird sanctuary	1,500
Savannah	Dinder (1935) – Low-rainfall savannahs	National park	890,000
	Radom (1982) – High-rainfall savannah	National park	1,250,000
	Basounda-Taia-Glabat (1994)	National park	15,000

Source: Abdelhameed et al, 2017; WCGA 2018

Radom National Park is in the high-rainfall savannah ecological zone. No recent scientific survey has been conducted in this park. The last survey was carried out by the WRC and UNESCO's Man and the Biosphere Programme in 1995. It revealed the presence of many endangered tree species such as *Anogeissus leiocarpus*, *Khaya senegalensis* and *Isoberlinia doka*. The forests of Radom provide habitat for many birds and wildlife species such as bushbuck (*Tragelaphus scriptus*), warthog (*Phacochoerus africanus*), spotted hyena (*Crocuta crocuta*), striped hyena (*Hyaena hyaena*), baboon (*Papio anubis*), patas monkey (*Erythrocebus patas*), green monkey (*Cercopithecus aethiopicus*) and ratel (*Mellivora capensis*) (Adam Al Mahadi personal communication 2017).

Radom National Park is home to birds such as tufted guinea fowl (*Numida meleagris*), saddle-billed stork (*Ephippiorhynchus senegalensis*), abyssinian ground horn-bill (*Bucorvus abyssinicus*), secretary bird (*Sagittarius serpentarius*), bustard (*Otis kon*), marabou stork (*Leptoptilos crumeniferus*) and crowned crane (*Balearica Pavonina*). Reptiles, including African python (*Python*

seba), tortoise (*Testudo sulcatus*), crocodile (*Crocodylus niloticus*), monitor (*Varanus niloticus*) and small lizards (*Agama spp*) are also found here (Higher Council for Environment and Natural Resources and WCGA 2004; Adam Al Mahadi personal communication 2017). The major predators in Radom are lion (*Panthera leno*), striped hyena, spotted hyena and black-backed jackal (*Canis mesomelas*).

6.5.3 Threats to wildlife

The decline in numbers and loss of some wildlife species are due to several factors:

- ➔ Agricultural expansion into rangelands and forests.
- ➔ Trespassing by pastoralists with their livestock; into protected areas and forest reserves. Livestock competes with wildlife for water and fodder and also spreads diseases such as anthrax and rinderpest. During the 1980s, rinderpest caused the death of many species in Dinder National Park (Abdelhameed et al. 2017);

- ➔ Poaching for wild animals and birds is rife inside and outside protected areas. Wild animals are poached for their skins or meat or for trophies. Game meat is dried and sold mostly to communities living near protected areas (Nimir 1983). Dinder National Park recorded most court cases for wildlife-related offences in the last three years, as Figure 6.2 shows. Some wild animals can be legally hunted for food or trade. Under the country's Wildlife Conservation and National Parks Ordinance (1986), hunting in Sudan is quota-based, allowing three gazelles and five rabbits per hunter per hunting season (WCGA 2018);
- ➔ The oil industry, which causes damage to wildlife habitats through exploration and extraction, as well as pollution of marine protected areas;
- ➔ Gold mining, whose use of poisonous cyanide and mercury is highly destructive to humans and wildlife (Abdelhameed et al. 2017);
- ➔ Pesticides and chemicals used to control insects such as locusts and grasshoppers could affect migratory birds (Lomer et al. 2001);
- ➔ The intentional lighting of fires, for example in bamboo tree harvesting in Jebel Al Dair, and in honey collection in Dinder National Park (Abdelhameed 2015);
- ➔ Climate change will have a negative impact on habitats for wild animals and birds (Abdelhameed 2016). Droughts and periods of low rainfall have increased in frequency in recent years, and this will affect protected areas in savannas and semi-arid regions. Mayas in Dinder National Park often dry up (WCGA 2018), which reduces forage quality and the availability of drinking water for wildlife;
- ➔ Tribal conflicts affect wildlife in many ways, especially in the Darfur region. Refugees and internally displaced persons often settle in or around protected areas. For example, tribes from Western Sudan moved and settled in more than 40 villages in and around Dinder National Park in 2003 (Abdelhameed 2015). The spread of small weapons during civil wars and conflicts also leads to an increase in poaching and illegal trade in wildlife;
- ➔ Poor involvement of local communities (living around protected areas) in the governance and management of protected areas;
- ➔ Poor implementation of management plans of protected areas due to lack of funding and expertise.



An aerial view of Radom National Park in South Darfur. Photo credit © Awad Siddeg



Secretary bird (*Sagittarius serpentarius*) is the main component of the Sudan national emblem. Photo credit © Awad Siddeg



Human activities within Radom National Park in South Darfur. Photo credit © Awad Siddeg

6 Biodiversity

6.5.4 Trade in wildlife

Both internal and external trade in wildlife is common in Sudan. External trade requires export and health certificates and is only permitted under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). As shown in Figures 6.3 to 6.6, Sudan exports live mammals, birds, reptiles and wild animal parts.

In addition to regulating trade in wildlife, Sudan has been attempting to boost wildlife populations through the establishment of wild animal farms. Since 1992, 30 farms have been certified for the breeding of various species of wild animals including gazelle, ostrich, crocodile, turtle, snakes and birds (WCGA 2018). The farms are largely owned by the private sector.



Making the traditional shoes (the markoob) from snakes' leather in El Fashir, North Darfur. Photo credit © UNEP

6.6 WETLANDS, FLOODPLAINS AND NILE RIVERINE FORESTS

The Nile system is a complex wetland ecosystem with numerous seasonal rivers and streams, among the largest of which are the Atbra, Dinder and Rahad. It also encompasses seasonal water courses (*Khors*) such as Baraka, El Gash and Abu Habil, natural depressions such as Al Gaab, and *wadis* such as El Mugaddam, Kaja, Nyala, Azum, Hawar, Ebra, Toal, Elkou and Salih (Abdalla and Karar 2010). Some of the *wadis* terminate in deltas such as Gash and Toker in Red Sea state and are important for irrigated agriculture. Khor Abu Habil drains the Nuba Mountains and contributes to the economy of Northern Kordofan state; it also harbours what is probably the largest population of lungfish (*Protopterus annectens annectens*) in Sudan. Wetlands are important sources of water for wildlife, breeding grounds for fish, reptiles, frogs, snails, birds and waterfowl, and habitats for water plants such as *Phragmites*, *Typha*, *Echinochloa spp* and some algae (Abdelhameed et al. 2013).

Sudan has a number of permanent and seasonal lakes (El Moghraby 2001; Ali O.M. 2013). Freshwater lakes include Lake Kundi in the southern part of Darfur region and Lake Keilak in South Kordofan. Lake Kundi's vegetation is characterized by *Ceratophyllum demersum* and *Nymphaea clarias*. Both lakes support fish species and avifauna, while Lake Keilak hosts many migratory bird species (Ayoub 2017). Sudan's saline lakes include Deriba Caldera in the volcanic massif of Jebel Marra, Malha Lake in the Medoub mountain series in Northern Darfur, and saline oases such as Nukheila, Atroun and Saleema in the north. Nukhaila

Oasis, in spite of its salinity and its location in the northern desert, is home to some savannah species and aquatic crustaceans such as *Artemia artemia* (El Moghraby 2013).

As well as wetlands and lakes, the country has several other important water features:

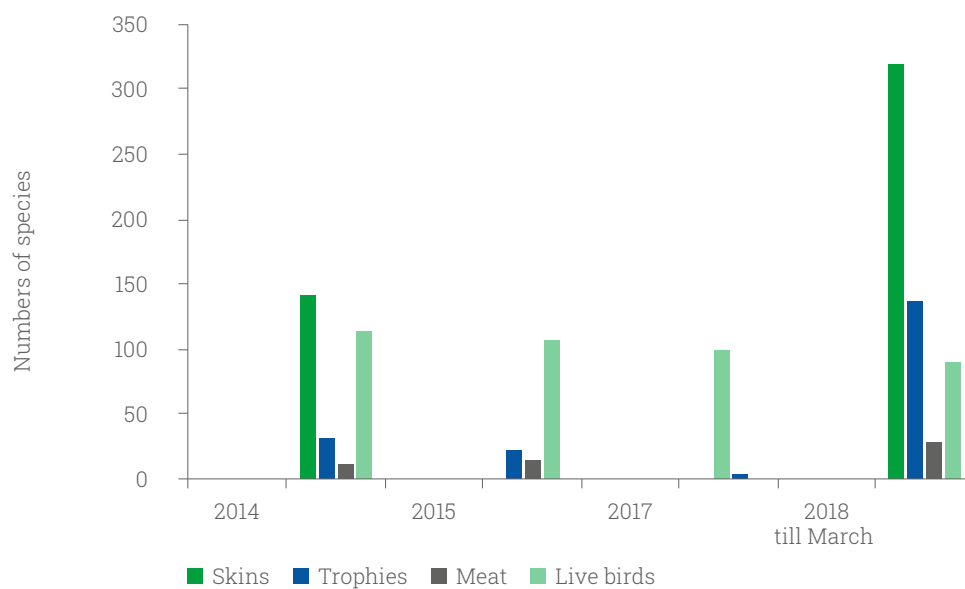
- ➔ *Mayas* are found along the Blue Nile River and in some protected areas, and are an important source of water and fodder during the dry season;
- ➔ The White Nile Birds Sanctuary, known as "the Sunt Forest", was established in 1939 in the Mogran area of Khartoum. It sustains large populations of resident and migratory waterfowl and other bird species. About 210 migratory species visit Sudan every year, including 89 species of waterfowl (El Moghraby 2013);
- ➔ The Nile Valley floodplains (*Gerif*) are important feeding grounds for waterfowl, as well as breeding and nesting sites for fish. The floodplains are known for their high agricultural productivity;
- ➔ Artificial wetlands include *haffirs* (rainwater harvesting reservoirs), dams and irrigation canals. People in North Darfur and South Kordofan states and in the Butana region rely on groundwater supplies from wells and *haffirs*. These artificial wetlands are important for bird and waterfowl species. Arafat Dam has the highest number of bird species – 731 according to the latest count – of all the country's artificial wetlands (Gaboush 2017);
- ➔ The Red Sea Coast has many important wetland habitats, including coral reefs, mangroves, bays, lagoons, sea grass beds and small offshore islands.



Maya (wet meadows/wetlands) ecosystems in Dinder National Park are habitats for water birds. Photo credit © UNEP

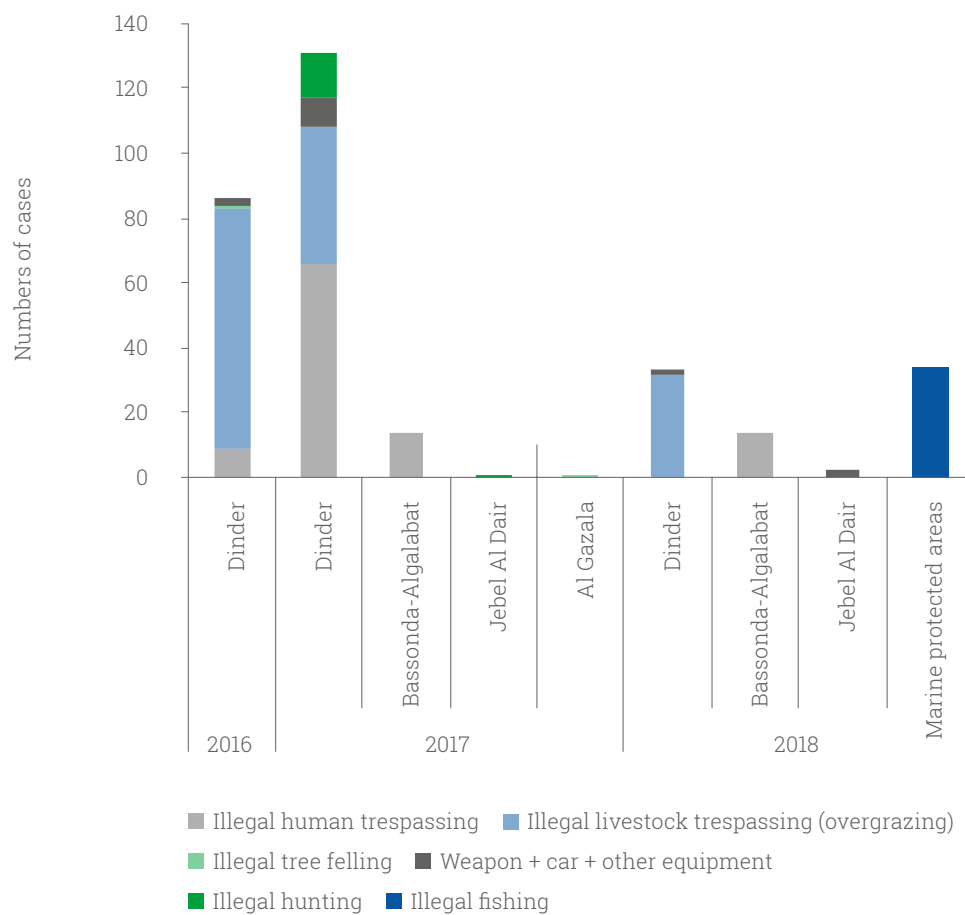
6 Biodiversity

Figure 6.1 Wildlife species poached outside protected areas (2014–2018)



Source: WCGA 2018

Figure 6.2 Court cases for wildlife-related offences inside protected areas (2016–2018)



Source: WCGA 2018

Figure 6.3 Trade (export) of mammals during 2014–2017 (WCGA 2018)

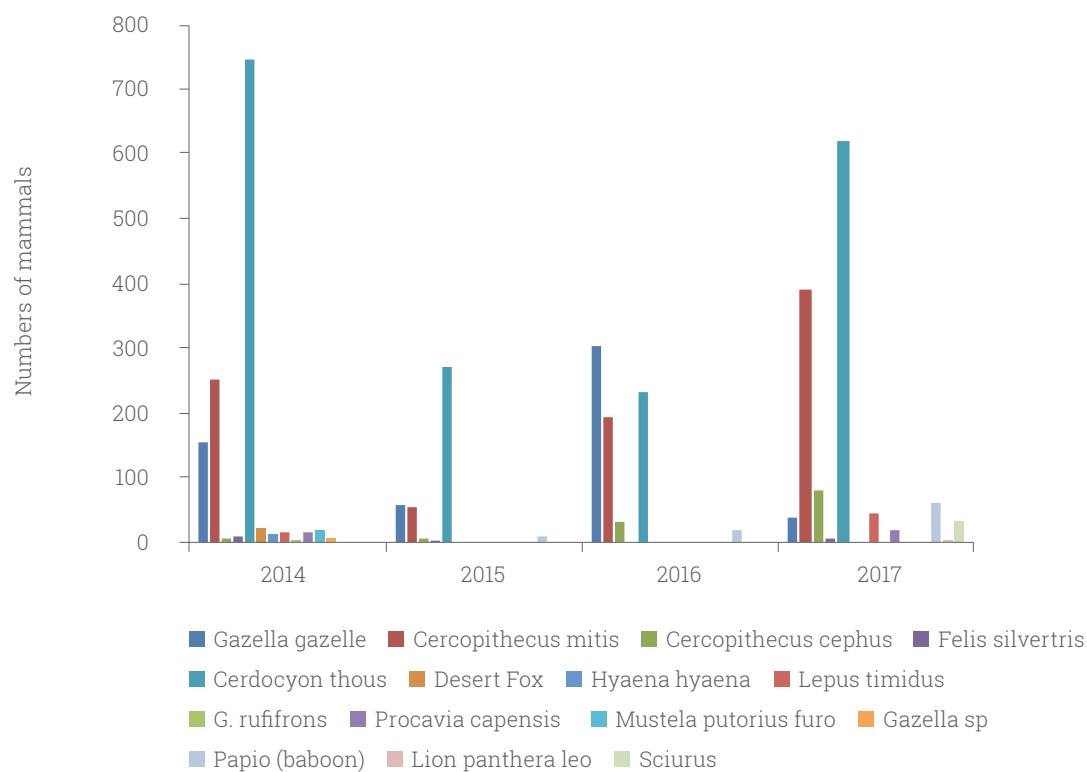
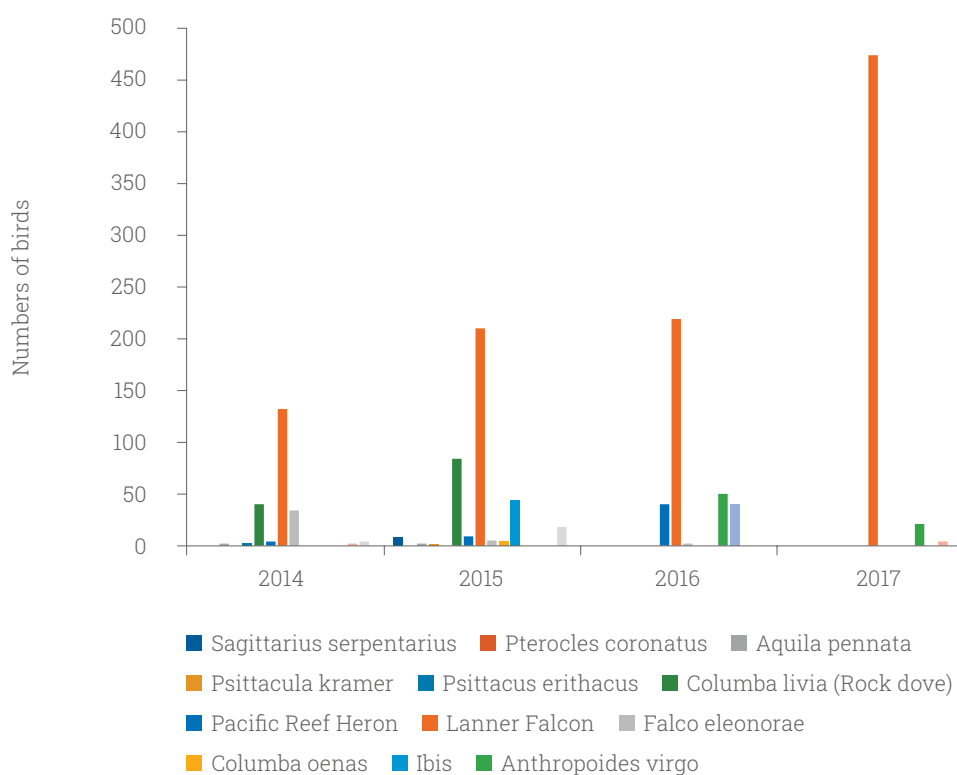


Figure 6.4 Trade (export) of birds during 2014–2017 (WCGA 2018)



6 Biodiversity

Figure 6.5 Trade (export) of reptiles during 2014–2017 (WCGA 2018)

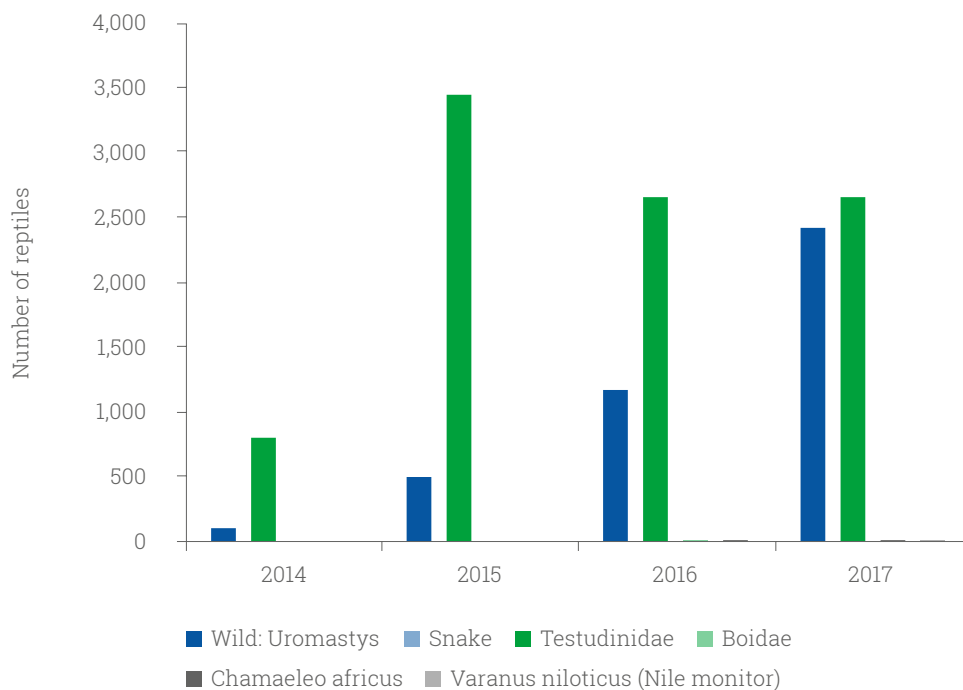
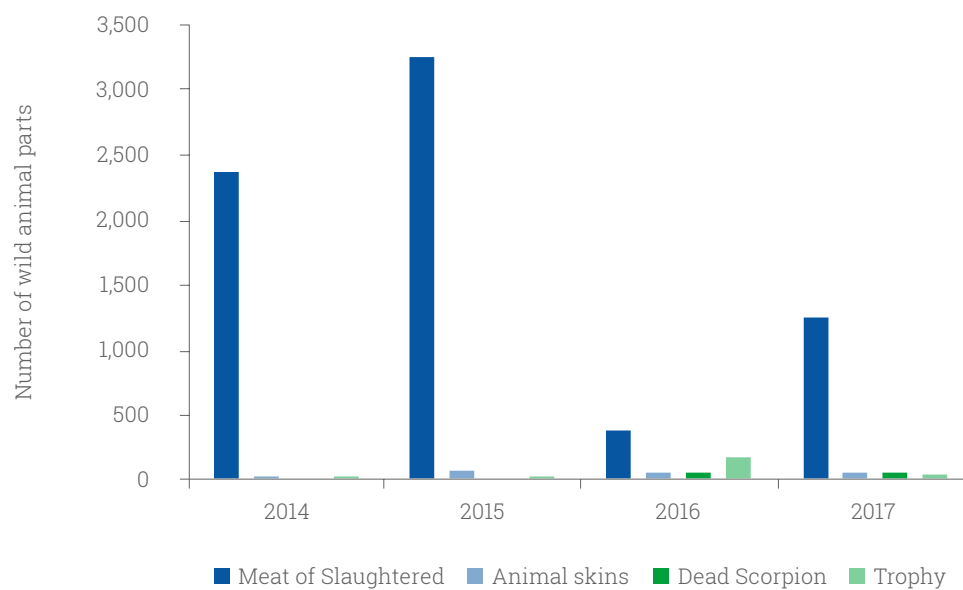


Figure 6.6 Trade (export) of wild animal parts (WCGA 2018)





The lotus (*Nymphaea michrantha*) is a floating-leaf aquatic plant in the White Nile. Photo credit © Osman Ali

6.6.1 Avifauna and waterfowl

Sudan is rich in birds with an estimated species number of 653 (Avibase 2020) and it ranks the third among African countries used as flyways by migratory birds. The Rift Valley/Red Sea flyway is considered the second most important flyway for migratory birds in the world. Over 1.5 million birds of 37 species, including five that are globally threatened, use this corridor to migrate between their breeding grounds in Europe and West Asia and their wintering grounds in Africa (Gaboush 2017; Moubark 2017). A joint survey by Sudan and France identified 3,132 wetland spots with over 500 wintering waterbirds in 2014 (Jean-Yve. M. and Pierre 2018). A survey carried out by foot and boat in 2014 found a total of 54,482 waterbirds (Jean-Yve. M. and Pierre 2018).

Birds face many threats including poaching, poisoning and electrocution following collision with electricity power lines. In 2017, 113 birds are known to have died through electrocution including Grayish owl, Abdim's stork, pied crow, black-headed heron and lesser kestrel (Moubark 2017).

6.6.2 Inland waters biodiversity

Sudan's inland waters are rich in biodiversity. They are home to the following flora and fauna:

- ➔ Aquatic plants, which occupy all the diverse habitats of the country's inland waters. Sudan's aquatic flora belong to 24 families and include 70 species, such as *Acacia nilotica*, *Faidherbia albida*, *Hyphaene thebaica*, *Tamirix indicus*, *Polygonum glabrum*, *Mimosa pigra*, *Ziziphus spina-christi* and *Phragmites spp*;
- ➔ Five families of phytoplankton (*Chlorophyceae*, *Bacillariophyceae*, *Cyanophyceae*, *Dinophyceae* and *Euglenophyceae*), including more than 70 genera (Sinada and Abdel Karim 1984). Epipelagic algae, which live on the interface between water and sediment, are found along the White Nile River, with diatoms (*Bacillariophyceae*) making up over 90 per cent (Abdel Karim and Ali O.M. 1985);
- ➔ Five types of aquatic macrophytes: free-floating (*Pistia stratiotes*), rootless submersed (*Ceratophyllum demersum*), rooted submersed (*Vallisneria sp*), floating-leaved submersed (*Nymphaea lotus*) and emergent (*Vossia cuspidata*, *Utricularia spp.*). There

is also one that grows on the bank but trails on the water surface (*Ipomoea aquatica*) (Ali O. M. 2009).

The only woody macrophyte that is found in inland waters is *Aeschynomene elaphroxylon* (Ambatch);

- ➔ Non-planktonic arthropods include many species of green and black midges that are indigenous to Sudan. Three riverine ones – *Tanytarsus lewisi*, *Simulium daminosum* and *Simulium griseicollis* – have health implications as they are associated with allergic symptoms in people living close to the Nile in northern and central Sudan (Cranston et al. 1981);
- ➔ Many species of molluscs, including 17 species in the White Nile, six in the Blue Nile, twelve in the River Nile and eight in West Sudan (Ali M. T. 2013);

Species of molluscs



- ➔ Several species of snail that host the parasite bilharzia, which causes the disease schistosomiasis: *Biomphalaria pfeifferi* (in all basins), *Bulinus forskali* (in all basins), *Bulinus globosus* (in irrigated canals) and *Bulinus truncates* (in the Blue Nile and irrigated canals) (Ali M. T. 2013).

6.6.3 Native reptiles

Various species of reptile are found in Sudan, including lizards, snakes and turtles (see Table 6.9). Among the most notable are:

- ➔ The savannah monitor (*Varanus exanthematicus*), a ground dwelling species found in bushes and burrows in sub-Saharan Africa. The savannah monitor is threatened by hunting for the leather, meat and pet trades (Mohammed et al. 1998);
- ➔ The black-necked agama (*Acanthocercus atricollis*), a common reptile that lives on trees and feeds on ants and beetles;
- ➔ The side-striped chameleon (*Trioceros bitaeniatus*), also common but threatened by capture for use as a pet;
- ➔ The leopard tortoise (*Stigmochelys pardalis*), found in Sudan's grassland and thorny bushes;
- ➔ Common snakes include the rhombic forest adder (*Causus maculatus*), the rufous beaked snake (*Rhamphiophis oxyrhynchus*), the common egg eater (*Dasypeltis scabra*), the fan-footed gecko (*Ptyodactylus hasselquistii*) and the northeast African carpet viper (*Echis pyramidum*);
- ➔ Reptilian species found in inland waters include *Trionyx truguis*, *Trionyx niloticus*, *Pelusios subniger*, *Varanus niloticus* and *Crocodylus niloticus* (El Moghraby 2013).

Sudan's reptiles are threatened and their population is declining due to unregulated hunting, trading for pets and increasing human encroachment on their habitats. Several measures have been taken to protect them including the designation of protected areas and the rearing of animals in captivity.



Nile crocodile (*Crocodylus niloticus*), Sai Island, North Sudan. Photo credit © Anaconda 2014



African chameleon or Sahel chameleon (*Chamaeleo africanus*), Kigid, Kerma, North Sudan. Photo credit © Anaconda 2014

6.6.4 Fish biodiversity

Fish are found in almost all Sudan's freshwater ecosystems (Ali M.T. 2013). The richest habitats are the Nile system and the lakes, though fish are also found in irrigated canals and in ponds unconnected to the Nile.

The Nile hosts 128 species belonging to 27 families. 25 of those species (belonging to 10 families) also occur in Lake Nubia (see Table 6.10).

Neumann et al (2016) reported that in general, many species seem to be in decline. Besides the fragmentation of populations, of major concern are the levelling and taming of the Nile, the dramatic decline of floodplains and the erosion of islands with the resulting in the Nile and the loss of suited spawning and nursing sites. Sudden water level drops can negatively impact not only lotic species but also species along shallow shores as observed at Sennar.

Sudan's commercially important freshwater fish species include *Clarias lazera* and *Tilapia zillii*, which are found in Lake Kundi in West Darfur. The commercially important fish in the Nile are *Oreochromis niloticus* (Nile Tilapia), *Bagrus docmak* (Catfish), *Protopterus annectens* (Lung fish) and *Clariasga riepinus* (Mud fish). Fish species of less commercial importance but of high nutritional value include *Babus spp*, *Mormyrus spp* and *Labeo spp*. (Moghraby 2001). Villages with nearby bodies of water depend on fish for their livelihoods, producing between 500 and 1,000 kg per hectare of water per year (Khalifa and Mahmoud 2015).

In a study on fish diversity in Lake Nubia, it was indicated that over a period of 40 years (1964–2015) the number of fish families dropped from 17 to 12 and the number of fish species dropped from 42 to 34. Water flow, water characteristics and fish behaviour were the main reasons for their disappearance (Mahmoud 2019).

The Red Sea contains more than 1,200 species of fish, about 10 per cent of which are not found elsewhere. These include 42 deep-water species that live on coral reefs, and 177 species of finfish, belonging to 30 families (Table 6.11). The most commercially important finfish are Grouper and Emperor such as *Lutjanus bohar*, *Lutjanus gibbus*, *Jack*, *Aphareus rutilans*, *Mullet scombridae* and *Panaeus indicus* (Alhaj et al. 2013). The Red Sea is also home to coral trout, grouper, emperor, barracuda, red snapper, Napoleon wrasse, blacktip shark, grey shark, silky shark, dogtooth tuna, bluefin trevally, titan triggerfish, giant humphead parrotfish and blue trevally (Ali M.E. 2015).

Among the other species of fish native to Sudan are the Red Sea Stonefish, also called a Dwarf scorpionfish, the Houndfish, a game fish which is often referred to as a crocodile needlefish. The Red Sea Bannerfish is easily recognizable from its colourful yellow, white, and black bands. Another species commonly found in the Red Sea is the thin sand eel which flourishes in freshwater, marine and tropical environments (Illsley 2017).

The coral ecosystems of the Red Sea face many threats from unguided fishing, marine tourism, coastal installations, coral reef removal, boat docking, intensive dredging and other human activities (Alhaj et al. 2013).

6.7 INTRODUCED INVASIVE SPECIES

Alien invasive species can damage ecosystems by displacing indigenous species via competition, predation or transmission of pests and diseases. Once established, they often spread aggressively.

In Sudan, invasive species have affected agricultural land, forests, rangelands and protected areas. Examples of invasive plants include:

- ➔ *Orobancha crenata*, commonly known as bean broomrape, a parasitic weed that colonized a 160-km stretch of the Nile in Northern state, including El Selaim basin;
- ➔ *Orobancha ramosa*, commonly known as hemp broomrape and locally as haluak, a parasitic weed that has spread over large areas in Sudan;
- ➔ *Prosopis juliflora* (mesquite), found in a number of irrigation schemes in Sudan; it grows into dense thickets, causing problems for farmers (Abdel Magid 2007; Ediris 2014);
- ➔ *Eichhornia crassipes* (water hyacinth), a highly invasive species found in the White Nile, Kosti area;
- ➔ *Jatropha curcas* (jatropha), a drought-resistant flowering plant that threatens the biodiversity of rangeland, agricultural and forest ecosystems;
- ➔ *Cannabis sativa* (hashish) is a problem in South Darfur, crowding out other vegetation and disturbing the natural ecosystem balance;
- ➔ *Acanthospermum hispidum* (Horabhawsa), a weed that has invaded Wadi Kaga, Wadi Nyala and other livestock watering sources in North and West

Kordofan states, smothering and suppressing rangeland grasses;

- ➔ *Xanthium brasiliicum* (Ramtok), found on the floodplains of seasonal water channels in the Butana plain, the Gash and Tokar Deltas and the central clay plain; it suppresses the endemic and more desirable plants that cattle graze on;
- ➔ *Forsetialongi siliqua* (Dahayan), a weed that invades overgrazed or disturbed vegetation on the rangelands of the semi-desert and the northern fringes of the low-rainfall savanna;
- ➔ *Sida cordifolia* (Nyada), a weed that grows in the wet season on loose and compacted red sands or around livestock watering sites; it has invaded overgrazed rangelands in Kordofan and Darfur;
- ➔ *Cassia memosoides* (Sakarnaba), a legume that has invaded the mayas of Dinder National Park.

The following are examples of alien insects that have invaded Sudan:

- ➔ *Parlatoria blanchardi*, a major pest of the date palm in northern and central Sudan during the second half of the 20th century; it seems to be on the decline;
- ➔ *Asterolecanium phoenicis* (Green pit scale), discovered in Algolid in northern Sudan in 1985; it spread far, causing severe infestation and complete drying of the plant leaflets;
- ➔ *Ceratitidis capitata* (Fruit fly), first detected in the mid-20th century and now abundant in northern Sudan;

Table 6.8 Native Reptiles of Sudan

	Common name	Scientific name
1	Savannah Monitor	<i>Varanus exanthematicus</i>
2	Black-Necked Agama	<i>Acanthocercus atricollis</i>
3	Side-Striped Chameleon	<i>Trioceros bitaeniatus</i>
4	Gaboon Viper	<i>Bitis gabonica</i>
5	Leopard Tortoise	<i>Stigmochelys pardalis</i>
6	Rhombic Forest Adder	<i>Causus maculatus</i>
7	Rufous Beaked Snake	<i>Rhamphiophis oxyrhynchus</i>
8	Common Egg Eater	<i>Dasypeltis scabra</i>
9	Fan-Footed Gecko	<i>Ptyodactylus hasselquistii</i>
10	Northeast African Carpet Viper	<i>Echis pyramidum</i>

Source: Ministry of Environment and Physical Development 2014

Table 6.9 Fish families and their species in Sudan (Collated from Neumann et al 2016)

No.	Family	Number of species
1	Protopteridae	1
2	Polypteridae	3
3	Arapaimidae	1
4	Gymnarchidae	1
5	Mormyridae	11
6	Cyprinidae	15
7	Distichodontidae	4
8	Citharinidae	2
9	Alestidae	7
10	Amphiliidae	1
11	Bagridae	2
12	Claroteidae	4
13	Schilbeidae	4
14	Clariidae	2
15	Mochokidae	10
16	Malapteruridae	1
17	Nothobranchiidae	2
18	Poeciliidae	1
19	Latidae	1
20	Eleotridae	1
21	Anabantidae	1
22	Channidae	1
23	Cichlidae	8
24	Tetraodontidae	1
	Total	85

Table 6.10 Common fish types found in the Sudanese Red Sea

Bony Fish	Number of species	Cartilaginous Fish	Number of species
Serranidae	19	Carcharhinidae	16
Lethrinidae	10	Scyliorhinidae	3
Carangidae	16	Triakidae	2
Lutjanidae	14	Sphyrnidae	2
Mugilidae	2	Triakidae	2
Sphyraenidae	7	Hemigaleidae	1
Sparidae	5	Heterodontidae	1
Synodontidae	4	Alopiidae	3
Labridae	28	Stegostomatidae	1
Priacanthidae	1	Rhincodontidae	1
Leiognathidae	2	Ginglymostomatidae	1
Gerreidae	1	Heterodontidae	1
Ariidae	1	Lamnidae	1
Blenniidae	5		
Terapontidae	2		
Siganidae	1		
Holocentridae	1		
Acanthuridae	7		
Chaetodontidae	8		
Balistidae	6		
Nemipteridae	4		
Mullidae	7		
Haemulidae	3		
Scaridae	15		
Apogonidae	3		
Clupeidae	6		
Pomacentridae	10		
Scombridae	9		

Source: Alhaj et al. 2013

- ➔ *Ceratitis cosyra* (Fruit fly), a serious pest of mango trees, dominant in central Sudan, particularly in Sennar and Blue Nile states;
- ➔ *Bactrocera cucurbitae* and *B. invadens* (Fruit flies), flies that cause extensive damage to cucurbits (gourds) and fruit trees; they spread very fast and are recorded in almost all parts of the country;
- ➔ *Tuta absoluta* (Tomato leaf miner), a devastating insect pest with a strong preference for tomatoes, though it also feeds on potato, eggplant, pepino, tobacco and solanaceous weeds; found in greenhouses in Khartoum state (Mohamed et al. 2015).

6.8 CONCLUSION

Ecosystems provide vital services to local communities. Yet their importance is often overlooked by policy-makers, who as a result do little to protect them. Many of the threats to Sudan's biological resources are due to a lack of understanding of their economic, cultural, spiritual and social value.

Although the secession of South Sudan resulted in the loss of some important habitats, including forests, rangelands and wetlands, the country still has remarkably diverse biological assets and heritage with 14 protected areas.

The expansion of agriculture poses one of the greatest threats to the country's ecosystems and biodiversity. To make way for farmland, forests are clear-felled

using heavy machinery, resulting in the total loss of natural plant cover and a drastic reduction in the abundance and richness of species. Traditional farming practices have led to overgrazing and degradation. Agriculture has also encroached on wetlands, disrupting their ecological function. Other major threats to natural habitats include the petroleum industry, gold mining, conflicts and a shortage of funds for conservation.

A major problem is the lack of legislation and regulatory frameworks. For example, there is no national legislation governing the sustainable use of wetlands. A gap in legislation is also behind the failure to control invasive species and to understand their impact on local biodiversity. The absence of clear management not only results in poor protection for biological resources, it also makes it difficult to maximize the economic benefits of biodiversity through tourism and other activities.

The biodiversity of Sudan could be preserved and enhanced via a package of programmes and actions including a government commitment to enforce and update legislation, research, capacity building, more involvement of stakeholders and stronger international partnership. Improved management of biodiversity in Sudan could contribute to the country's efforts towards a better environment, sustainable development and peace.

References

REFERENCES

1. Abdalla, S. and Karar, M. (2010). Water Policy of Sudan: National and Co-Basin Approach, Ministry of Irrigation and Water Resources, Sudan. Regional Centre on Urban Water Management. Tehran.
2. Abdelhameed, S. M., Hamid, A. A., Awad, N. M., Moghraby, E. E. and Osman, O. A. (1997). Watershed management in Dinder National Park. International Union of Forest Research Organization (IUFRO). Conference, Tampere, Finland. September 1995. *Agriculture and Forest Meteorology Journal*, 84, (2), 89-96.
3. Abdelhameed, S. M., Nimir, M. B. and Eljack, A. O (2008). The present status of protected areas in Sudan. Proceedings of the International Scientific Conference of ARRC/ Ministry of Science and Technology, August 17–21 2008. Sudan Currency Press, pp. 155–180.
4. 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.
5. Abdelhameed, S. M. (2015). Evaluation of Ecosystem services of Dinder Wetland/ Sudan. Nile Ecosystems Valuation for Wise Use (Nile-Eco-VWU) (2015-2016) of Nile Basin, Project. Nile Basin Capacity Building Network. Retrieved from: Guidelines%20for%20wetlands%20valuation%20(5).pdf
6. Abdelhameed, S. M. (2016). The impact of Climate Change on Natural Heritage and its Management in Sudan. African World Heritage Seminar "thinking ahead" 3-5 May 2016, Johannesburg, South Africa.
7. Abdelhameed, S. M., Ali, A. M. and Nimir, M. B. (2017). Developing Drivers of Deforestation and Forest Degradation for Sudan REDD Programme. Driver Aspect 3.C. Wildlife, Fauna and Flora in Wetlands, Protected Areas and National Parks in Sudan.
8. Abdel Karim, A. G. and Ali, O. M. (1985). Studies on the Freshwater Algae of the Sudan: IV – The epipelagic flora of a freshwater impoundment. *Sudan Journal. of Science*, 1,1–12.
9. Abdel Magid, T. D. (1995). *Prospects of Irrigated Forest Plantations*. The case of Abdel Magid Scheme. (Master of Science, thesis. University of Khartoum, Khartoum, Sudan).
10. Abdel Magid T. D. (2001). Forest Biodiversity and its Impact on Non-wood Forest Products. Published by the Forest National Corporation on the occasion of centennial anniversary of Sudan's forestry service.
11. Abdel Magid T. D. (2007). *An Approach towards Mesquite Management in Sudan: the case of Kassala State*. (Doctoral thesis. University of Khartoum, Khartoum, Sudan).
12. Abdel Magid, T. D. and Badi, K. H. (2008). Ecological Zones of the Sudan. Paper Presented in the workshop on the importance of Wetland, in Sudan. Nile Transboundary Environmental Action Project.
13. Abdel Magid, T. D., Mamoun G. M. and El Mubarak, S. M. (2015). The State of the Sudan Forests' Biodiversity for Food and Agriculture. Report submitted to the Quality Control Unit, Ministry of Agriculture and Forestry.
14. Abdelnour, H. O. and Abdel Magid, T. D. (1997). The Human activities in the Sudan during the 20th century and its effect on the forests of the Sudan. Environmental Forum, Sudanese Environment Conservation Society.
15. Abdoun, S.O. M. (2020). Incentives for Reforestation and Forest's Plantations Option, under the National Strategy of REDD+ Program in Sudan. *Journal of Advances in Ecological and Environmental Research*, 5, (2), 53-85. Retrieved from: <http://www.ss-pub.org/journals/aeer/vol-5/vol-5-issue-2-february-2020>
16. Abu -Gideiri, Y. B. (1997). The state of the marine environment in the Red Sea and Gulf of Aden (2nd draft). PERSGA, Jeddah. Saudi Arabia.
17. Alhaj, A. A, Ali, M. E. and Al Awad, A. N. (2013). Final report on the completed questionnaire in the Republic of Sudan on marine biodiversity. ISESCO. 30 pp.
18. Al Hadi, A. (2015). Jebel Marra/ Darfur/Sudan: a proposed natural Heritage site. Workshop for natural heritage tentative list. UNESCO Khartoum Office.
19. Ali, O. M. (2009). The Aquatic Plants of Sudan. In H. Dumont (Ed.). *The Nile: Origin, environments, Limnology and Human Use*. (1st ed., pp. 479–494). Springer Publisher. Germany.
20. Ali, M. T. (2013). Status of fishery stock and productivity in dams' lakes of Sudan. ElTahir Consultancy. Sudan.

21. Ali, M. E. (2015). Habitat Monitoring in Dungonab Bay–Mukkawar Island Marine Protected Area. Sudan. Strengthen scientific partnership to support listing of Sanganeb and Dungonab Bay/ Mukkawar Island as UNESCO World Heritage site.
22. Ali, O. M. (2013). Assessment and Stocktaking of Biodiversity in the Inland Wetlands of the Sudan. Prepared for Sudan's Fifth National Report to the Convention on Biological Diversity.
23. Antonio, A. (2017). United Nations Education, Science and Culture Organization. Biosphere reserves at Red Sea coast and islands, Sudan (mission Nov. 2017).
24. Armitage, F. B. (1985). Irrigated forestry in arid and semi-arid lands: A synthesis. The International Development Research Centre. Ottawa, Canada.
25. 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>
26. Ayoub, N. (2017). Surveys on Waterfowl communities and proposed protected areas in Darfur State. A workshop "Towards the establishment of new reserves and threats to wildlife in Sudan" The Sudanese Wildlife Society in collaboration with the UNESCO Chair of the Cousteau Environmental Technologies. 27 September 2017.
27. Badi. H. and Abdel Magid, T. D. (2017). Preventive Attributes Against Forest Fires with Particular Reference to the Low Rainfall Savannah Region of Sudan: A Review. *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>
28. Cranston, P. A., Gad El Rab, M. O. and Kay, A. B. (1981). Chronomid midges as a cause of allergy in the Sudan. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 75 (1). pp, 1–4.
29. El Moghraby, A. I. (2001). Towards an Action Plan for wetlands in the Sudan. Ramsar Convention Workshop. Khartoum, 5-6 Sept. 2001.
30. El Moghraby, A. I. (2013). On the wetlands of the Sudan. UNEP Project, (pp 96).
31. Elsiddig, E. A., and Abdel Magid, T. D. (2008). Degradation of Forest Resources along the Nile and the surrounding Clay plains of Central Sudan. International Forum of the Nile Water Initiative, Nile Trans-boundary Environmental Action Project (NTEAP).
32. 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>
33. Forest National Corporation (1995). Forests Products Consumption Survey.
34. Forest National Corporation (2017). Comprehensive report submitted to the Council of Ministers.
35. Gaboush, N. (2017). Wild bird census in the Red Sea State. A workshop "Towards the establishment of new reserves and threats to wildlife in Sudan". The Sudanese Wildlife Society in collaboration with UNESCO – Cousteau Ecotechnie Chair in Environmental Education. 27, September 2017.
36. Gaffar (2011). Forest Plantations and Woodlots in Sudan. African Forest Forum Working Papers Series, 1 (15), 1-58. Retrieved from: <https://www.sifi.se/wp-content/uploads/2012/02/Forest-plantations-and-woodlots-in-Sudan.pdf>
37. Hakim, S., B. Fadlalla, N. M., and Wahab, S. (1978). Ecosystems of the Vegetation of Dinder National Park WRC. (unpublished report).
38. Hassaballah, K., Mohamed, Y. A. and Uhlenbrook, S. (2016). The Mayas wetlands of the Dinder and Rahad tributaries of the Blue Nile Basin (Sudan). In C. M. Finlyason, G.R. Milton, R.C. Prentice and N.C. Davidson (Eds.). *The Wetland Book. II. Distribution, Description and Conservation*. (pp 1287–1298). Springer Publisher, Germany. Retrieved from: https://link.springer.com/referenceworkentry/10.1007%2F978-94-007-4001-3_223
39. Hassan and Tag Consultants. (2018). In-depth analysis of Drivers of Deforestation & Forest/Range Degradation. Republic of Sudan REDD+ Programme (pp 134). Retrieved from: <https://www.reddplussd.org/phocadownload/Drivers%20of%20Deforestation%20&%20ForestRange%20Degradation.pdf>
40. Harrison, M. N. and J. K. Jackson (1958). Ecological Classification of The Vegetation of The Sudan. Khartoum, Agriculture Publications Committee.
41. Higher Council for Environment and Natural Resources and Wildlife Conservation General Administration (2004). Management plan for Dinder national park. UNDP/GEF project SUD/98/G41 and SUD 00/014. Khartoum. Sudan.

42. Huwitallah, K. O. (2016). The experience of the General Authority for Research on Animal Wealth in the field of adaptation to climate change. Fourth Technical Workshop on Adaptation to Climate Change. North Kordofan State. 27–29 November 2016.
43. Illsley, C.L.(2017). Native fish species of Sudan. Environment. WorkdAtlas. Retrieved from: <https://www.worldatlas.com/articles/native-fish-species-of-sudan.html>
44. Jean-Yve. M. and Pierre D. (2018). Khor Abu Habil Alluvial Fan Wetlands. Importance for wintering migratory waterbirds. Khor Abu Habil Wetlands Workshop, Khartoum- February 2018.
45. Khalid, A. (2015). Assessment of Fishery resources in the transitional zone of Dinder Biosphere Reserve. United Nations Education, Sciemce and Culture Organization-Man and the Biosphere.
46. Kheir Al Seid, S. (2016). Adaptation and mitigation of the impact of climate change on rangeland Climate Change Forum – Animal Health in Sudan, University of Bahary. 24-25 February 2016, Khartoum.
47. Lomer, C. J., Bateman, R., Johnson, D.J., Langewald, J. and Thomas, M. B.I (2001). Biological Control of Locusts and Grasshoppers. *Annual Review of Entomology*. 667–702. Retrieved from: https://www.researchgate.net/publication/12216333_Biological_Control_of_Locusts_and_Grasshoppers
48. Man and the Biosphere (2017). Dinder-Al Atish Initiative for Establishing a Trans-boundary Reserve between Sudan and Ethiopia. United Nations Education, Science and Culture Organization MAB.
49. Mahgoub, F. (2014). Current Status of Agriculture and Future Challenges in Sudan. *Current African Issues*, 57, pp 98. Nordiska, Africa, Institutet, Uppsala.
50. Ministry of Agriculture and Forestry (2015). Sudan's Country Report contributing to the State of the World's Biodiversity for Food and Agriculture. Quality Control and Export Development Unit. Retrieved from: <http://www.fao.org/3/CA3455EN/ca3455en.pdf>
51. Ministry of Environment and Physical Development (2014). Sudan's Fifth National Report to the Convention on Biological Diversity. The Higher Council for Environment and Natural Resources. Retrieved from: <https://www.cbd.int/doc/world/sd/sd-nr-05-en.pdf>
52. Mohammed, A. S., S. A. Abdelhameed, A. S. Mohammed, and B. A. Mohammed (1998). New Aspects in trade and investment of wildlife in Sudan. Proceedings of 8th Arab Vetrenary Conference. Khartoum, March 24-28, 1998 (in Arabic).
53. Mohamed, E.S.I, Mahmoud, M.E.E., Elhaj, M.A.M, Mohamed, S.A. and Ekesi, S. (2015). Host plants records for tomato leaf minor (*Tuta absoluta*) in Sudan. Bulletin OEPP EPPP Bulletin,46,1,108–111. Retrieved from: <https://doi.org/10.1111/epp.12178>
54. Mahmoud, Z. N. (2019). Fish diversity in Lake Nubia in relation to water level. *International Journal of Fisheries and Aquatic Studies*. 7(5), 210–214 53.
55. Moubark, A. I. (2017). Effect of high voltage lines on birds. A workshop on "Towards the establishment of new reserves and threats to wildlife in Sudan". The Sudanese Wildlife Society in collaboration with the United Nations Education, Science and Culture Organization Chair of the Cousteau Environmental Technologies. 27, September 2017.
56. Neumann D., Obermaier H. and Moritz T. (2016). Annotated checklist for fishes of the Main Nile Basin in the Sudan and Egypt based on recent specimen records (2006-2015). *Cybium*, 40 (4), 287–317).
57. Nikolaus, G. and Musa, D. (1987). Distribution Atlas of Sudan's birds with notes on habitat and status. Bonographeen. N. 25, Bonn.
58. Nimir, M. B. (1983). *Wildlife Values and Management in Northern Sudan*. (Doctoral thesis Colorado State University, Colorado, USA.)
59. Osman, N. A. and Mohammed, S. E. (2016). A compiled checklist of seaweeds of Sudanese Red Sea coast. *Journal of Coastal Life Medicine*, 4 (2), pp: 114–120. Retrieved from: DOI: 10.12980/jclm.4.2016j5-231
60. Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden. PERSGA/GEF (2004). Survey of the proposed marine protected area at Dunganab Bay and Mukkawar Island, Sudan. Report for PERSGA. PERSGA, Jeddah.
61. Sinada, F. A. and Abdel Karim, A. G. (1984). A quantitative study of the phytoplankton in the Blue and White Niles at Khartoum. *Hydrobiologia*, 110, 47–55.

62. Talaat, A. M. D and Mohamed, A.G. (2012). Development Strategy of the Traditional Rain-fed Agriculture: Forestry Sector. Retrieved from: https://www.researchgate.net/publication/309727094_Development_Strategy_of_the_Traditional_Rain-fed_Agriculture_forestry_Sector
63. United Nations Education, Science and Culture Organization. (2016). Sanganeb Attol and Dugonab Bay -Mukkawar Island Marine National Parks as UNESCO World Heritage Sites. Retrieved from: <https://whc.unesco.org/en/news/1529>
64. United Nations Convention on Biodiversity (1992). Convention on Biological Diversity. Retrieved from: <https://www.cbd.int/doc/legal/cbd-en.pdf>
65. United Nations Environment Programme (2007). Sudan Post Conflict Environmental Assessment. https://postconflict.unep.ch/publications/UNEP_Sudan.pdf
64. Warrag, E. I., Elsheiksh, E. A. and Elfeel. A. A. (2002). Forest Genetic Resources Conservation in Sudan. Forest Genetic Resources, 30. FAO, Rome, Italy. Retrieved from: <http://www.fao.org/3/Y4341E13.htm>
65. World Bank (2017). World Development Indicators database, Country profile Sudan.
65. Wildlife Conservation General Administration (WCGA) (2018). Protected Areas Department Annual Report.
66. Wildlife Conservation General Administration (WCGA) and Wildlife Research Centre (WRC) (2014). Assessment of Natural Resources in Al Gazaly area, Northern State. 16 pages (in Arabic).

7

Persistent Environmental Issues

7.1 INTRODUCTION

Sudan suffers many long-term environmental problems, including desertification, deforestation, the loss of biodiversity, water scarcity, pollution, poor waste management, soil erosion, and contamination from chemicals that remain in the environment for a long time (Buccini 2004). These problems affect not only the natural environment, but also people's livelihoods and the stability of communities.

Efforts to control them appear to be failing – in fact many of the problems seem to be getting worse. A new approach is needed: a comprehensive environmental management policy that considers the views of all sections of society backed by financial support. The successful management of persistent environmental problems would not only improve and conserve the natural environment, it would also boost economic growth and improve people's lives.

7.2 DESERTIFICATION

The United Nations Convention to Combat Desertification (UNCCD) defines desertification as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climate variations and human activities" (UNCCD 1994).

Desertification also refers to the process of land turning into desert. UNEP has estimated that 35 million km² of the world's rangelands, rain-fed crops and irrigated land – an area approximately the size of North and South America combined – is affected by desertification (Khairalseed 2015). It can have a serious impact on national economies, reducing food production and displacing people from the land. It is one of the most serious socio-economic problems of our time, particularly in Asia and Africa where 37 per cent of the land is desert.

7.2.1 State of desertification in Sudan

Sudan is a dry country located in the Sahelian zone with low, variable rainfall. It is one of the countries most seriously affected by desertification in Africa. The region affected by desertification is the arid and semi-arid land between latitudes 12°N and 18°N (Desert Encroachment Control and Rehabilitation Programme (DECRP) 1976). This covers 1.78 million km², about 72 per cent of the country (Ministry of Agriculture and Forestry 2006). It includes the best grazing lands, as well as cultivated areas that produce 90 per cent of Sudan's cereals and oilseeds and 85 per cent of its firewood (National Drought and Desertification Control Unit 1999).



Desert is threatening the narrow fertile strip of the River Nile in Northern Sudan. Photo credit © UNEP

7 Persistent Environmental Issues

The process by which desertification happens is still not clear. Satellite data of Sudan from the mid-1980s showed the fringe of the Sahara Desert in the Kordofan and Darfur regions oscillating north or south depending on annual rainfall, with vegetation retreating during the droughts and expanding during wet years. UNEP estimated that between 1935 and 2000 the southern margin of the Sahara Desert in Sudan advanced by 200 km southwards. According to Figure 7.1, it is clear that the southern extent of Sudan's desert areas shifted dramatically between 1958 and (Eltoum et al 2015).

Research using remote sensing has led to new insights into the pattern and extent of desertification in Sudan. A study in North Kordofan state revealed that desertification has significantly prevailed over vegetation re-growth over the last two decades, particularly around rural villages (Dawelbait and Morari 2012). This is mainly due to changes in land use and the mismanagement of natural resources, such as deforestation and overgrazing. The area of land undergoing medium to high desertification was estimated at more than 120,000 km²; by contrast, the government's reforestation measures on land sustained by higher rainfall have resulted in low to medium re-growth over an area of about 20,000 km² (Dawelbait and Morari 2012).

In River Nile state, extreme conditions of desertification were shown to affect the valleys in the state. The study showed extreme conditions of desertification affecting 24,482 km² in the valleys of the semi-desert River Nile state. Re-growth conditions were observed over 1,193 km², while desert conditions covered 71,298 km² (Dawelbait and Morari 2012). The major factors behind this desertification were drought and climate variation, aggravated by the mismanagement of natural resources. The situation is not helped by the fact that the soil is highly vulnerable to wind and water erosion. Irrigated agricultural projects in Northern state were also exposed to desertification (Dawelbait and Morari 2012).

An analysis of remote sensing and GIS data for the years 1973, 1987, 2001 and 2011 for Wadi Al Kanger in Khartoum state gives a picture of how the extent of land affected by desertification can fluctuate from year to year. The data show that in 1973, more than 6.14 per cent of this area was covered by sand, and that this had increased to 7.31 per cent by 1987. In 2001 it had retreated back to 6.7 per cent, but then increased again to 7.31 per cent by 2011 (Elhag et al 2014). The changes could be due to the variation in rainfall during the years of the study.

Figure 7.1 Extent of Sudan's vegetation and desert areas in 1958 (yellow line) and 2013 (red line) (Eltoum et al, 2015). The two lines mark the southern extent of the desert. The map was produced with MODIS EVIS 2013.



A 2013 study used advanced geospatial technology to classify soil desertification trends in White Nile state (Elgetaina locality) into very severe, severe, moderate, light and non-degradation (Hano 2013). The results showed that over 24 years, the area of severe degradation had decreased by about 73 km², but the area of very severe degradation had increased by 69.5 km², at a rate of 2.9 km² per year. They also showed an increase in areas of light and no degradation and a decrease in the area of moderate degradation.

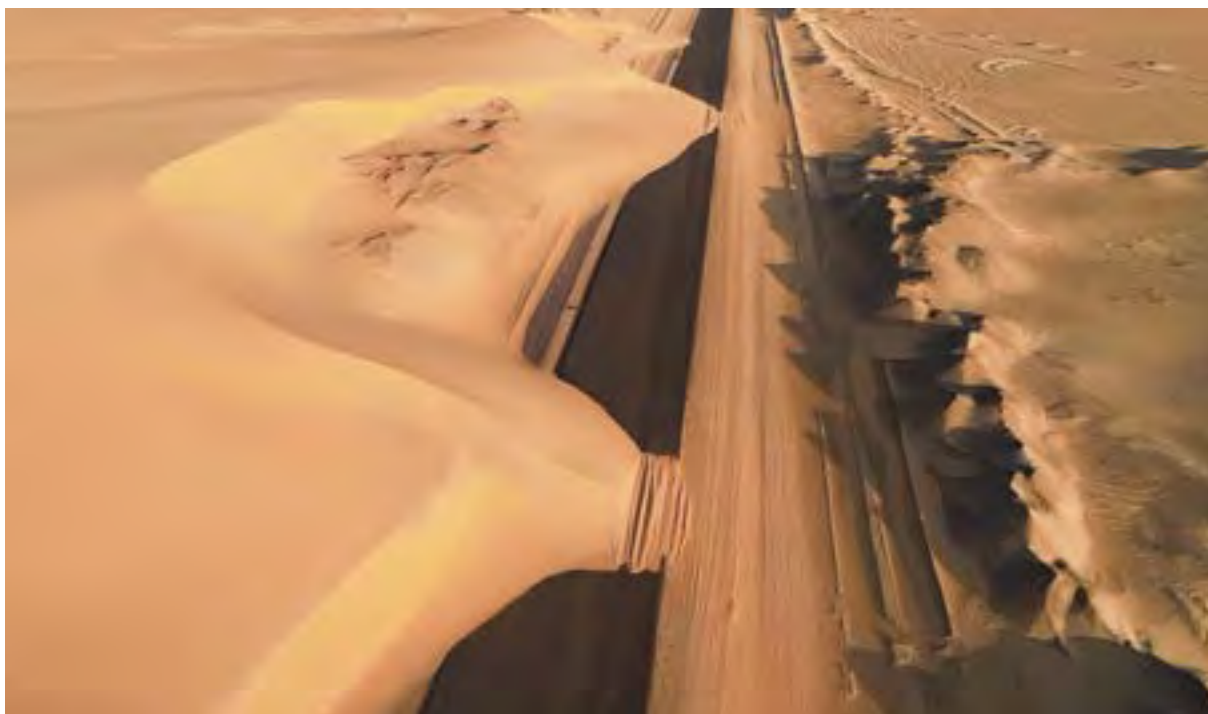
Another study published the same year used satellite imagery for the years 1987, 2000 and 2005 to measure the extent of sand encroachment and vegetation deterioration in the Al-Butana area (Edris et al, 2013). The data showed that between 1987 and 2005, sand cover advanced southwards while vegetation cover deteriorated over most of the study area.

In 2016, Mohamed et al used historical data and remote sensing to compare the change in central Sudan's ecological zones between 1958 and 2010 (Figures 7.2 and 7.3). Their results showed drastic changes, including an 11 per cent increase in desert area, a 13.2 per cent decrease in semi-desert and a 6.8 per cent increase in woodland savannah. Mountain vegetation had decreased by approximately 3 per cent (Mohamed et al 2016).

By contrast, a recent study in North Kordofan state, southwest of Bara locality, revealed a more nuanced picture. Over the past three decades, the area marked by very severe and severe vegetation degradation has decreased, while the area of moderate and slight vegetation degradation has increased (Mariam 2019) (Figures 7.4 and 7.5).

About half of Sudan's population lives in areas affected by desertification. In its 2006 Framework for Combating Desertification in Sudan, the government grouped the states affected by desertification into three categories according to what they share in terms of climate, soil, vegetation cover and human activities (Ministry of Agriculture and Forestry 2006). The first category includes the most arid states, located in the northern and northeastern areas of Sudan: Northern, River Nile and Kassala. The high aridity and excessive agricultural land use have resulted in serious desertification.

The second category includes the states in the central clay plains of Sudan and the main irrigation schemes: Gedaref, Sennar, Gezira and White Nile. This region enjoys a relatively high annual rainfall (100–500 mm). While the area used to have good vegetation cover, current land use practices such as intensive mechanization, deforestation, over-grazing and mining are causing serious degradation, including sand dune encroachment.



Sand movement obstructing major highway in Nawa, Northern Sudan. Photo credit ©UNEP

7 Persistent Environmental Issues

Figure 7.2 Mean annual rainfall for the period between 2000 and 2010 (Mohamed et al. 2016)

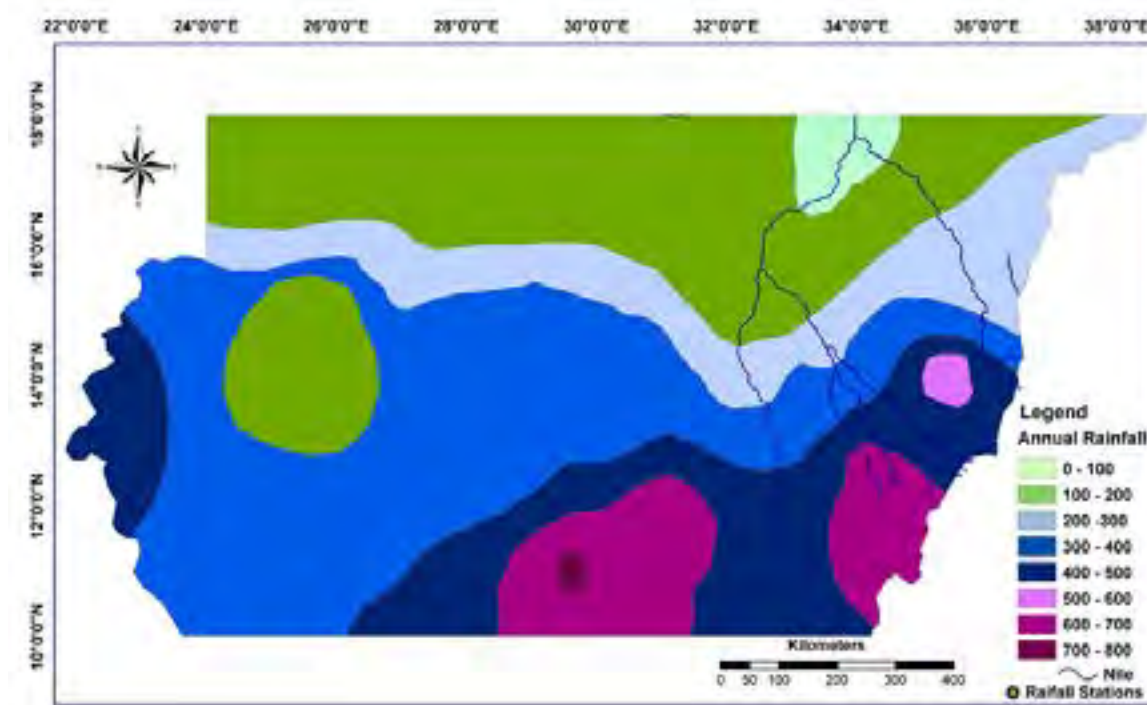
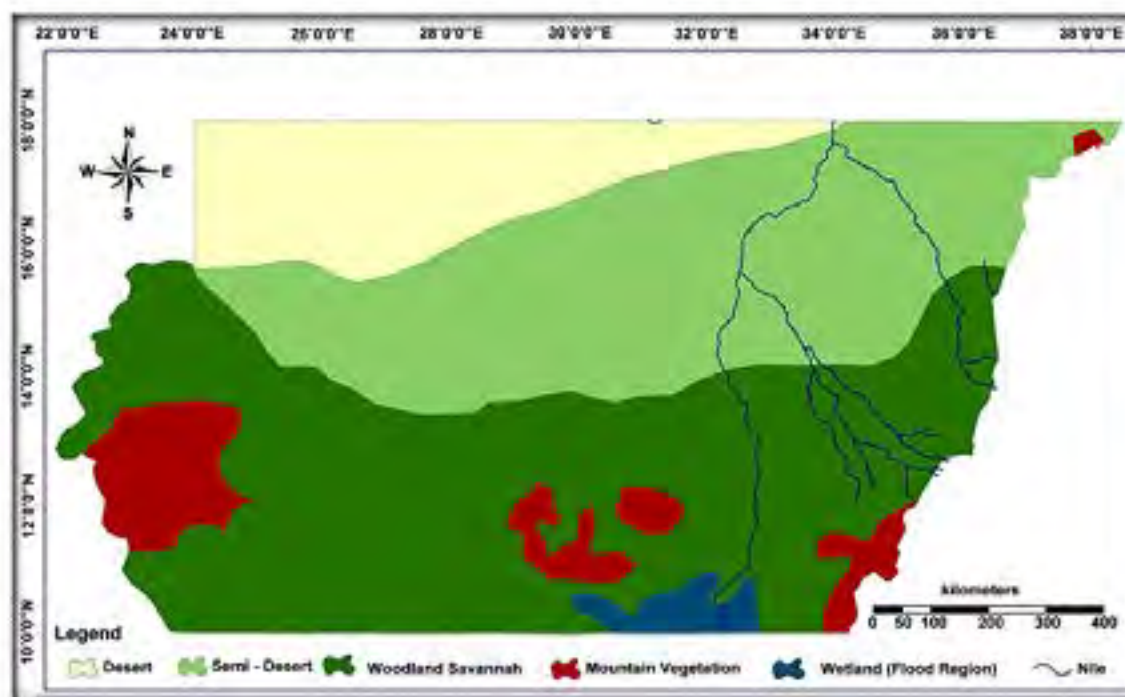
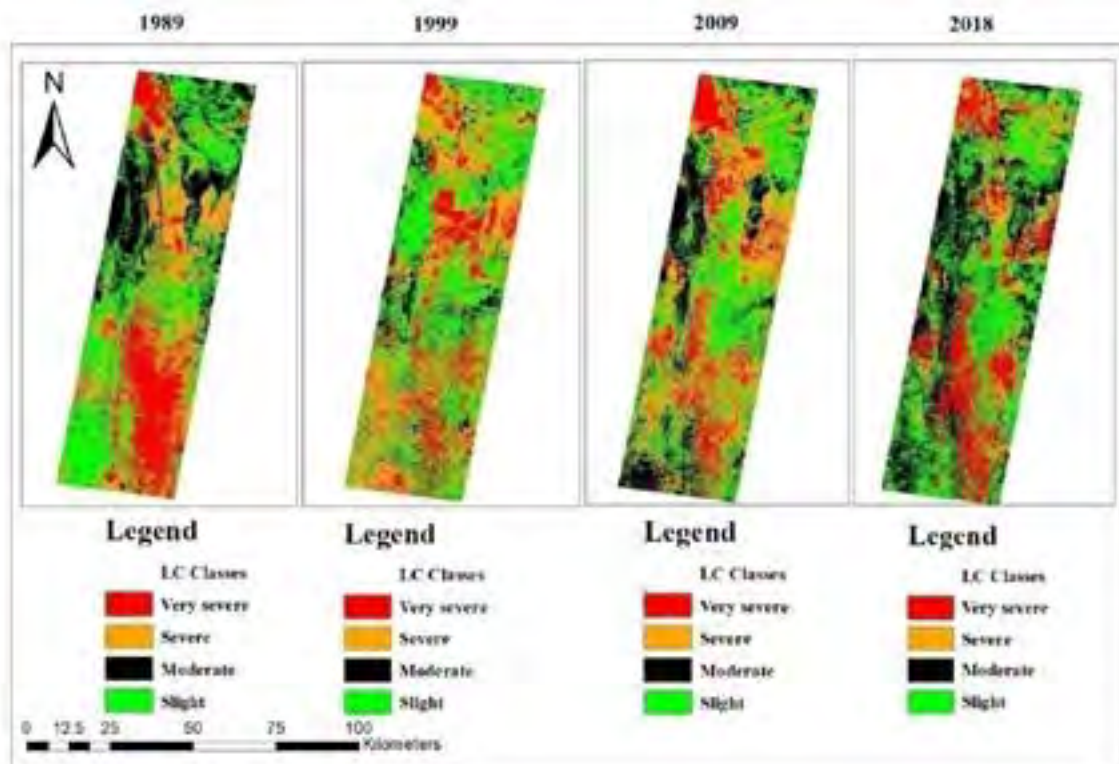


Figure 7.3 A modified map of the ecological zones of central Sudan based on Harrison and Jackson (1958) (Mohamed et al. 2016)



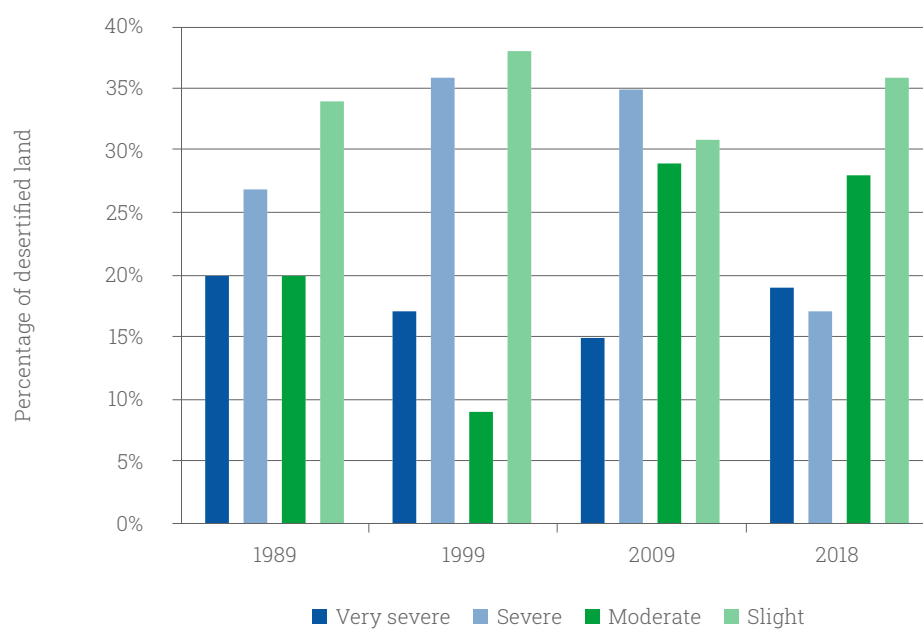
7 Persistent Environmental Issues

Figure 7.4 Desertified land dynamic in area southwest of Bara locality



Source: Mariam 2019

Figure 7.5 Desertified land dynamic in area southwest of Bara locality



Source: Mariam 2019

7 Persistent Environmental Issues

The third category includes the western states of North Kordofan, West Kordofan, North Darfur and West Darfur, where soils are predominantly sandy and permeable and are extensively used in rain-fed traditional farming. These states also contain the main grazing areas for nomadic pastoralists. A combination of climate change, overgrazing and overcultivation are contributing to land degradation.

7.2.2 Causes of desertification

Global climate change is one of the most significant causes of desertification (Mohamed 2016). Climate change brings higher temperatures, lower rainfall and considerable variation in both temperature and rainfall, all of which decrease the amount of water available for vegetation growth and increase the frequency, duration and severity of drought (Kassas 1995). Human factors such as population growth, overgrazing, deforestation, unsustainable irrigation practices and urbanization exacerbate the effects of climate change and are major contributors to desertification (Ouma 2007). The most important of these factors are summarized below.

Overgrazing

Overgrazing has become widespread in Sudan because of the increase in animal numbers and the reduction in pasture caused by the expansion of rain-fed cultivation. The number of livestock far

exceeds the carrying capacity of the land: as far back as 2001, a study estimated that the area of rangeland required to support the national herd amounted to 95 million hectares, while the available rangeland did not exceed 36.4 million hectares (Darag 2001). Over-grazing causes the destruction of vegetation and the removal of soil cover, which makes the land vulnerable to wind and water erosion and can lead to desertification. Earlier studies indicated that 74 per cent of degraded land in Sudan was damaged by overgrazing (Ayoub 1998). The overstocking situation worsened following the secession of South Sudan and the loss of some of the country's prime grazing land.

Deforestation

Deforestation leads to soil erosion and the loss of soil fertility, resulting in stunted plant growth and eventually desertification. While the harvesting of trees for timber is permitted in forest reserves, the illicit cutting of trees outside the reserves is rampant. In Sudan, wood is mostly used for fuel.

At the turn of the 20th century, the contribution of forestry to the national energy supply was estimated at 70 per cent (Forests National Corporation 1995), a situation that has not changed much.

As Figure 7.6 shows, there were large-scale changes in vegetation cover, mainly in trees, in the southern regions of Sudan between 2000 and 2017.



Overgrazing in a sparsely vegetated pasture is one of the causes of desertification. Photo credit © UNEP

7 Persistent Environmental Issues



Cutting of trees for fuelwood is a major cause of land degradation and desertification. Photo credit © UNEP

Cultivation

The cultivation of marginal land in low-rainfall areas is a significant cause of land degradation in Sudan and leads to desert-like conditions. Poor agronomic practices in both irrigated and rain-fed agriculture are major contributing factors to desertification. For example, the failure to conserve soil quality can lead to a loss of soil fertility, permeability and nutrients (DECARP 1976; Hano 2014). In 1998, a study by Ayoub concluded that 22 per cent of soil degradation in Sudan was a result of poor agricultural practices, a situation that prevails today.

Water use

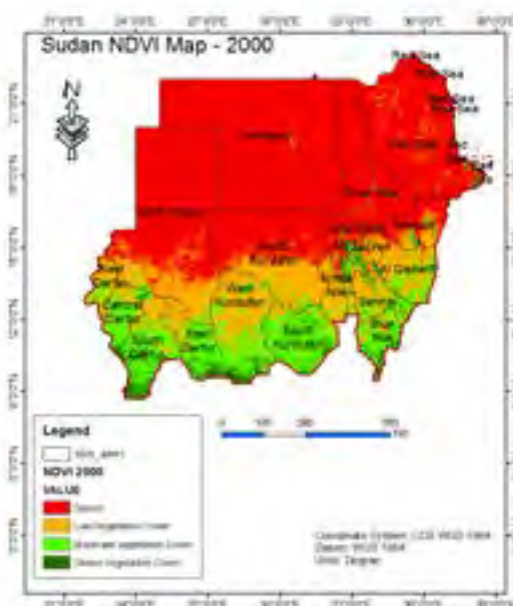
The over-exploitation of groundwater reserves for drinking and irrigation on the margins of the desert

lowers the water table and triggers the southwards advancement of the Sahara into Sudan's agricultural lands (DECARP 1976).

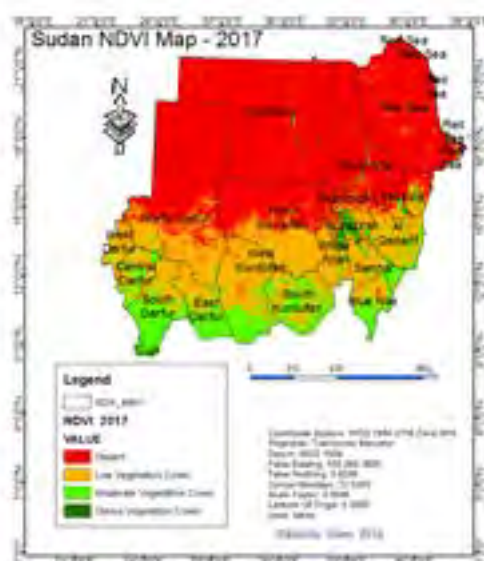
Fire

The practice of burning grass, shrubs and trees to prepare the land for cultivation is widely practised in Central Sudan. Unfortunately it exposes the soil to erosion and eventually to desertification (Mohamed et al. 2016). A report released in 2001 stated that fire has destroyed 15–30 per cent of the herbaceous vegetation in the savanna region of central Sudan (Ministry of Agriculture and Forestry 2006.).

Figure 7.6 Sudan normalized difference vegetation index maps produced from MODIS 2000 and 2017. Edited by the contributing author (Hano 2019)



Source: Sudan's NDVI map 2000



Source: Sudan's NDVI map 2017

7 Persistent Environmental Issues

Mining

Excessive mining in arid and semi-arid regions results in the loss of trees and vegetation cover. Mining is becoming a major source of employment for many Sudanese. It is mostly practiced in the northern parts of the country where the land is arid and vulnerable to desertification.

Soil erosion by wind

Wind erosion is widespread in Sudan. North Kordofan and North Darfur are two of the worst-hit states. In the most extreme cases entire villages can get buried under sand dunes (Ministry of Agriculture and Forestry 1999).

Soil erosion by water

Water erosion is prevalent in central and eastern Sudan, where much of the country's rich agricultural land is located.

Weak policies

Desertification is made worse by misguided policies. For example, prioritizing crop production over other land uses has led to the removal of natural forests. Weak coordination between different government institutions in the fields of agriculture, natural resources, planning and investment, and the failure to enforce laws governing the use of natural resources, are also to blame.

7.2.3 Effects of desertification

Desertification has a direct impact on the environment and local economies, including the loss of crop and livestock production, reduced carrying capacity for grazing animals, reduced tree cover, increased fire hazard, lower groundwater reserves and the loss of wildlife. In many places, the effects of desertification are plain to see. In North Kordofan and North Darfur states, sand is continuously moving into productive soils, and the entire length of the Nile is subject to serious dune encroachment, particularly the area between Delgo and Karima in northern Sudan (Babiker et al. 1992).

But there are often many indirect impacts too. For example, a reduction in crop, rangeland or forest productivity may result in reduced incomes for farmers and pastoralists, higher prices of food and timber, higher rates of hunger or malnutrition, reduced tax revenues because of lower spending, more unemployment, a heightened risk of conflict, greater dependence on disaster relief and an increase in rural-urban migration. Rural-urban migration affects not just the rural areas that the migrants leave, but the urban areas that they settle in, where they increase the pressure on social services, which often leads to greater poverty and social unrest.



A village threatened by sand burial due to sand dunes movement in Northern Sudan. Photo credit © Osman Ali



Sand movement threatening date palm trees in Tangasi, North Sudan. Photo credit © UNEP

7.2.4 Responses to desertification

Awareness of desertification in Sudan can be traced back to the early 1940s, when the Soil Conservation Committee produced a report highlighting the need to combat desert creep by controlling the misuse of natural resources (Ministry of Agriculture and Forestry 1999).

Sudan declared its full support for combating desertification after the International Conference on Human and Environment in Stockholm in 1972, when the country was already severely affected by the phenomenon. In 1977, Sudan submitted its programme for combatting desertification to the United Nations Conference on Desertification in Nairobi, Kenya. The programme, known as DECARP, proposed several projects aimed at stopping desert encroachment, though due to the difficulty in obtaining funds only a few were started (Ministry of Agriculture and Forestry 1999).

One of the key institutions behind Sudan's long-term strategy to combat desertification has been the National Desertification Control and Monitoring Unit, established in 1978 with help from the United Nations Development Programme. In 1993, with additional technical assistance from the European Union, the

monitoring unit undertook a thorough study of the extent of desertification in the country. For the first time, Sudan was able to quantify the extent of the problem, which concluded that just over half the land between latitudes 10° and 18° was prone to desertification. Following this, in 1995 Sudan became one of the first countries to sign and ratify the 1994 United Nations Convention to Combat Desertification (UNCCD). In 1998, DECARP was updated by the National Action Plan (NAP) to Combat Desertification.

The monitoring unit helped prepare Sudan's Desertification National Action Plan, which was completed in 2006. The goal is to prevent desertification in unaffected areas, correct damage in moderately affected areas and rehabilitate badly damaged areas. Among other things, the plan aims to prioritize food security over cash crops; promote reforestation, the efficient use of water resources and the restoration of grazing lands; and establish new sustainable farming systems.

In 2009, as part of the action plan, the government formed the National Council for Combating Desertification. In 2015, the task of combatting desertification was assigned to the Ministry of Environment, Natural Resources and Physical Development, and two years later the council became part of this ministry (Seedahmed 2017).

7 Persistent Environmental Issues

The council's mandate covers a number of projects to combat desertification in Sudan, including:

- ➔ Reconstruction of the gum arabic belt in Kordofan state and Darfur;
- ➔ Reconstruction of pastures in Kordofan state;
- ➔ Rehabilitation of grasslands for carbon sequestration in Kordofan state;
- ➔ Provision of tree belts in the River Nile and Northern States;
- ➔ Kordofan state resource development;
- ➔ Sustainable natural resources development (the Green Belt Project);
- ➔ Wadi El Ku Project (North Darfur–UNEP);
- ➔ Adaptation to the effects of climate change.

As an outcome of the National Comprehensive Development Strategy (1992-2002), the National Centre for Research was mandated to establish the first desertification research institution in the country, and consequently the Desert Research Department was established as part of the Environment and Natural Resources Research Institute. In 2003, the department later re-joined its mother institute to constitute the Environment Natural Resources and Desertification Research Institute.

Sudan's academic research into desertification received another boost in 2003 with the establishment of the UNESCO Chair of Desertification at the University of Khartoum. The main objectives of the chair are to carry out research and training, to document the effects of desertification and to raise awareness. Another objective is to support the University of Khartoum's Institute of Desertification and Desert Cultivation Studies, the first of its kind in Sudan. The chair's publications in English and Arabic are a major source of information on desertification for researchers, students and practitioners.

Sudan has passed a number of laws to combat desertification and to improve the management of rangelands and pasture. The Forest and Renewable Natural Resources Act of 2002 and the Interim National Constitution of 2005 also address the issue.

There have been a number of successes in Sudan's decades-long fight against desertification. One example is the Women's Forestry Project which started in 1994 and promoted the role of women in a wide range of forestry-related activities in communities in River Nile state in Northern Sudan. The project area was a wide zone of dryland affected by severe



Community forests nursery in Um Gidabo, North Darfur. credit © Practical Action

7 Persistent Environmental Issues



Opening of firelines is an effective method of decreasing the impact of fire on grazing lands. Photo credit © World Bank

desertification and land degradation. The Women's Forestry Project achieved major objectives including the training of women on agricultural extension work (improving farming practices through research and the application of new knowledge), the establishment of home nurseries, and the production of citrus trees (Ministry of Agriculture and Forestry 2006).

7.3 PESTICIDES

Pesticides were first used in Sudan in 1941 to control cotton pests in Gezira (Higher Council of Environment and Natural Resources (HCENR)/United Nations Industrial Development Organization (UNIDO) 2014). While they have increased agricultural productivity, they have caused many environmental problems. Some pesticides not only remain in the environment for many years, they also accumulate in living systems.

The increased use of pesticides in Sudan is largely a response to the needs of a growing population. Sudan's population was 33.98 million in 2011, reaching 42 million in 2018 and estimated at 44.4 million in 2020. It is expected to reach 57.28 million by 2030 (Central Bureau of Statistics 2018). The extra demand for vegetables, cereals, meat and milk products, coupled with a gradual decrease in available farmland due to the encroachment of the Sahara Desert, has resulted in more intensive agriculture and a greater use of fertilizers and pesticides.

Sudan's annual use of pesticides is estimated at 5,000 tonnes, of which 2,500 to 3,000 tonnes are imported (Ministry of Agriculture and Forestry 2018). Sudan's pesticide imports make up 5 per cent of Africa's pesticide imports and 10 per cent of the Arab region's (Omer 2017) (Table 7.1).

Table 7.1 Pesticide imports (2011–2017)

Type	2011	2012	2013	2014	2015	2016	2017
Solid (kg)	1,328,780	1,360,432	315,093	510,094	367,146	604,807	73,129
Liquid (l)	4,412,163	5,644,570	4,523,380	6,308,925	4,518,397	6,689,012	7,376,679
Aerosol (unit)	2,237,708	2,281,792	1,339,300	1,736,584	1,532,560	1,494,120	1,393,096
Mosquito repellent (unit)	8,634,240	1,848,960	2,895,070	1,018,500	2,909,878	1,552,203	6,522,624

Source: Ministry of Agriculture and Forestry 2018

7 Persistent Environmental Issues

Besides Gezira, pesticide use is widespread in other large state-owned farming schemes such as those run by Rahad Agricultural Corporation, New Halfa Agricultural Corporation and Elsuki Agricultural Corporation. Recently, several cotton-producing companies have started using insecticides and herbicides in traditional rain-fed agriculture in Gedaref and Damazin. Farmers in Kordofan state are mainly concerned with controlling desert and migratory locusts to protect the hashab trees (the gum arabic-producing tree, *Acacia senegal*), though they also use pesticide in powder form to protect the sesame crop from locusts. The Desert Locust Control Organization for East Africa (DLCO-EA), which coordinates locust control in East Africa and is based in Red Sea state, has overseen the spraying of large quantities of insecticide every year for more than 40 years (UNIDO 2012).

Between 1945 and 1956, insecticides were applied using sprayers mounted on tractors and trucks. Spraying by fixed-wing aircraft was introduced in the 1950–51 season, and by 1966–67 all the insecticide spraying on cotton and wheat was carried out by aerial spraying. Herbicides continue to be applied by tractors (Musa 2014).

Many of the pesticides used in Sudan have had serious negative consequences. DDT (*Dichlorodiphenyl-trichloroethane*), which accumulates in ecosystems and has toxic effects on many vertebrates, was introduced in 1945 (HCENR/UNIDO 2014); it was banned, along with dieldrin, in 1981 (El Hindi 1994). Several other long-lasting chemicals have been used, including many (like DDT and dieldrin) that contain persistent organic pollutants (POPs), toxic substances that are now globally restricted. Until the early 1990s, the Blue Nile and White Nile Corporations used pesticides that contained POPs. The Sudanese sugar company, Kenana Sugar Company, was a major user of POP-pesticides to control termites (Musa 2014).

Storage facilities for pesticides in Sudan are generally inappropriate, including storage of persistent organic pollutant pesticides. The facilities belong to the Plant Protection Directorate, agricultural schemes, Agriculture Bank and private companies. Many of them are in disrepair and located close to irrigation channels or residential areas, including Samrab Store in Khartoum



A container in Gezira State containing sachets with remains of Ficam W (Bendiocarb). Photo credit © Osman Ali



Plastic bags and cartons filled with sachets with residues of Ficam W (Bendiocarb) in Sinja, Sinnar State. Photo credit © Osman Ali

7 Persistent Environmental Issues

North locality, and Qurashi store area, Hesaheisa stores and Bayeda stores in Gezira state (Bashir 2013). Others are not protected against flooding, such as Awaad stores in Kassala state. At Hesaheisa stores in Gezira state, pesticides have been found leaking into the environment (HCENR/UNIDO 2014).

7.3.1 Persistent organic pollutants

POPs can be carried great distances by air and water and remain in the environment for many years without breaking down. They have adverse effects on the environment and on human health, causing cancer, endocrine disorders and disruption of the immune system. The Stockholm Convention on Persistent Organic Pollutants, which was signed in 2001 and came into force in 2004, imposes a worldwide ban on the production and trade of twelve POPs. These are known as the dirty dozen and include aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex and toxaphene (Stockholm Convention 2004). Since then the Stockholm Convention has added more pesticides to the banned list, including chlordecone, alpha hexachlorocyclohexane, beta hexachlorocyclohexane, lindane, pentachlorobenzene and endosulfan (UNEP 2011).

Most of the POPs restricted by the Stockholm Convention were widely used in Sudan. Aldrin was used until the 1970s to treat seed and soil, chlordane from 1948 to 1988 for termite control, dieldrin between 1950 and 1970 as a substitute for DDT to control insect pests, and endrin as an insecticide and a rodenticide (HCENR/UNIDO 2014). Alder-T and deidre-B were used to protect cotton and sorghum seed from insects and fungi. The control of rats, mice and birds was mainly achieved with poisoned baits containing endrin.

Although the country has banned most POPs, endosulfan – the oldest chemical registered in Sudan – continues to be used to control pests on a variety of crops including coffee, cotton, rice, sorghum and soybeans (see Table 7.2). Lindane is still used for

controlling ectoparasites such as ticks on livestock, and onion farmers use it to control thrips and cutworms and to protect faba beans from store pests (HCENR/UNIDO 2014).

Sudan used to produce some of these pesticides itself; currently it produces none (Ministry of Agriculture 2018). In 1963, Shell Chemicals established a formulation plant to produce insecticides such as endrin, DDT, dieldrin and toxaphene for the agricultural schemes at Marinjan and Wad Medani (HCENR 2014). The plant stopped production in 1991 (HCENR 2007). An investigation revealed that soil and groundwater near the plant had been contaminated with POPs and other pesticides produced there (HCENR 2014). The plant and the incinerator were dismantled and scrapped, and the contaminated soils were removed in 2007 (HCENR 2007).

POPs have a serious impact on the endocrine systems of vulnerable and highly exposed populations, including farmers, children and young women of child-bearing age. Unborn children are at risk too, since POPs can be transferred to the foetus via breast milk, causing developmental problems. POPs also affect the reproductive health of men.

There is plenty of evidence that these chemicals are taken up by humans. Research carried out in 1994 in 11 areas of limited or intensive pesticide use in Sudan detected DDT, heptachlor epoxide and dieldrin in human blood samples (Elbashir 1998). The study found that blood levels of these pesticides were highest for those living or working in irrigated cotton schemes (average 260.63 ppb), where huge amounts of these pesticides were used up to 1981, followed by sugarcane schemes (204.0 ppb), traditional rain-fed areas (55.11 ppb), and riverine areas (55.13 ppb). Blood levels of DDT and other organo-chlorines decreased with increasing distance from irrigated cotton schemes. The highest concentration of DDT (617.94 ppb), heptachlor epoxide (170.23 ppb), HCH (91.66 ppb) and dieldrin (82.00 ppb) were observed in blood samples collected from Medani, Hesaheisa and Kenana.

Table 7.2 Recent Endosulfan imports in litres

Year	2011	2012	2013	2014	2015	2016
Quantity	465,000	262,600	0	18,800	0	70,000

Source: Pesticide Registration Office 2018

7 Persistent Environmental Issues

The adverse effects of POPs on the environment have been well studied. These chemicals can remain in the soil and water for many years. Babiker et al (1998) found significant amounts of endosulfan, DDT, nitrogen and 2,4-D (2,4-dichlorophenol) in soil and water around the Qurashi store area and Hesaheisa stores in Gezira state. Elmahi (1996) found high levels of DDT, heptachlor and dieldrin in irrigated cotton soils in Gezira. Dieldrin and heptachlor have been detected in the soils of sugarcane schemes, and aldrin, dieldrin and heptachlor in the riverine soil of northern Sudan. The longer POPs persist in the environment, the more likely they are to be taken up by living organisms, where they accumulate in fatty tissues as toxic substances.

7.3.2 Obsolete pesticides and wastes

Sudan has a large volume of obsolete pesticides, defined as being banned, degraded, damaged, past their expiry date, unidentified or otherwise unfit for use (FAO 2001). Between September 2004 and March 2005, Sudan's Higher Council for Environment and Natural Resources (HCENR) carried out a national inventory of the obsolete stocks, empty containers and contaminated soil at pesticide storage sites

across various states, under the National Implementation Plan for the Stockholm Convention. The inventory found 234 tonnes of obsolete pesticides at 341 sites. It also found 528 tonnes of empty contaminated containers, 8,850 tonnes of contaminated soil (Musa 2014) and about 400 tonnes of seeds dressed with banned pesticides.

A separate inventory of agricultural scheme stores across the country, carried out in 2013 by the Plant Protection Directorate, uncovered about 600 tonnes of pesticides, 90 tonnes of which were POPs. 6000 m³ of soil around these stores was found to be contaminated.

Storage of the stockpiles is generally poor, with different pesticides often piled together. Most obsolete pesticides in the irrigation schemes were found stored in the open, with no labels on containers or with labels that were unreadable. Some of the drums were broken and rusted due to exposure to harsh weather conditions and dust (Butrous et al. 1998).

Tables 7.3, 7.4 and 7.5 show the locations and quantities of pesticide wastes, contaminated soils and empty pesticide containers around the country, which altogether exceed 600 tonnes (Butrous et al 1998).

Table 7.3 Distribution of obsolete pesticides

Location	Liquid (l)	Solid (kg)	Solidified (kg)	Contaminated soil (m ³)	Empty drums
Plant Protection Department	176,240	102,419	16,730	1,135,32	868
Blue Nile Schemes	1,000	—	---	---	---
White Nile Schemes	1,700	—	---	225,00	---
Suki Scheme	1,850	4,900	—	---	---
Rahad Scheme	50,023	4,80	72,340	180,40	964
New Halfa Scheme	21,040	-	9,540	128,80	684
Gezira Scheme Board	152,661	25,692	4,604	4,879,00	5,530
Chemical Companies	15,404	—	—	---	---
Customs Department	1,617	16	—	---	---
Total	421,535	137,917	108,218	6,548.52	8,046

Source: Butrous et al. 1998

7 Persistent Environmental Issues

Table 7.4 Obsolete pesticides and contaminated soil in stores

Location	Liquid (l)	Solid (kg)	Solidified (kg)	Contaminated soil (m ³)	Empty drums
Khartoum HQ	2,350	35,380	-	34,00	-
Khartoum State Samarb & Khogalab	7,835	3,336	-	237,00	-
Dongola Debba, Merwi & Dongla	37,129	12,875	2,470	3,50	147
Damer	13,380	2,575	4,420	5,67	72
Berber	11,406	3,490	1,200	0.24	36
Shendi	9,294	6,662	240	0.21	28
Swakin	28,245	-	1,300	0.45	125
Sinkat	5,005	-	-	-	72
Kassala	19,790	2,876	2,000	-	50
Gedaref	9,955	3,474	5,100	36.25	45
Medani	6,000	2,220	-	-	-
Sennar	400	260	-	28.00	34
Kosti	7,067	8,300	-	-	-
Dueim	-	495	-	-	-
Damazin	10,120	8,008	-	90.00	259
El Obeid & Semeih	2,775	725	-	700.00	-
Kadugli	-	2,885	-	-	-
Abu Gibeiha	2,300	-	-	-	-
El Maryam	1,300	-	-	-	-
Nyala	-	8,858	-	-	-
El Genaina	1,889	-	-	-	-
Total	176,240	102,419	16,730	1,135,32	868

Source: Butrous et al, 1998

7 Persistent Environmental Issues

Table 7.5 Obsolete pesticides and contaminated soil at irrigation schemes

Location	Liquid (l)	Solid (kg)	Solidified (kg)	Contaminated soil (m ³)	Empty drums
New Halfa Scheme New Halfa HQ & Sabaat, Um Rahaw & Shebeik	21,040	–	9,540	128.80	684
Rahad Scheme HQ	50,023	40,890	72,340	180.40	964
Suki Scheme HQ	1,850	4,900	–	–	–
Blue Nile Scheme El Khayare	1,000	–	–	–	–
White Nile Scheme Dueim	1,700	–	–	225.00	–
Gezira Board Sscheme Barakat, Massalamia, Hasaheisa, Wad Habouba, Kab El Gidad, Wad El Mansi, Taboub & Wad Eltorabi	152,661	25,692	4,608	4,879.00	5,530
TOTAL	228,274	35,482	86,482	5,413,2	7,178

Source: Butrous et al 1998

7.3.3 Pesticides management

The Pesticides Act was passed in 1974 to limit the intensive use of pesticides. It was amended in 1994 to become the Pesticides and Pests Control Products Act. Through the National Pesticides Council, the Act regulates all activities relating to the registration, importation, storage, transportation, use and formulation of pesticides in Sudan. Seven bylaws have been derived from the Act. These are:

1. Trading and organization of the commercial handling of pesticides and pests control products bylaw (2006);
2. Organization of storage and transport of pesticides and pests control products bylaw (2006);
3. Importation of pesticides and pest control products bylaw (2002);
4. Registration of pesticides and pests control products bylaw (2002);
5. Inspection of pesticides and pests control products bylaw (2002);
6. Protection of personnel dealing with pesticides and pests control products bylaw (2002);
7. Formulation of pesticides and pests control products bylaw (2000).

The National Pesticides Council is a multidisciplinary council with representatives from all relevant institutions including the ministries for Agriculture, Health and Animal Resources, research institutions, customs bodies, universities, the Sudanese Agro-chemicals Association, the HCENR and the Sudanese Standards and Meteorology Organization. The National Pesticides Council is responsible for registering and evaluating pesticides and pest control products; approving the recommendations of the technical committees on the agricultural, veterinary and health effects of these products; licensing their manufacturing, processing, trade or disposal; and prohibiting or restricting their use.

The National Pesticides Council is one of many governmental and non-governmental organizations involved in the trade, registration, handling, storage and use of pesticides in Sudan. Others include:

- ➔ The Plant Protection Directorate is concerned with plant protection and ensures the availability of quality pesticides for crop production (Ministry of Agriculture 2009).
- ➔ The National Malaria Administration is responsible for malaria control efforts (El Hindi 1994).

7 Persistent Environmental Issues

- ➔ The Sudanese Agro-chemical Association is the national association of private pesticide importers. It provides technical information and training and awareness for retailers and distributors of agro-chemicals (Ministry of Agriculture 2009);
- ➔ The HCENR is responsible for the country's environmental protection policy. It tackles issues to do with POPs, including monitoring their management and phase-out (HCENR 2008);
- ➔ The Sudanese Standards and Meteorology Organization oversees the development of the country's standards and ensures conformity with them. The organisation also seeks to protect consumers' health and safety from unsafe goods, including pesticides;
- ➔ The Customs General Administration is responsible for ensuring that only registered products, including pesticides, can enter the country. The import of pesticides requires an importation license from the office of the registrar, a certificate of origin and an analysis certificate from an independent laboratory recognized by the Sudanese Standards and Meteorology Organization.

The country also has many research institutes that study all aspects of pesticide use, including agricultural entomology, plant pathology, bird pests,

tsetse entomology, mosquito entomology, pesticides toxicology and environmental pollution (Ministry of Environment, Natural Resources and Physical Development 2009).

7.3.4 Policy response measures

Sudan signed the Stockholm Convention in 2004 and ratified it in 2006. In 2007 it published its National Implementation Plan, which provides details of the strategies and actions required to meet the country's obligations under the convention. The plan was updated in 2013, when Sudan considered issues such as the effects of POPs exposure on vulnerable and highly exposed populations, socio-economic aspects of food and water safety measures, the treatment of contaminated materials and the cost of remediation for contaminated soil and sites. In response to its obligations under the Stockholm Convention, Sudan has banned or severely restricted a number of pesticides, as shown in Table 7.6.

As part of Sudan's efforts to reduce its stock of obsolete pesticides, the National Pesticides Council began analyzing expired pesticides in 2014 to determine whether they were fit for use. In 2015,

Table 7.6 Banned or severely restricted POPs pesticides

Name of Chemical	Response Level	Details of Restriction (e.g. reason for control action, remaining allowed uses)
Aldrin Dieldrin Chlordane Chlordimeform Heptachlor	Severe restriction	Hazardous substance. Responsible for a number of poisoning incidences and deaths. To be used only for the control of termites – "white ants" – in dead wood.
DDT	Severe restriction	Development of resistance in agricultural pests. To be used only in the control of public health pests.
Lindane	Severe restriction	The Gamma isomer is the only effective part of lindane and can be used for the control of insect pests. The other constituents of lindane are injurious.
Methyl Parathion	Severe restriction	To be used only in mixture with other pesticides.
Monochrotophos	Severe restriction	Hazardous substance. To be used only for the control of cotton pests.
HCH mixed isomers	Banning	Registered in Sudan. Later was banned.

Source: HCENR/UNIDO 2014

7 Persistent Environmental Issues

the National Pesticides Council, in collaboration with the Sudanese Port Corporation, cleared the country's seaports of all leftover pesticides. The Council has also developed a system with the Custom General Administration that ensures the quick release of pesticides entering the country, and for the management of leftovers (pesticides not licensed to enter the country and those that are licenced but not claimed and collected by the importers).

7.4 SOLID WASTE

The management of solid waste – characterized as any unwanted solid material from residential, industrial or commercial sources – represents a major challenge to the municipal administrations in Sudan. Waste management practices must be sustainable and support good human health, a clean environment and economic growth.

The rapid growth in Sudan's population, especially in urban areas, has led to an increase in the quantity and types of municipal solid waste, as shown in Table 7.7. Despite the great efforts by many municipalities to address waste management issues, there are still problems in some areas with the non-collection or poor disposal of waste, including hazardous waste. Most hazardous waste in Sudan is from industry, healthcare institutions, pesticides or electronic goods. Hazardous waste can have grave consequences for human health and the environment. To deal with this, Sudan needs a national integrated waste management strategy and legislation that covers waste generation, collection, transportation, recycling, reuse and disposal.

7.4.1 Waste production and streams

Waste production in Sudan is increasing not only because of population growth, but also because average consumption among Sudanese is growing. Average per capita household consumption expenditure increased from \$1,000 in 2011 to \$1,140 in 2016 (World Bank 2017), representing a jump of 8 per cent over five years. One consequence of this is an increase in the amount of waste produced, especially in urban settlements. Waste management is particularly poor for those Sudanese who live within or on the outskirts of the state capitals or in the crowded camps for refugees and internally displaced persons.

Municipal solid waste

The urban areas of Sudan generate all forms of waste, including household, industrial, health and agricultural waste. In most cases, the amount of waste generated is too much for local authorities to deal with. For example in 2016, Khartoum generated 6,600 tonnes of solid waste a day, of which 4,200 tonnes was collected (Azubair 2016).

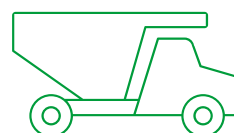
Sudan's 42 million people each generate an average of 0.5 kg of waste a day (Ministry of Environment and Physical Development 2018), resulting in 7.67 million tonnes of waste a year for the whole population (Central Bureau of Statistics 2018). In 2006, the Ministerial Committee on Waste estimated the efficiency of the country's waste collection services at 33 per cent. This has not changed much, which implies that 5.1 million tonnes of waste are left uncollected each year. As a result, it is common for waste to accumulate within residential areas and on vacant land. Some of the waste that is not collected is informally recycled with few safety measures, which puts citizens and workers at risk.

Waste a year (in million tonnes)

Generated
7.67



Capacity to collect
5.10



The quantity and diversity of waste are major problems for Sudan's authorities. Toxic products from landfill sites can leach into groundwater, while the natural decomposition of waste can produce explosive gases such as methane. Waste attracts cockroaches, flies and rodents, and waste collection sites are fertile feeding and breeding grounds for insects and other carriers of communicable diseases, to say nothing of their appalling smells and displeasing aesthetics. Accumulation of waste on streets and around community bins is a threat to health and hygiene, and storm water drains are often clogged by solid waste. Open burning is a problem at some waste disposal sites, which exposes residents to air pollution.

7 Persistent Environmental Issues



Exposed municipal solid waste in El Fashir, North Darfur State. Photo credit © UNEP

Box 7.1: Waste Management in Khartoum state

During 2004-2005, Khartoum state conducted a survey of solid waste management in seven localities, with the assistance of the Japan International Cooperation Agency (JICA). The survey concluded that there was no adequate system of waste collection. It established that 5,000 tonnes of waste was generated per day in Khartoum state (JICA 2013). The collection rate at the time of the survey was 65 per cent, implying that 3,200 tonnes was collected every day.

In 2016, another survey established that waste generation in Khartoum state had increased to 6,600 tonnes per day, of which 4,200 tonnes was safely disposed of at four landfill sites (Azubair 2016). In areas without a collection service, waste was left scattered, leading to foul odours, a proliferation of harmful insects and a deterioration in hygiene.

Khartoum state has three waste collection sites from which waste is transferred to landfills. Teba transfer station in Khartoum locality serves Khartoum and Jebel Awlya localities; Abo Weledat transfer station in Omdurman locality serves Um Badah, Omdurman and Karary localities; and Hattab transfer station in Bahari locality serves Khartoum Bahari and Sharg Elneel localities. The four landfill sites in Khartoum state include three for municipal solid waste from Omdurman, Bahri and Khartoum, while the fourth, in Omdurman near Dongla Street, is mainly for hazardous waste. While waste is received daily at all sites, it is not covered with soil as it should be because of a lack of equipment, resulting in some of it being scattered and burnt (Ali 2011).

Khartoum's waste management is regulated by the state's Environmental Protection Law of 2008. Meanwhile the state's master plan for waste management, which was prepared in 2013 (Khartoum state Cleansing Authority 2016), aims to raise waste collection efficiency to 90 per cent by 2028.

Following two surveys conducted by JICA in 2013, Khartoum state invested in additional compactors, containers, bulldozers and excavators to help it develop its capacity for waste collection and disposal and improve hygiene at the sites. It was estimated that the move would benefit 6.27 million people living in Khartoum state.

7 Persistent Environmental Issues



Japan International Cooperation Agency (JICA) has implemented a project for improvement of solid waste management in Khartoum state. Photo Credit ©Bushra Jabalabi



Open burning of domestic waste exposes residents to air pollution. Photo credit © UNEP

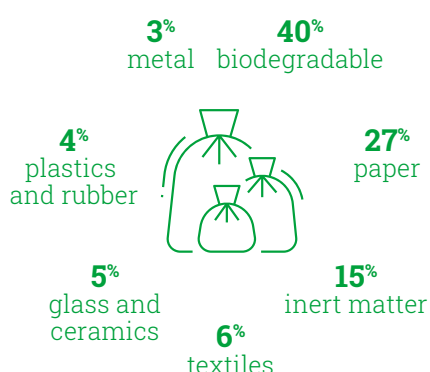
7 Persistent Environmental Issues



Waste pickers at the main Khartoum landfill site. Waste management is problematic throughout Sudan. Photo credit © UNEP

Sudan's waste composition includes 40 per cent biodegradable (food and agriculture), 27 per cent paper, 15 per cent inert matter (waste such as sand and concrete that is neither chemically nor biologically reactive and will not decompose or only very slowly), 6 per cent textiles, 5 per cent glass and ceramics, 4 per cent plastics and rubber, and 3 per cent metal (UNDP 2015). Some waste is recycled, including newspapers, plant material, scrap metal and plastics. Recycling rates are lower in rural areas due to the logistics and costs of collection and transportation. Overall, the country's solid waste disposal facilities are inadequate. Most landfill sites do not have necessary equipment such as loaders and trucks, and most of them do not meet sound engineering standards.

Waste composition



Plastic waste

One of the major innovations of the past century has been the introduction and wide adoption of plastics for many day-to-day products that previously relied on traditional materials such as wood, stone, leather, metals, glass, cotton and ceramics. Plastics are generally safe for human beings, cheap and widely available, and can have many different applications.

The increased demand for plastic products has resulted in more plastic waste in solid waste streams in Sudan and elsewhere. Most plastics are durable and degrade very slowly. They remain in the environment for long periods, blocking water drainage systems and harming livestock and birds when consumed. Some plastics are thrown or washed into rivers and end up in the oceans.

Thermoplastics, which are recyclable, constitute 80 per cent of all plastic waste generated in Sudan (Energy and Waste Treatment Services Company 2016). 148 factories in Sudan are involved in the production of plastic items (Ministry of Industry 2018), and most of them recycle plastic waste. Furthermore, some local authorities such as in Gedaref and Khartoum states have made it illegal to use plastic bags. However, the failure to segregate plastic waste, the absence of organized systems for waste collection, and the poor economic value in low-grade plastics make plastic waste management a challenge in Sudan.

7 Persistent Environmental Issues

Table 7.7 Estimated amount of solid waste generated by states (2017)

State		Blue Nile	Gedaref	Gezira	North Darfur	Northern	North Kordofan	Red Sea	River Nile	South Kordofan	White Nile
Municipal Solid Waste (MSW) Generation (t/y)		561,200			7,200	511	1,316	5,306,498	835,6	922,000	713,6262
Per Capita MSW Generation (kg/day)	Urban Areas	0.5	0.8		0.6	0.6	1	0.38	0.75	0.5	0.6
	Rural Areas	0.5	0.6		0.6	0.6	0.5	0.38	0.75		
Generation of Other Types of Solid Waste *(t/y)	Agricultural	117	100		20	0	33		46	150	
	Industrial	3	23		20	30	100		8	5	
	Medical	17	4		60	70	143		70	20	
Collection System Coverage (%)	Urban Areas	40	25		25	35	64	70	35	20	50
	Rural Areas	16	10		0	0	14	30	1	5	--
Type of Collection System (%)	Door to Door	30			100	100	29.3	50	15	20	90
	Container	81	15				27	50	4	60	5
	Other	31					20		81	20	4
Machinery	Trucks	2 (3 t)	23 (2.5 t)	1 (10 t)		4 (2 t)	Truck (8 t) container (21 t) Container (16 t)	2 Trucks (7M) 3 Back loaders	9 (3-10 t) 2 car (supervisor)		6 (5-8 t)
	Tractor with trolley	4 (5 t)	15 Tractor	1 tractor (6 t)		8 (3 t)	Tractor (4 t)	41 tractors (3 t)	29 (3-5 t)		5 (4 t)
	Compactor	(5 t)	3 (3 t)	compactor (8 t)		19 (5 t)	compact or (16 t)	2 compact or (8 m) compact or 4 (16 m)	4 (12 t)		
Collection Frequency	Urban Areas	Twice a week	Twice a week	Weekly		Daily	Once a week	Twice a week	Once a week	Twice a week	Once a week
	Rural Areas	Twice a week	Once a week	Monthly		Daily	Once a week	Twice a week	Once a week		Once a week
	Markets	Daily	Twice a day	Daily		Daily	Twice a week	Twice a day	Twice a day	Daily	Once a day
No. of Workers		73	225	–		201	283	480	262		490
Collection Time for covering all the routes (hours)		8	14	–		6	3-4	18	4-6	15	18

Source: Ministry of Environment and Physical Development 2018 *(t/y) = tonne/year



A collection site of plastic waste in Khartoum State. Photo credit © Abdelrahman Al Khalifa



A plastic recycling factory in Khartoum State. Photo credit © Takreer Recycling

7 Persistent Environmental Issues

Industrial waste

Despite efforts to reduce the amount of waste in manufacturing – for example through environmental standards and product stewardship schemes – almost 80 per cent of Sudan's industrial waste ends up in landfills (Azubeir and Abdelhalim 2012).

The industrial sector is the main source of hazardous waste. Sudan is still in the early stages of adopting cleaner manufacturing and production policies and more effective waste disposal measures for hazardous waste (El Hassan 2012). For example, the failure to allocate specific disposal sites for hazardous waste means it is often disposed of without treatment and in non-designated places.

Another common type of industrial waste produced in Sudan are polychlorinated biphenyls (PCBs), a group of organic compounds which are classified as POPs. Most PCBs are chemically inert liquids. They are

widely used as electrical insulating fluids, hydraulic fluids, lubricating fluids and carbonless copy paper, and are also found in transformers and capacitors (HCENR/UNIDO 2014). The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal lists PCBs as one of 12 POPs requiring special attention. All PCBs used in Sudan are imported. Table 7.8 shows the number of PCB-containing transformers and capacitors by state.

In recent years, there have been several big cases of industrial waste spilling into the environment in Sudan. These include the accidental spill of 500 tonnes of molasses from North West Sennar Sugar factory into the Blue Nile in March 2006, which resulted in a major fish kill (Abdel Magid and El-Hassan 2006), and the leak of 100,000 litres of liquid organochlorine into the soil at Rabak Cement Factory (Abdel Magid and El Hassan 2006).

Table 7.8 Number and locations of condensers and capacitors containing PCBs

State	25 KV A	50 KA A	100 KV A	200 KV A	250 KV A	300 KV A	400 KV A	500 KV A	630 KV A	750 KV A	1000 KV A	1250 KV A	1600 KV A	2500 KV A	To- tal- No.
Khar- toun	0	17	16	23	0	19	1	42	1	16	47	1	4	0	187
North & East Sudan	1	4	6	10	1	5	1	8	1	1	9	1	0	0	48
Darfur	0	1	3	2	0	1	0	0	0	0	0	0	0	0	7
Kor- dofan	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Central Sudan	0	0	0	4	0	3	1	2	0	2	1	0	0	0	13
Total	1	22	25	39	1	28	3	52	2	19	57	2	4	0	255

Source: HCENR 2014



Untreated effluent flows from sugar factories to water courses is a major source of industrial pollution. Photo credit © UNEP

Medical waste

Medical wastes are considered hazardous because they contain materials that can be toxic or infectious. Medical wastes may be made up of any of the following categories:

- ➔ Infectious waste, which constitutes material that may contain pathogens such as bacteria, viruses, parasites or fungi in sufficient concentration or quantity to cause disease in susceptible hosts. Infectious waste may also include waste contaminated with blood or other body fluids, cultures and stocks of agents from laboratory work, and waste from infected patients in isolation wards (WHO 2004);
- ➔ Sharp items such as needles, hypodermic needles, scalpels, blades, knives, infusion sets, saws, broken glass and pipettes that can cause cuts or puncture wounds;
- ➔ Pathological waste, consisting of tissues, organs, body parts, blood, body fluids and other anatomical material from surgery and autopsies on patients. Pathological waste may also include human foetuses and infected animal carcasses (UNEP 2003);
- ➔ Pharmaceutical waste, which includes expired, unused, spilt or contaminated pharmaceutical products such as vaccines and sera that are no longer required and, due to their chemical or

biological nature, need to be disposed of carefully. The category also includes heavily contaminated discarded items (WHO 2013).

Compared with other waste, medical waste contains a much higher percentage of polyvinyl chloride, which is used in intravenous bags and tubing, blood bags, collection and specimen bags, anaesthesia masks, examination gloves, catheters, feeding tubes, dialysis tubing, sharp containers, bed pans, inflatable splints and patient identification bracelets.

In Sudan, the amount of medical waste is growing rapidly due to the increase in population and the spread and expansion of healthcare services in all states. The major sources are hospitals, clinics, laboratories and research facilities.

The main treatment processes for medical wastes are autoclaving, microwaving, chemical disinfection, irradiation, plasma system and incineration (Wolper 1995). Incineration, which is a suitable treatment for most types of medical waste, has several advantages, including volume reduction of the waste and the destruction of pathogens and hazardous organic matter (Vesilind et al 2002). In Sudan, the infrastructure for the treatment and disposal of medical waste is very limited, and much of it ends up in landfill sites (UNDP 2015).

7 Persistent Environmental Issues



Exposed medical waste in North Darfur. Photo credit © UNAMID

Sanitation and sewerage systems

Sewage is wastewater and comes mainly from homes. Much wastewater in Sudan is discharged onto land or into water without being suitably treated. Some industries dispose of their wastewater in open ponds. The discharge of sewage effluent provides ideal conditions for the breeding of malaria mosquitoes, houseflies and other insect disease vectors. About 80 per cent of the diseases reported in Sudan are water-borne (Khadam 2017).

Sudan Multiple Indicator Cluster Survey of 2014 revealed that 70 per cent of the urban population and 63.5 per cent of the rural population have access to safe drinking water (Central Bureau of Statistics and UNICEF 2016). Only 39.9 per cent has access to sanitation facilities such as pit latrines or flushed toilets, and there is a stark urban-rural divide, with 63.2 per cent in urban areas having access compared with 23.6 per cent in rural areas (Khadam 2017). About 10 per cent of those with access to sanitation facilities use the improved 'wet' systems with septic tanks and aqua-privies (Khadam 2017). Disposal of effluents from septic tanks and aqua-privies has serious environmental impacts on water resources through pollution of shallow and deep-water boreholes.

Access to drinking water



70%
of the urban
population

63.5%
of the rural
population

Most industrial plants do not have dedicated water treatment facilities. Effluent is typically released either into the sewerage system or directly into water or onto land. Many industries dump their waste directly into the Nile River. Places such as Khartoum North, Wad Medini and Port Sudan are particularly at risk of pollution from industry (Box 7.2) (El Hassan 2012). Certain industries generate large amounts of wastewater, including tanneries, sugar production, oil production and metal fabrication (Table 7.9). One positive development is that a few large enterprises such as Kenana Sugar Company and some oil companies have installed or are in the process of installing wastewater treatment plants of their own.

7 Persistent Environmental Issues

Table 7.9 Wastewater output of major industries in Sudan (Abdel-Magid and El Hassan 2006)

Industry	Location	Estimated flow in m ³ /d	Waste treatment	Disposal site
Sugar	Elgenaid	–	None	Blue Nile
	Elgirba	–	None	Atbara River
	Kennana	22440	None	White Nile
	Sennar	27072	None	Blue Nile
	Assalaya	–	None	White Nile
Tannery	Khartoum Wad Medani	71	Partial activated sludge	Soba S.P. Blue Nile
Textile	Khartoum	–	None	Elhaj Yosuf S.P*.
	El Hassahisa	40	–	On site, near Blue Nile
	Wad Elhadad	–	None	On site, near Blue Nile
Refinery	Elgaili	1050	–	On site
Oil and soap	Khartoum	10	None	Elhaj Yousif S.P. Soba S.P.
Power plants	Khartoum	–	None	Blue Nile
	Sennar	–	None	Blue Nile
Dairy	Khartoum	–	None	On site
Food	Khartoum	–	None	On site local S.P.

S.P.: Stabilization ponds

Box 7.2: Industry and environmental problems in Khartoum State

Khartoum's sewage infrastructure, which began operating in 1959, was designed to serve 80,000 people with an estimated consumption rate of 150 litres per person per day. It served 11.75 km². The project consisted of a pipe network of 168 km, with pipe diameter ranging from 150 to 700 mm. There were 1,861 manholes, 16 lifting and pumping stations and Al-Guoz sewage treatment plant. Al-Guoz was designed to treat 12,500 m³ per day, but due to the expansion of the served area and the increase in population the amount of wastewater eventually exceeded the capacity of the station.

In 2004, Khartoum's sewage network and pumping stations were rehabilitated and the new Soba treatment plant was built. The new system consists of 303 km of pipes of sizes ranging from 175 to 800 mm diameter, 20 lifting and pumping stations, waste stabilization ponds with a capacity of 28,000 m³ per day, and a wastewater treatment plant with a capacity of 40,000 m³ per day. There are plans to build a sewerage pipeline to transfer treated wastewater effluent from the Soba plant to the Soba cattle breeding plant.

The new system covers the area of Khartoum Centre, Khart 2 and 3, Amarat and Industrial Area, between Nile Street to the north and Street 61 Alamarat to the south. The network has been extended by adding the following areas in the city of Khartoum: Eastern Deum – Garden City – Presidential Villas – International University of Africa – Arquette block 65 – Kenana Market and the United Nations – Durrat Al Lamb Network- Al Nassr Residential complex – AlWaha Tower.

7 Persistent Environmental Issues



Domestic sewerage treatment pumps in Khartoum State. Note the residential area in the background and the cropped area in the front. Photo credit © UNEP

The government is striving to provide basic safe water and suitable sanitation for everyone. Due to the excessive cost of installing centralised sewerage systems for large towns, authorities have been opting for decentralized systems that cover selected zones. For example, there is an ongoing project to build a decentralized sewerage system for the old central districts of Omdurman, with a capacity of about 10,000 m³ per day (Tahir 2017). Decentralized systems have also been installed for Al Muhandseen and Academic Complex, with a capacity of 5,500 m³ per day; Al Manshia, with a capacity of 4,500 m³ per day; and Thawra Hara, with a capacity of 2,000 m³ per day.

7.4.2 Waste management

Efforts to improve Sudan's waste management system face many challenges. The most important are the lack of an integrated waste management system; inadequate regulations to limit industrial and hazardous waste; the absence of a waste sorting system; poor infrastructure; the lack of data on waste quantities, types and characteristics; the high cost of waste collection, transportation and landfill; low levels of environmental awareness; and poor household

practices when dealing with municipal solid waste. Various pieces of legislation are in place to promote good waste management. The 2001 Environment Protection Act is the umbrella law on environmental issues. The Public Health Act, amended in 2008, is designed to protect the general health of individuals. The Environmental Health Act, amended in 2009, seeks to ensure that the environment is kept in a state that supports human, plant and animal life through the provision of basic necessities such as clean water, clean air and proper waste management. These federal laws are supported by state-level laws such as the 2008 Khartoum State Environmental Protection Law.

Various public awareness and education campaigns are being rolled out with the aim of reducing the amount of waste that reaches landfills by 25 per cent by 2030. The campaigns also seek to increase the level of recycling to 40 per cent by 2030, to promote waste separation at source, and to develop standards for packaging materials (Energy and Waste Treatment Services Company 2016). Universities and research centres are also playing a role, including the development of waste treatment technologies such as waste-to-energy and composting.

7.5 CONCLUSION

Desertification, pesticides and waste are some of the persistent environmental issues that Sudan needs to address to conserve its environment and protect the health of its people.

Desertification is a major environmental problem, exacerbated by population growth, poverty, the clearance of vegetation cover, overgrazing, mechanized farming, recurrent drought and fluctuation in rainfall and temperature. The situation has been made worse by the independence of South Sudan, which resulted in the loss of pasture and the overgrazing of the remaining rangelands, and by climate change, which has ushered in more arid conditions.

Desertification results in reduced land productivity, increased migration, the loss of biodiversity and increased poverty. In response, the government has established the National Council for Combating Desertification, the Institute of Desertification and Desert Cultivation Studies, the UNESCO Chair of Desertification, and a station for desert research. A number of shelter belts and reforestation plots have been planted in different areas of Sudan.

Despite these efforts, along with Sudan's ratification of the UNCCD and the development of its National Action Plan to Combat Desertification in 2006, the problem is getting worse. The extent of the issue is hard to assess due to the scarcity of historical data. As well as remediation efforts, such as afforestation programmes as detailed in the National Action Plan, more monitoring is essential to map ecological changes and the susceptibility of the environment to desertification.

Unlike desertification, pesticide contamination is entirely a human-made problem. Sudan has been using pesticides since 1941 to combat plant diseases and pests, secure food supplies for the growing population and conserve human and animal health through vector control. The use of pesticides has negative impacts on human health and eco-systems. Human exposure to pesticides is primarily through residues in food and drinking water. The most serious issues with pesticides relate to the use of POPs, which persist in the environment for many years, and stockpiles of chemicals which deteriorate and leak into the soil and water, endangering the health of people and wildlife.

The management of all types of waste – solid municipal, medical, industrial and wastewater – is a major challenge in Sudan. Population growth, increased urbanization and the growing market in consumer goods has led to an increase in waste volumes, so that existing waste management systems can hardly cope. Solid waste management in most areas of Sudan is inefficient, with inadequate procedures for collection, sorting, transportation, recycling and disposal. There is no system for proper wastewater treatment and disposal except in limited districts of the capital Khartoum.

In addition to upgrading Sudan's waste management systems, the government should encourage the private sector to invest in recycling (e.g. production of energy from waste) by introducing supporting legislation and regulatory mechanisms such as concessional loans. It is also essential to raise public awareness about the importance of reducing consumption, and of recycling and reusing waste.

References

REFERENCES

1. Abdel Magid, I. M and El-Hassan, B. M. (2006). The Effects of Industrial Pollutants on Water Resources in the Sudan. In I. M. Abdel-Magid (Ed.). *Selected Papers in Environmental Engineering*. 1, 262–272. Sudan Academy of Sciences.
2. Abhilash P. C., Singh N. (2009). Pesticide use and application: An Indian scenario. *Journal of Hazardous Materials*, 165, 1–12. Retrived from: <https://doi.org/10.1016/j.jhazmat.2008.10.061>
3. Abusalma, E. A., Elhassan, A. M., Erami, M. and Salghi, R. (2014). Pesticides Residues: Endosulfan and DDT in cows' milk in Gezira State, Sudan. *Morocco. Journal of Chemistry*, 2 (3), 125–135. Retrived from: <http://repo.uofg.edu.sd/handle/123456789/3277>
4. Abuswar, A. O and Darag, A. (2002). Study for integration of production and processing of forage in Arab region. Sudan case. Arab Organization For Agricultural Development.
5. Ali, O. M. (2011). Environmental Impact Assessment of the Proposed Omdurman Landfill Project, *Institute of Environmental studies*, University of Khartoum.
6. Ali, M.M. and Bayoumi A.M. (2004). Assessment and mapping of desertification in western Sudan using Remote Sensing techniques and GIS. International Conference on Water Resources and Arid Environment.
7. Ayoub, A. T. (1998). Extent, severity and causative factors of land degradation in the Sudan. *Journal of Arid Environment*, 138, 397-409. Retrieved from: <http://dx.doi.org/10.1006/jare.1997.0346>
8. Azubair, W. Abdalhalim, A. (2016). *City Sanitation Plan of Khartoum*- IIT Rookee Publisher: Alternative Hydro Energy Center.
9. Bashir, N. (2017). Pesticides waste in the Sudan, presentation at the National Research Council Workshop on Chemicals Waste, Holiday Villa Hotel, Khartoum.
10. Butrous, M. G., Eltigani, T. A. and Sanad, A. A. (1998). Report on the Inventory of Obsolete and Unwanted Pesticides Stocks, Contaminated Soils and Empty Containers.
11. 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=W1siZiIsIjIwMTYvMDUvMTg0MjEvNTkvNTEvODg3L1N1ZGFuXzlwMTRfTU1DU19FbmdsaXNoLnBkZiJdXQ&sha=32907fc39e6e2e6e>
12. Central Bureau of Statistics (CBS) (2018). Population number, census and projected estimates.
13. Dawelbait, M. and Morari, F. (2012). Monitoring desertification in a Savannah region in Sudan using Landsat images and spectral mixture analysis, *Journal of Arid Environments*, 80, 45–55. Retrieved from: DOI: 10.1016/j.jaridenv.2011.12.011
14. Desert Encroachment Control and Rehabilitation Programme (DECRP) (1976). Sudan's Desert Encroachment Control and Rehabilitation Programme. The General Adm. for Natural Resources, Min. of Agr. Food & Natural Resources and The Agr. Res. Council, National Council for Res. in coll. with UNEP, UNDP and FAO, 227 pp.
15. Edris O. H. A., Dafalla M. S., Ibrahim M. M. M. and Elhag A. M. H. (2013). Desertification Monitoring and Assessment In Al-Butana Area, Sudan, Using Remote Sensing And GIS Techniques. *International Journal of Scientific and Technology Research*. 2, (3), 181-184. Retrieved from: <http://www.ijstr.org/paper-references.php?ref=IJSTR-0313-5955>
16. Elbashir, A. M. (1998). Organochlorine insecticides levels in human blood samples collected from residents in areas of limited and intensive insecticides use in the Sudan. Sudan: M.Sc. Thesis, Faculty of Agriculture, University of Khartoum.
17. Elhag, A. M. H., Adam, A. H, M. and Elsheikh, A. R. (2014). Desertification Assessment, using Remote Sensing, GIS and other Techniques. Case study: Wadi Al Kanger, Sudan. *Journal of Natural Resources & Environment Studies* 2 (3), 1-6. Retrieved from: <http://researchpub.org/journal/jonares/number/vol2-no3/vol2-no3-1.pdf>
18. 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, Khartoum, Sudan.

19. Elnour, A. B. (2017). Socioeconomic characteristic of water resources and sanitation facilities in Sudan. In A. M. Salih. (Ed.). *Water Resources of Sudan, Water resources of Sudan*, chapter 20 (1st ed., pp. 496-514). University of Khartoum.
20. Eltoum, M. A, Dafalla, M. S. and Ibrahim, I. S. (2015). The Role of Ecological Factors in Causing Land Surface Desertification, the Case of Sudan. *International Journal of Agriculture and Ecology Research*. 4 (3), 105-116. Retrieved from: https://www.researchgate.net/publication/279726144_The_Role_of_Ecological_Factors_in_Causing_Land_Surface_Desertification_the_Case_of_Sudan
21. Energy and Waste Treatment Services Company (EWTSCO) (2016). Report on plastic waste in Khartoum State.
22. 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: International symposium and Workshop. Combating Desertification: Connecting Science with Community Action. Tucson, Arizona, USA.
23. Food and Agriculture Organization (2001). Farmer Self-Surveillance of Pesticide Poisoning Episodes: Report on a One Month Pilot: August 15-September 15, 2000. FAO Programme for Community Integrated Pest Management in Asia, Field Document.
24. Food and Agriculture Organization of the United Nations (FAO) and United Nations Environment Programme (2012). Land cover in Sudan, FAO, Sudan. Retrieved from: <http://www.fao.org/3/a-be896e.pdf>
25. Food and Agriculture Organization and United Nations Environment Programme (1984). Map of Desertification hazards: explanatory note. Nairobi, Kenya.
26. Forest National Corporation (1995). Forest National Corporation, Department of Management Annual Report. Khartoum, Sudan: Forest National Corporation.
27. Glover, E. K. (2005). Tropical dryland rehabilitation: Case study on the participatory forest management in Gedaref, Sudan. Doctoral Dissertation. University of Helsinki, Tropical Forest Report No. 27. Helsinki: Hakapaino Oy. Retrieved from: <https://researchportal.helsinki.fi/en/publications/tropical-dryland-rehabilitation-case-study-on-participatory-fores>
28. Hano. A. I. (2013). Assessment of Impacts of Changes in Land Use Patterns on Land Degradation/Desertification in the Semi-Arid Zone of White Nile State, Sudan, by Means of Remote Sensing and GIS. Ph.D. thesis. University of Khartoum. Retrieved from: <http://shura.shu.ac.uk/19184/1/10694064.pdf>
29. Hano, A. I. and Csaplovics, E. (2014). Monitoring and Modelling Vegetation Cover Dynamic And its Linkage With Human Activities and Climate Variation in Semi-arid Zone, Sudan by Means of Remote Sensing and in Situ. in Proceedings of Conference on Global Monitoring and Modelling Vegetation, France.
30. Harrison. N. M. and Jackson, J. K. (1958). Ecological Classification of the Vegetation of the Sudan. Forests Bulletin, 2, Agricultural Publications Committee, Khartoum.
31. Higher Council for Environment and Natural Resources (2007). Shell Chemical Pesticides Formulations. Plant Dismantling and Soil Excavation Report. Maringan, Gezira State.
32. Higher Council for Environment and Natural Resources (2008). National Capacity Self-Assessment. Report and Action Plan (NCSA)
33. Higher Council for Environment and Natural Resources /United Nations Industrial Development Organization (2014). National Implementation Plan (NIP) for Stockholm Convention 2005.
34. Hellden, U. (1988). Desertification Monitoring: Is the Desert Encroaching? *Desertification Control Bulletin* 17, 8–12.
35. Ibrahim, F. N. (1978). The problem of Desertification in the Republic of the Sudan with Special Reference to Northern Darfur Province. Monograph Series, 8. Development Studies and Research Centre (SRC). Faculty of Economic & Social Studies, University of Khartoum.
36. International Fund for Agricultural Development (2001). Desertification as global problem. Paper produced on conference of the parties, Cop. V. Document number WFS FS03.1–12 Oct; (2001). Geneva, Switzerland.
37. Japan International Cooperation Agency (2013). Project for Improvement of Solid Waste Management in Khartoum State Report. Retrieved from: <https://www.jica.go.jp/sudan/english/activities>

38. Kassas, M. (1995). Desertification: a general review. *Journal of Arid Environments* 30 (2), 115–128.
39. Khadam, M. A. (2017). Water, Health and Sanitation Nexus. In A. M. Salih (Ed.). *Water Resources of Sudan* (1st ed., pp. 387-360). Water Reserach Center, University of Khartoum.
40. Khairalseed, A. R. (2015). Desertification in Sudan, concept, causes and control. *ARPJ Journal of Science and Technology*, 5(2), 87–91. Retrieved from: <http://www.indiaenvironmentportal.org.in/files/file/Desertification-Sudan.pdf>
41. Khartoum State (2016). Ministry of Urban Planning and Infrastructure. Soba Stabilization Ponds Plant records 2016.
42. Klemas, V. (2011). Remote Sensing of Wetlands: Case Studies Comparing Practical Techniques. *Journal of Coastal Research*, 27, 418–427.
43. Laki, S. L. (2009). Desertification in the Sudan: causes, effects and policy options. *International Journal of Sustainable Development and World Ecology*. 1(3), 198–205. Retrieved from: DOI: 10.1080/13504509409469874
44. Lamprey, H. F. (1975). Report on the desert encroachment reconnaissance in northern Sudan, 21 Oct. to 10 Nov., 1975. UNESCO/UNEP. (mimeo.), 16 pp.
45. Lonergan, S. (2005). The role of UNEP in desertification research and mitigation. *Journal of Arid Environments*. 63(3), 533-534. Retrieved from: DOI: 10.1016/j.jaridenv.2005.03.001
46. Mariam, A. M. (2019). Detecting and Mapping Important Vegetation Species and their Role for Sand and Sand Dunes Stabilization Based on Geospatial Techniques in Semi-Arid Zone, M.Sc. Thesis. University of Khartoum.
47. Middleton, N. J. and Thomas, D. S. G. (1997). (Eds.). *World Atlas of Desertification*, (2nd Ed, pp 182). Publisher: Edward Arnold, New York. Retrieved from: [https://doi.org/10.1002/\(SICI\)1096-9837\(199903\)24:3<280::AID-ESP955>3.0.CO;2-7](https://doi.org/10.1002/(SICI)1096-9837(199903)24:3<280::AID-ESP955>3.0.CO;2-7)
48. Ministry of Environment and Physical Development. (2007). Sudan National Implementation Plan for the Stockhom Convention on Persistent Organic Pollutants (POPs).
49. Ministry of Environment, Natural Resources and Physical Development (2009). Ministerial Committee on Waste Report. Ministry of Environment, Natural Resources and Physical Development.
50. Ministry of Agriculture and Forestry (1999). Towards the National Action Plan to Control Desertification. (Unpublished). Sudan
51. Ministry of Agriculture and Forestry (2006). Sudan National Adatation Plan: A Framework For Combating Dsestrification In Sudan in The Context of The United Nations Convention To Combat Desertification.
52. Ministry of Environment and Physical Development (2018). Waste Generation R ate Per Person Per Day.
53. Ministry of Agriculture and Forestry (2017). Number of pesticides formulation companies, registrar office records. National Pesticides Council.
54. Ministry of Agriculture and Forestry (2018). Pesticides Registration Office, National Pesticides Council, Plant Protection Directorate (PPD) Mohamed, M. A. and Bayoumi, M. (2004). Assessment and Mapping of Desertification in Western Sudan Using Remote Sensing Techniques and GIS. International Conference on Water Resources and Arid Environment.
55. Mohamed, N. A. H., Bannari, A., Fadul, H. M. and Zakieldeen, S. (2016). Ecological Zones Degradation Analysis in Central Sudan during a Half Century Using Remote Sensing and GIS. *Advances in Remote Sensing*, 5, 355–371. Retrieved from: <https://doi.org/10.4236/ars.2016.54025>
56. Mohamed, T. A. (2016). Monitoring and Analyzing of Desertification Trend in North Sudan Using MODIS Images from 2000 to 2014. Illinois, USA: Department of Geography and Environmental Resources, Southern Illinois University Carbondale.
57. Musa, K. G. (2014). Pesticides Management in Sudan presentation at SSMO workshop on sound management and disposal of pesticides.
58. Omer, S. E. (2015). Safe Use of Pesticides, Sudanese Standard and Metrology Organization Workshop on Import, storage, handling and use of pesticides and fertilizers, Friendship Hall, Khartoum.

59. Ouma, G. O. and Ogallo, L. A. (2007). Desertification in Africa. Retrieved from: <http://profiles.uonbi.ac.ke/gouma/publications/desertification-africa>
60. Purkis, S. and Klemas, V. (2011). *Remote Sensing and Global Environmental Change*. Wiley – Blackwell. New Jersey USA.
61. Salih, A. M. (1996). The geographical extend of desertification in Sudan. *Al-Buhuth Scientific Journal*, 5, 18–40.
62. Salih, A. M. (2007). Action Pogrammes for Combating Desertification. Published by: UNESCO Chair of Desertification University of Khartoum, Sudan.
63. Salma, A. (2016). Mapping and Assessing Desertification Status and its Impact on Socio-economic Livelihoods in Western Omdurman, M.Sc. thesis. University of Khartoum.
64. Seedahmed, A. (2017). Features of Sudan efforts to combat desertification. Ministry of Environment, Natural Resources and Physical Development Council for Desertification workshop. July 2017 Khartoum Sudan.
65. Sharpe, R. (2009). Male Reproductive Health Disorders and the Potential Role of Exposure to Environmental Chemicals. Retrieved from: <http://www.chemtrust.org.uk/wp-content/uploads/ProfRSHARPE-MaleReproductive-Health-CHEMTrust09-1.pdf>
66. Stebbing, E. P. (1953). The Creeping Desert in the Sudan and elsewhere in Africa. McCorquodale and Co. (Sudan), Khartoum. Sudan. *Journal of Arid Environments*, 38, 397–409.
67. Tahir, A. M. (2017). Khartoum State Sanitary Corporation (KSSC) database
68. The International Union of Pure and Applied Chemistry (IUPAC) (2006). Pure and Applied Chemistry, Glossary of terms relating to pesticides. Retrieved from: <https://www.iupac.org/publications/pac/2006/pdf/7811x2075.pdf>
69. Thomas, D. S. G., and Middleton, N. J. (1994). *Desertification: Exploding the myth*. John Wiley and Sons, Chichester, England.
70. United Nations Convention to Combat Desertification. (1994). United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa.
71. United Nations Development Programme. (2015). Rapid Assessment: Healthcare Waste Component of Global Fund HIV/AIDS, TB and Malaria Projects in the Republic of the Sudan, Supplement to the HCWM Toolkit for Global Fund Practitioners and Policy Makers. Retrieved from: https://www.eurasia.undp.org/content/rbec/en/home/library/hiv_aids/rapid-assessment-health-care-waste-global-fund.html
72. United Nations Environment Programme. (2003). Technical Guidelines for Environmentally Sound Management (ESM) of Persistent Organic Pollutants (POPs) Wastes. Retieved from: <https://chm.pops.int/Portals/0/flash/popswastetrainingtool/eng.pdf>
73. United Nations Environment Programme. (2006). The Manual of compliance with and enforcement of multilateral environmental agreements. Retrieved from: <https://wedocs.unep.org/bitstream/handle/20.500.11822/7458/-Manual%20on%20Compliance%20with%20and%20Enforcement%20of%20Multilateral%20Environmental%20Agreements-2006743.pdf?>
74. United Nations Environment Programme. (2009). Sudan Environment Outlook 2009, prepared by Sudanese Team of the African Environment Information Network.
75. United Nations Environment Programme. (2011). Assessment of PCDD/PCDF release inventories-status 2011. Toolkit Update2. Retrieved from: http://www.chem.unep.ch/pops/pcdd_activities/inventories/Toolkit%20update%202_GIS%20inventoriespdf
76. United Nations Industrial Development Organization. (2012). Sudan Chemicals Management Profile, Currency Press Khartoum.
77. Vesilind, P. A., Worrell, W. A. and Reinhart, D. R. (2002). *Solid waste engineering*, Brooks/Cole-Thomson Learning, Pacific Grove, CA.

78. World Health Organization. (2014). Safe management of wastes from health-care activities. Retrived from: www.searo.who.int/.../safe_management_of_wastes_from_healthcare_activities.pdf
79. World Health Organization. (2015). Status of health-care waste management in selected countries of the Western Pacific Region.
80. Wolper, L. E. (1995). (Ed.). Health Care Administration: Principles, Practices, Structure, and Delivery. New York: Aspen Publication Inc.
81. World Bank. (2017). National accounts data, and OECD National Accounts data files. Retrieved from: <https://www.indexmundi.com/facts/sudan/household-final-consumption-expenditure-per-capita>



8

Emerging Environmental Issues

8.1 INTRODUCTION

Sudan is affected by many environmental issues including desertification, deforestation, loss of biodiversity, water scarcity, air and water pollution and pesticide contamination. While many of these issues are decades old, recently some new environmental problems have appeared that threaten to have a serious impact on the country. Examples include the use of mercury by artisanal miners, the growth in electronic waste, the proliferation of two-stroke engine vehicles (rickshaws) as a cheap means of public transport, and the use of polluting self-generated electricity by industries, rich households and markets.

Although the country has tried to address these problems within the current institutional and legislative framework, evidence suggests they are getting worse. There are growing calls for a more serious approach to tackling them, based on a comprehensive environmental management policy. This would mean, among other things, involving artisanal miners, rickshaw drivers and other groups in public awareness and training programmes to instill good environmental practice.

The successful management of these issues will improve not only Sudan's environment, but also its economy, the stability of its communities and the health and livelihoods of its people.

8.2 ARTISANAL GOLD MINING

In Sudan, the term "artisanal mining" is used to describe mining that is done using traditional means (El Samani 2015), with simplified, low-intensity forms of exploration, extraction, processing and transportation. Artisanal mining is principally done in pursuit of gold, though there is limited artisanal mining for other minerals such as chromite, limestone and salt.

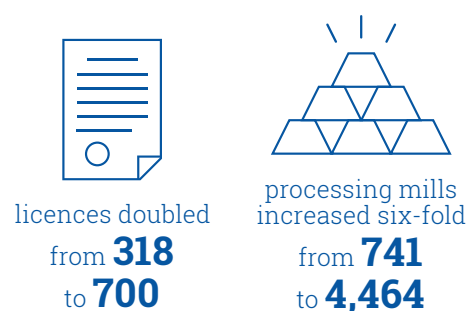
Artisanal gold mining is believed to have taken place as far back as the ancient Nepta and Kush civilisations around 1600 B.C. (Abbas 2014). The country has always been famous for its gold resources, which are relatively easy to exploit. Figure 8.1 illustrates different concessions of minerals, including gold, iron, copper, uranium and chromite, owned by Sudan's states, the Sudanese private sector and foreign companies. The yellow colour represents potential gold mines in the Northern and North-eastern parts of Sudan, Gedaref state, North and South Kordofan states, and southern

part of Blue Nile state (El Samani 2015). Gold mining has surpassed oil production in foreign currency earnings, and much of the earned foreign currency is used to import oil which the country used to export. Figure 8.2 shows gold mining areas across the country (El Samani 2015).

Since the 1990s, the introduction of metal detectors as an affordable technology for exploration has given a great boost to those working in artisanal mining. Artisanal miners can rent out these metal detectors, which cost not more than \$10,000 (Calkins 2014), on an hourly or daily basis. They are increasingly being used by artisanal miners in the north and east of the country. An Australian metal detector company in its 2016 annual report declared Sudan one of its biggest customers for hand-held metal detectors (Codan Limited 2016).

During the last five years, partly due to the popularity of these devices, Sudan has experienced a gold mining boom. The country started to export refined gold in 2012 and the Sudan Tribune reported that gold exports earned \$2.2 billion that year (Collins 2012). In 2014, gold mining licences more than doubled from 318 to 700, and the number of processing mills increased six-fold from 741 to 4,464. In addition, gold service licences exceeded one thousand in 2014 (Elsamani 2015).

Artisanal gold mining in 2014



About 80 per cent of gold discoveries in 2016 were made by artisanal miners, who operate not far from the concessions of licensed companies (Ministry of Minerals 2017). As Figure 8.3 shows, gold production by artisanal miners far exceeds that by big private and public companies. The output of artisanal miners reached a peak of more than 60 tonnes in 2014, which was six times the amount produced by the big private and public companies (Ministry of Minerals 2017).

8 Emerging Environmental Issues

Figure 8.1 Sudan mining concessions awarded to different international companies (El Samani 2015)

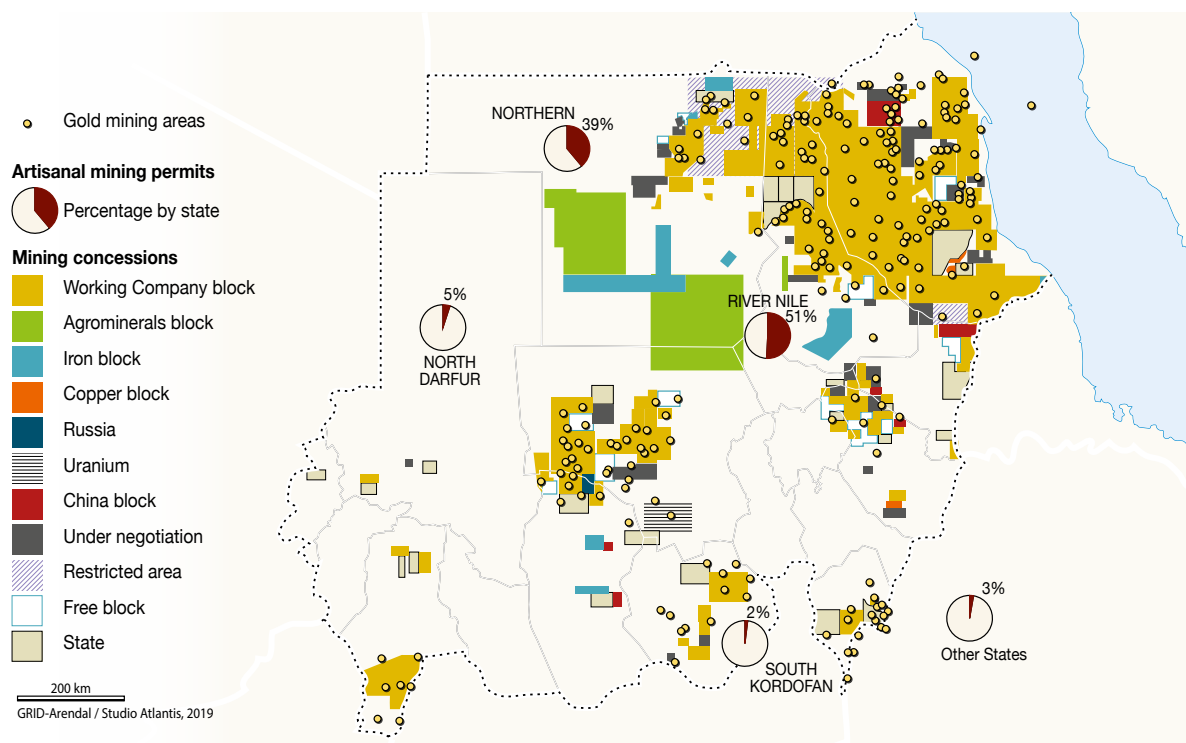
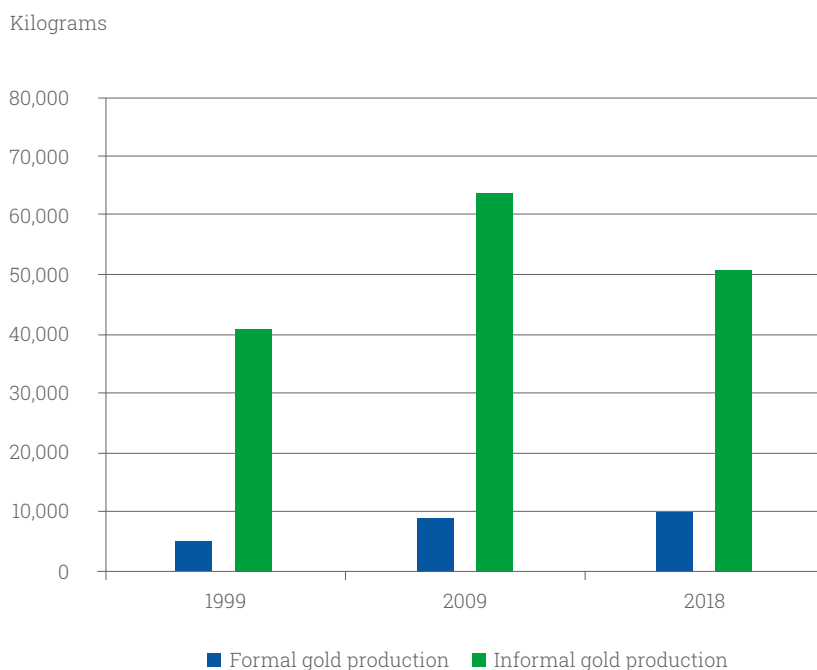


Figure 8.2 Gold mining territories in Sudan (El Samani 2015)



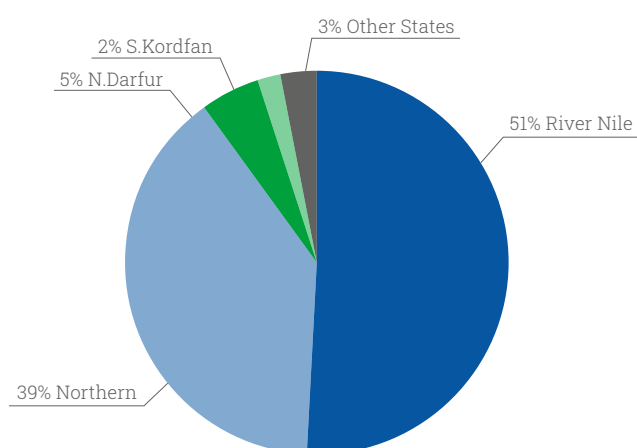
8 Emerging Environmental Issues

Figure 8.3 Gold production in Sudan 2013–2015 (Plotted from data from Ministry of Minerals)



Source: Ministry of Mineral Reports (2014 & 2015)

Figure 8.4 Share of artisanal mining permits by state in 2015 (Re-plotted from El Samani 2015)



Source: Re-plotted from El Samani 2015

Figure 8.4, derived from a survey by the Ministry of Minerals, shows the Proportion of artisanal mining permits granted by the states in 2015 (Ministry of Minerals 2017). The survey indicated that 90 per cent of artisanal miners are located in River Nile and

Northern states, and that they are working in just 20 sites out of the 221 surveyed. The popularity of these sites is thought to be due to the relative safety of northern states and the easy transportation and other logistics.

8 Emerging Environmental Issues

8.2.1 Mining policy

Due to the desperate economic situation in the country following the secession of South Sudan in 2011, Sudan relaxed its minerals policy to encourage the production of minerals, attract investment in the mining sector, and increase foreign currency earnings from minerals, especially gold (Ministry of Minerals 2017). In 2012, the Ministry of Minerals issued regulations on artisanal mining that covered issues such as registration, environmental protection and the selling of gold to the Bank of Sudan. Several other national laws are relevant to artisanal mining, including the Labour Act (1997), Environmental Protection Act (2001), Environmental Health Act (2009), Child Act (2010), and Minerals Wealth Development and Mining Act (2015).

In addition, Sudan is committed to international conventions such as the Minamata Convention on Mercury (2013), the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989), the International Labour Organisation's Worst Forms of Child Labour Convention (1999), the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (1998), and the Bamako Convention on the Ban on the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa (1991).

The policy of making the Bank of Sudan the sole official buyer of gold from artisanal miners has

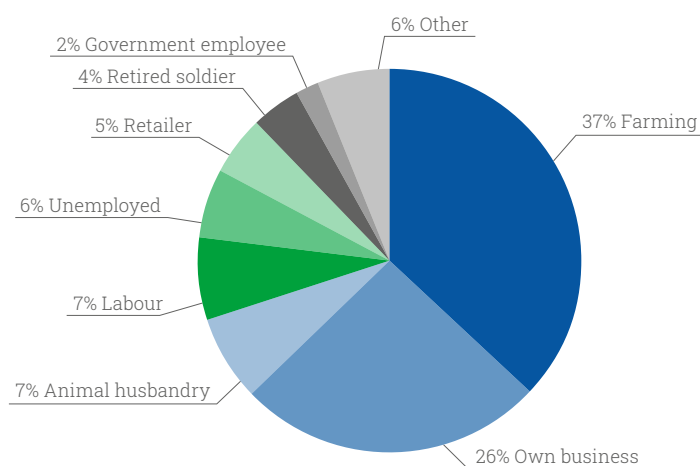
encouraged some miners to seek international prices for their gold, which are generally higher. One study concluded that 34 per cent of the gold produced by artisanal miners in 2016 was smuggled out of Sudan (Onour 2018). Gold is smuggled from state to state; the highest smuggling rates are out of states affected by war, such as South Kordofan and Darfur, and states with easily accessible borders such as Northern and Red Sea. This practice is made easier by weak enforcement of laws governing natural resources management.

8.2.2 Gold mining demographics

Nearly one million Sudanese people work in the artisanal gold mining industry (El Samani 2015). Over the years, gold mining has attracted farmers, workers and students at the expense of their respective trades. Studies by the Ministry of Minerals in 2014 and 2015 showed that 37 per cent of artisanal gold miners were farmers and 27 per cent were private business owners who had left their original jobs in search of quick wealth. It is possible to earn ten times more from gold mining than from farming or other professions (El Samani 2015).

Figure 8.5 depicts the earlier occupations of artisanal miners who switched from their original professions (El Samani 2015). Artisanal gold mining does not much affect unemployment figures since only 6.5 per cent of the unemployed find jobs in this profession (El Samani 2015). However, the loss of labour is thought to have a negative impact on the agricultural sector.

Figure 8.5 Previous occupations of artisanal gold miners (El Samani 2015)



Source: Ministry of Mining 2015

8.2.3 Mercury threat

After grinding and washing the gold ore, artisanal miners use mercury to extract the metal from soil and sediment. The mercury and gold combine together to form an amalgam; this is then heated, releasing the gold and vaporizing the mercury. Being exposed to mercury vapour during this process can have serious health effects and lead to brain damage, cancers and respiratory diseases. A recent study found that mercury played a role in 2,000-3,000 cancer cases and a 30 per cent increase in respiratory diseases in the Abu Hamad area during 2011-2017 (Ibrahim 2018).

Mercury is also damaging to the environment. Mercury vapour is released into the atmosphere and recycled into lakes and rivers. It remains in the environment without being broken down and is taken up by fish and other organisms and passed along the food chain.

Gold miners use large quantities of mercury. One study stated that two to three tonnes of mercury are

required to extract one tonne of gold (Appleton and Williams 1998); another put the ratio at 1.3:1, meaning that 83 tonnes of mercury would be required to produce 64 tonnes of gold (Ibrahim 2015). In more recent research, Ibrahim showed that each treatment cycle loses between 3.87 and 4.91 per cent of mercury by weight (Ibrahim 2018); the implication is that this mercury escapes into the environment (Mine Engineer 2012).

Although trade in mercury is banned under the Minamata Convention, a huge amount of mercury is imported into Sudan for use by artisanal gold miners or en route to neighbouring countries such as Chad and the Central African Republic (Figure 8.6). About 60 to 100 tonnes of mercury pass through Sudan to other countries. Most mercury imports into Sudan come from China and Hong Kong (UNEP 2017). The European Union exported 35.8 tonnes of mercury to Sudan from 2005 to 2011 (Zettl et al. 2015), and 79 tonnes in 2015 (Lassen et al. 2016).



Grinding of crushed rocks by artisanal miners causes a dual hazard from dust and grinder's exhaust. Photo credit © Osman Ali

8 Emerging Environmental Issues



Mercury is used to extract gold from the powdered ore rocks. Photo credit © Awad Siddeg



The manual wet processing where mercury and gold combine to form an amalgam. Photo credit © Awad Siddeg



The sieving to get the amalgam. Photo credit © Awad Siddeg



Open heating of the amalgam where mercury sublimes directly to the atmosphere. Photo credit © Awad Siddeg



The final reward. Photo credit © Osman Ali

Emerging Environmental Issues

Figure 8.6 Mercury imports to sub-Saharan Africa 2010–2015 (after Lassen et al. 2016)

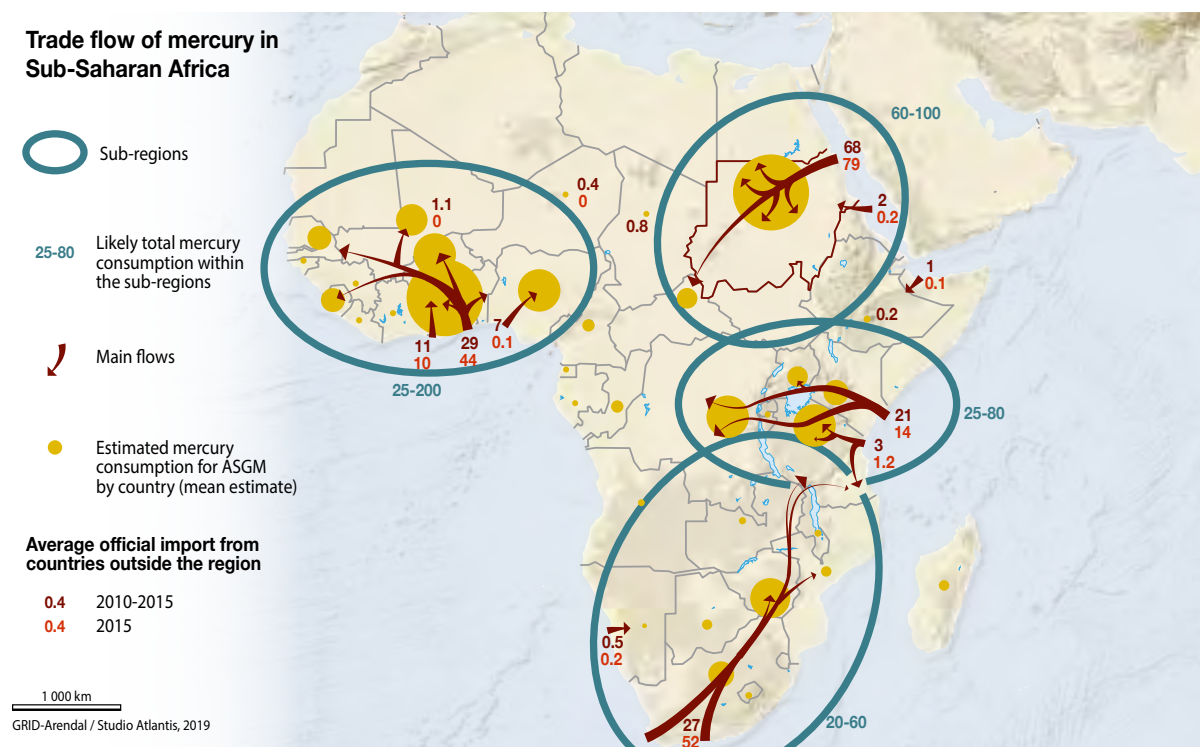
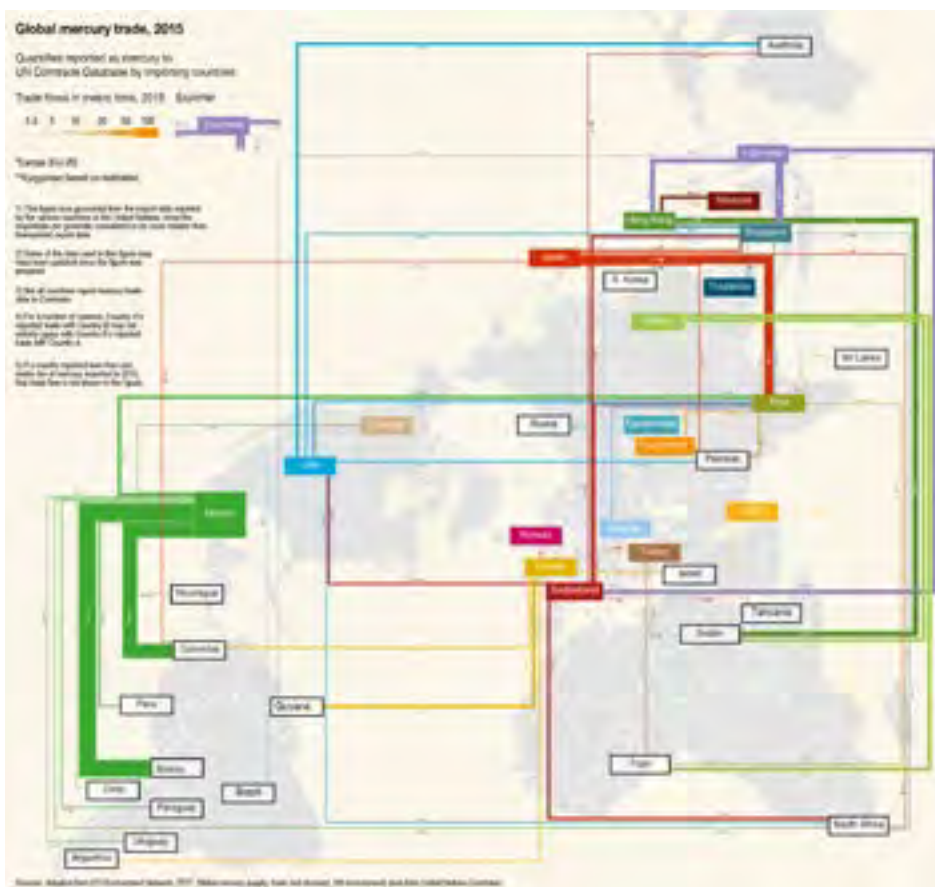


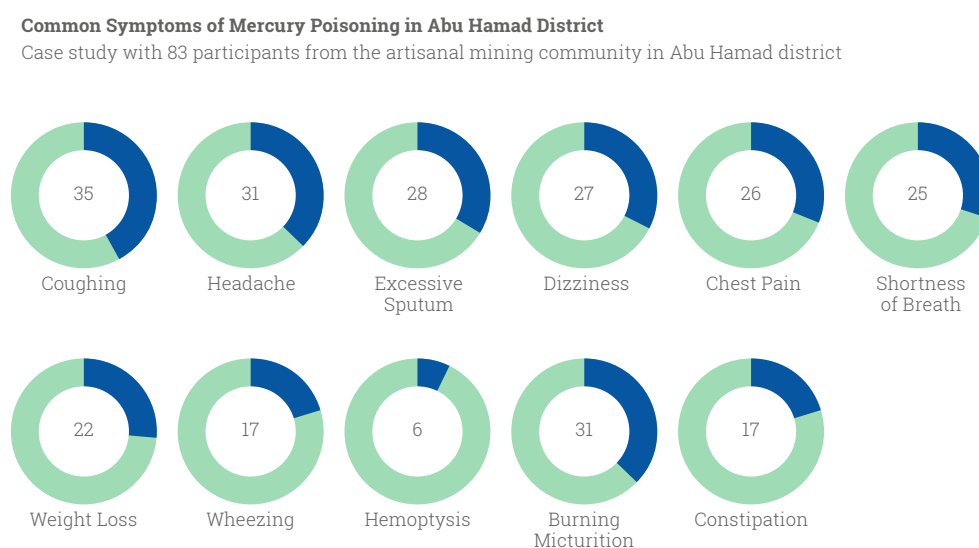
Figure 8.7 The global mercury trade (UNEP 2017)



Box 8.1: Case Study

Between December 2012 and January 2014, a team from Al-Rabat University tested the effect of mercury exposure in 83 artisanal miners in Abu Hamad district in Sudan. The miners were aged 18-55 and had been working in artisanal mining for more than six months. They reported a range of health problems, as shown in Figure 8.8. The serum mercury level in the gold miners was 24.9 mg per litre, compared with 1.4 mg per litre for an unexposed control group (Tyrab et al. 2016).

Figure 8.8 Number of miners with clinical symptoms



Source: Tyrab et al. 2016

In 2017, Sudan's Ministry of Minerals, in cooperation with relevant states, started a public awareness campaign to inform artisanal miners of the dangers of using mercury and encourage alternative ways of extracting gold, such as panning, sluicing or the use of centrifuges. New regulations were brought in to restrict the import of mercury. The ministry also encouraged the establishment of mining cooperatives as a way of pooling resources and investing in safer means of processing gold (Ministry of Minerals 2017). In most states in Sudan, gold mining is still unregulated. It is hoped that more will be done to encourage miners to stop using mercury and adopt practices that are safer and less environmentally damaging.

8.2.4 Other impacts of artisanal mining

Besides these human health and environmental hazards, artisanal mining has broader socio-economic impacts. Vast tracts of land that were once pastoral and agricultural have been transformed into mining areas, especially in the Gedaref area in eastern Sudan. Not only has the land been lost to farming, but farmers have abandoned their traditional way of life to hunt for gold. Furthermore, the popularity of gold mining has resulted in an influx of treasure-hunters from different parts of the country, as well as from neighbouring countries in West and East Africa. The effects of this on local communities is not known.

8 Emerging Environmental Issues

In the Butana region, the social and environmental impacts of gold mining have been well studied. They include a shortage of agricultural labour, and substantial negative environmental effects. Pollution of soil, air, rangelands and haffir water has become a major health hazard for humans and animals. New diseases previously unknown in the area have also been reported. Another consequence is the proliferation of weapons and criminal activities, including animal thefts. The price of land has risen dramatically, and violent conflicts over rights of access to land are becoming common.

Although there is no data on the impact of gold mining on migratory birds in Sudan, there is a potential threat from the open tailing ponds where cyanide is used to extract gold.

8.3 ELECTRONIC WASTE

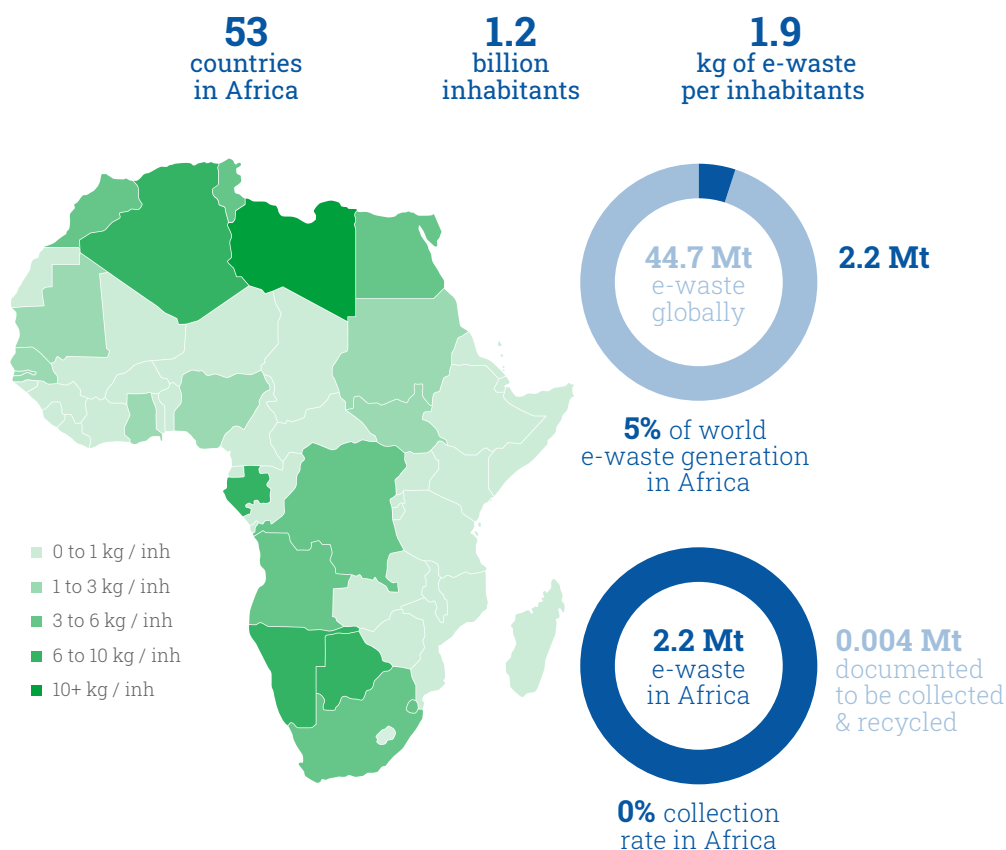
Obsolete or defective electronic equipment, or e-waste, is one of the fastest growing waste streams in the world. In developed countries, it averages one per cent

of all solid waste. Global production of e-waste was estimated at 44.7 million tonnes a year in 2016 (Baldé et al. 2017). E-waste includes electrical appliances, communication devices, sat navs, and any products with a battery or plug (Baldé et al. 2017). Imports of used or low-quality electronic devices may also be classified as e-waste.

The average amount of e-waste produced per capita in Sudan is estimated at between three and six kg per year, as shown in Figure 8.9 (Baldé et al. 2017).

The absence of any sort of segregation during the collection and disposal of solid waste in Sudan makes it difficult to quantify the amount of e-waste in the overall waste stream, and there is no information about the amount that finds its way to landfills. An inventory of the e-waste stream in Khartoum state in 2010 found that by far the most common item was electric lamps, which made up 61 per cent of the total by weight, as shown in Table 8.1 (Gamma 2012). Computers and mobile phones together represented less than 16 per cent.

Figure 8.9 Electronic waste in Africa (Baldé et al. 2017)



8 Emerging Environmental Issues

Table 8.1 Quantities of e-waste in Khartoum state per year (Gamma 2012)

Equipment	Weight (tonnes)	Stock of equipment (2010)		Flow of waste/year
		%	Weight of waste	% of waste
Refrigerator	3938.577	31.12	393.86	14.48
TV	2048.352	16.19	204.84	7.53
Computer	1151.642	9.10	287.91	10.58
Mobile	198.921	1.57	132.61	4.87
Lamp	4975.254	39.31	1658.42	60.96
Iron	342.335	2.71	42.79	1.57
Total	12,655.08	100.00	2720.43	100.00

An investigation into e-waste in Greater Khartoum in 2010 (some of the results of which are depicted in Table 8.2) made the following observations (Alamin 2010):

- ➔ A large volume of unused electronic and electrical equipment is stored in official institution stores, company stores and repair and maintenance workshops;
- ➔ Only a small proportion of this e-waste ends up in landfill;
- ➔ Waste is not segregated at any stage of waste management.

A 2013 survey estimated the number of mobile phones in use in Sudan at between 27 million and 36 million (Said 2014). The mobile phone market is growing fast, and phones are quickly replaced with new models. It is not clear where the old mobiles end up. A mobile phone is considered essential, especially among the young: for a student who passes an exam, the most desirable gift would likely be a new mobile. Professionals such as plumbers, carpenters, car mechanics, electricians and public transportation drivers would find it difficult to do their job without one. Mobile phones are also becoming an efficient, fast and trustable means for transferring cash, for example between parents and their children who are at universities in distant parts of the country.

8.3.1 Mobile phones

Mobile phones were first introduced into Sudan in 1997. Since then mobile phone ownership has grown quickly. A 2010 study into mobile phone subscribers in the Arab region ranked Sudan sixth out of 22 countries (Figure 8.10) (Allam 2010).

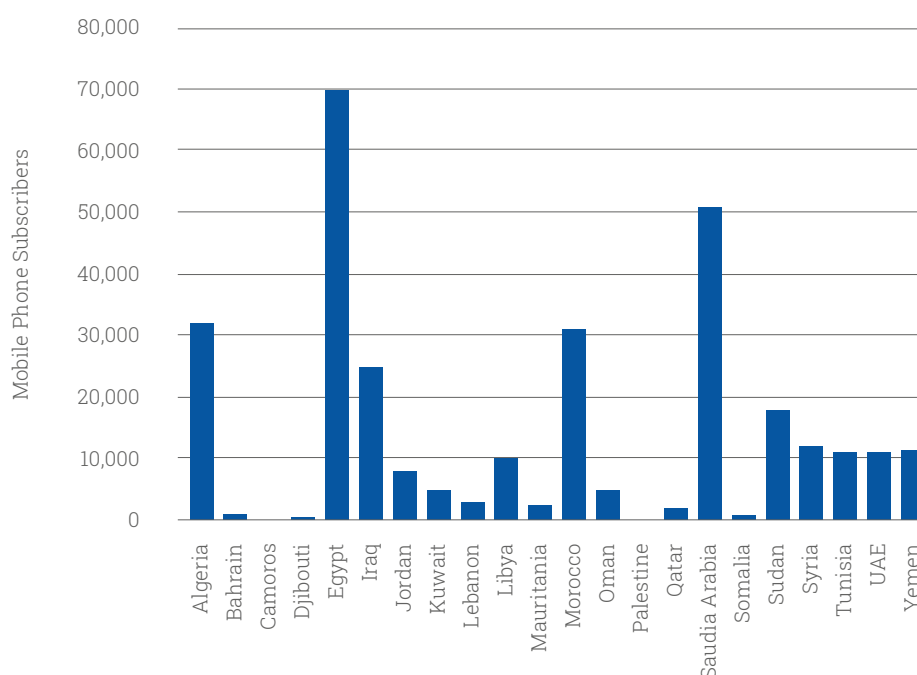
8 Emerging Environmental Issues

Table 8.2 shows the results of a study predicting the growth in e-waste by appliance type in Greater Khartoum from 2010 to 2020 (Alamin 2010).

Table 8.2 Projection of e-waste flow in Greater Khartoum (tonnes/year) 2010–2020 (after Alamin 2010)

Equipment	Refrigerator	TV	Computer	Mobile	Total
2010	393.86	204.84	287.91	132.61	1010.42
2011	433.25	225.32	316.70	145.87	1121.14
2012	274.63	245.8	345.49	159.13	1025.05
2013	512.02	266.28	374.28	172.39	1324.97
2014	551.41	286.76	304.07	185.65	1327.89
2015	590.80	307.24	431.86	198.91	1528.81
2016	630.18	327.72	460.65	212.17	1630.72
2017	669.57	348.20	489.44	225.43	1732.64
2018	708.95	368.69	518.23	238.69	1834.56
2019	748.34	389.16	547.03	251.95	1936.48
2020	787.73	410.21	575.93	265.21	2039.08

Figure 8.10 Numbers of mobile phone subscribers in Arab countries in 2010 (Allam 2010)





Electronic waste in Khartoum (radios, recording devices, and laptops). Photo credit © Abdelrahman Al Khalifa

8.3.2 Hazards of electronic waste

Dumping e-waste or burning it – a common practice in cities – can represent a serious health and environmental hazard because of the dangerous metals such as cadmium, rhodium and beryllium and other chemicals found in electronic devices (Mahmoud 2018). Some of these chemicals may react to normal daytime temperatures, releasing poisonous gases into the air (Baldé et al. 2017). For this reason, electronic devices should be dismantled and disposed of with great care. Ideally they should be reused or their components recycled (Sahu and Srinivasan 2008).

Unfortunately there are no policies or laws that cover the disposal or import of e-wastes. The general practice is to dump them in public waste disposal areas. This could lead to a serious problem as the volume of e-waste builds up at these sites. There is currently little public awareness of the dangers that discarded electronics pose to the community.

One solution is to limit imports of used or low-quality electronic devices that are likely to have a short shelf-life and quickly end up as e-waste. There are calls for the Sudanese Standards and Metrology Organization to adopt and implement proper standards to limit such imports.

8.4 TRANSPORT AND ENERGY

Khartoum and its suburbs are growing rapidly. Unfortunately the city's services, particularly in transport and electricity, have failed to keep up. As a result, residents have been providing their own solutions. Three-wheel rickshaws have become a common sight on the streets, where they make up for a lack of buses. And those who can afford it are installing their own self-generated electricity units to avoid the frequent electricity outages during the hot summers.

The downside to both these developments is worsening urban air pollution. The country's air pollution laws are inadequate. Only a few countries in Africa have effective air pollution restrictions, and Sudan is not one of them. The main sources of urban pollution are the two-stroke engines that power rickshaws, and petroleum-powered electric generators (Jalal 2006). These emissions, especially particles less than 2.5 microns across, can affect respiratory systems, damage vegetation and contribute to photo-chemical smog (Smith et al. 2017).

8.4.1 Three-wheel motorcycles (rickshaws)

Before three-wheel motorcycles (commonly called rickshaws in India, Pakistan and Bangladesh) arrived in Sudan in the early 1990s, the use of motorbikes in the country was very limited. Rickshaws are a cheap mode of transportation and a solution to transportation problems in big cities. They are also convenient as they can access areas where affordable public transport may not be available.

In 2013, the number of registered rickshaws in Khartoum was estimated at 69,000 (Al Tayeb and Nimir 2017). It is likely that the real number is much higher, since many rickshaw drivers or owners are dissuaded from registering by the high fees. Figure 8.11 shows imports of two-stroke vehicles into Sudan between 2012 and 2016.

Rickshaws are inherently unsafe as they have no doors and are often unlicensed and driven by young, untrained drivers. Many of them are old and emit excessive exhaust fumes that affect both the passengers and the environment.

Two-stroke rickshaws use a premixed fuel-oil mixture consisting of around 96 per cent gasoline and 4 per cent lubricating oil, which is more polluting than the fuel used in four-stroke engines (Table 8.3). Service stations in Sudan do not offer premixed fuel to motorcyclists, which means drivers must mix it themselves, and they often use cheap mixes that create more pollution. As Figure 8.12 shows, emissions from two-stroke engines in Sudan is worsening. The data in Figure 8.13 was calculated knowing the number of vehicles on the roads each year, and assuming engine size of 100 cc, use of pre-mix fuels, an average daily distance of 60 km and 350 working days per year (Al Tayeb and Nimir 2017).

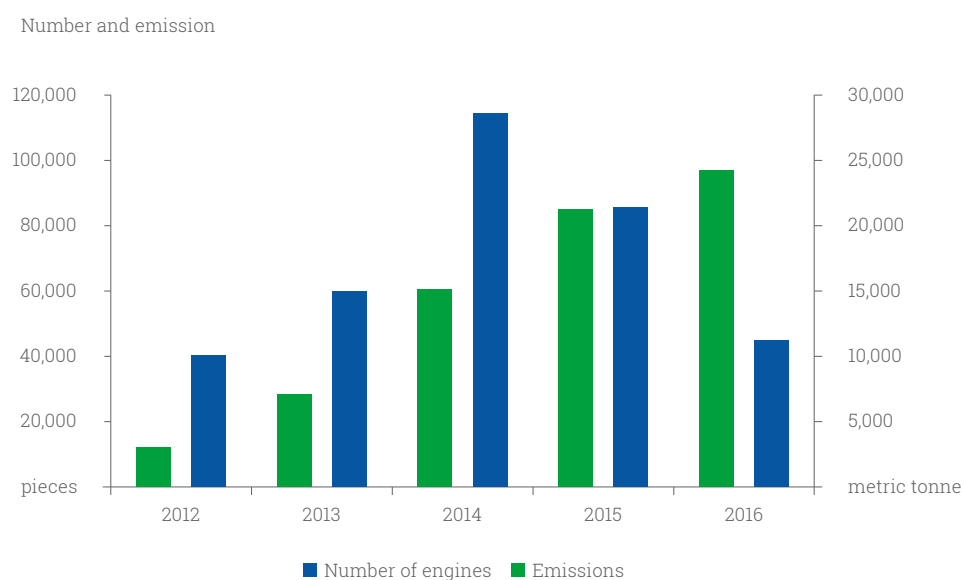
Emissions from two-stroke engines, particularly particulate matter and unburned hydrocarbons, cause damage to the human respiratory system and to vegetation. They can also result in photochemical smog. Since the serious environmental impacts of two-stroke engines have become known, there are growing efforts to stop their manufacture in Western Europe, Japan and USA (Jalal 2006).

8 Emerging Environmental Issues



Rickshaws in Khartoum. Photo credit © Taha Abdelbaghi

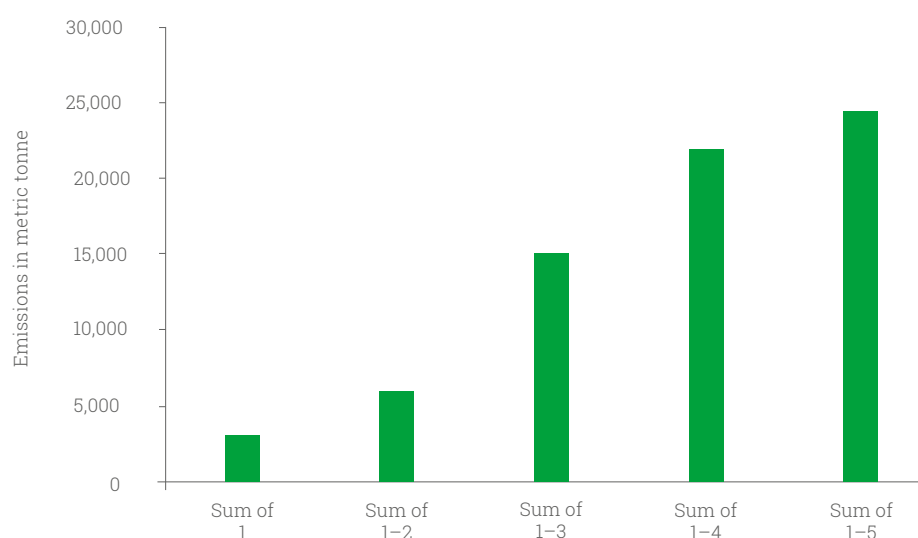
Figure 8.11 Number of two-stroke vehicles imported into Sudan 2012–2016 (Al Tayeb and Nimir 2017)



Source: Al Tayeb and Nimir 2017

8 Emerging Environmental Issues

Figure 8.12 Emission increase from two-stroke engines (2012–2016)



Source: Al Tayeb and Nimir 2017

Table 8.3 Comparison between emissions from two-stroke and four-stroke engines (Jalal 2006)

Pollutant	Emissions compared to four-stroke	Comments
Particulate matter	Significant	Lubricating oil, which is mixed with gasoline in two-stroke engines, is less combustible than gasoline. As a result some of the oil is emitted in the exhaust without being burned. Furthermore, drivers often mix in twice the manufacturer's recommended mix of oil (4 per cent), believing it will improve performance. It is estimated that particulate emissions from a single two-stroke motorcycle are comparable to those from a diesel truck or bus. Particulates, particularly the finer ones, are associated with respiratory problems.
Unburned hydro-carbons	Significant	Hydrocarbons are emitted unburned when the air-fuel mixture fails to burn properly in the engine, causing partial combustion and misfiring. When this happens, about 30 per cent of the gasoline can exit the exhaust unburned. Some gasoline components like benzene are carcinogens, while others combine with NOx to form ozone.
Carbon monoxide	Much lower	This is because much has been emitted as unburned hydrocarbon.
NOx	Much lower	As above.

8 Emerging Environmental Issues

The situation would improve if oil companies were obliged to make premixed two-stroke fuel for motorcycles, and if rickshaw drivers were trained in correct engine maintenance and the use of engine oil. Given the growing number of rickshaws and the worrying levels of pollution, the Sudanese government should work towards banning the import of motorcycles with two-stroke engines. It should also aim to improve the public transport system so there was less of a need for rickshaws.

8.4.2 Electricity generators

The lack of a reliable power supply in Sudan has led many people to install their own diesel and petrol-driven electricity generators. Generators use a mix of diesel and oil. They vary in size, with small and medium-sized units common in residential areas and large units used in markets and industrial areas. In homes, generators are used to supply households with electricity during power outages. Generators release significant amounts of emissions due to the incomplete burning of the diesel-oil mix, and this affects the air quality in residential areas (Tong et al. 2016; Nimir and Saeed 2018).

Table 8.4 shows the number of households in Khartoum state with their own generator, according to their standard of living or class.

Power outages in Sudan are more frequent over the five months of summer because of the high demand for air-conditioning. Power outages occur during the rest of the year but are less frequent. Table 8.5 shows the average total length of time of outage in Khartoum during the summer and the rest of the year.

Table 8.6 shows the amount of energy consumed during periods of outage each year in Sudan.

Most of the generators not only contribute to air pollution, they also cause noise pollution. While self-generation of electricity gives comfort to the owners of a house, it can be very annoying to their neighbours.

There would be no need for noisy, polluting generators if Sudan had a stable electricity supply. Until that happens, the government needs to regulate to ensure that only high-quality generators are imported into Sudan.

Table 8.4 Numbers of households with generators in each residential class

Class (standard of living)	Percentage	Number of households	Percentage of households with their own generator	Number of households with their own generator
1 st and 2 nd	6	54,900	30	16,470
3 rd	40	366,000	10	36,600
Newly planned	10	91,500	5	4557
Squatter	44	402,600	0	0
Total	100	915,000		57,570

Table 8.5 Length of power outages in Sudan

Time of year	Percentage of time when power is out	Time in hours
In summer (5 months)	15 per cent	540
Rest of year (7 months)	5 per cent	252
Total		792

8 Emerging Environmental Issues

Table 8.6 CO₂ emissions from residential electricity self-generation

Annual energy consumption (per household), KWH	26,500
Annual energy consumption (during outage), KWH	132,665,325
Annual energy consumption (during outage), Ktoe	11.4
Annual energy consumption (during outage), TJ	475
Annual emissions, tCO ₂	33.818

8.5 CONCLUSION

Emerging environmental issues in Sudan include artisanal gold mining, electronic waste, two-stroke vehicles and self-generated electricity. Whereas artisanal mining takes place across most of the country and e-waste is a problem for all communities, rickshaw motorcycles and standby generators mostly affect urban areas, especially Greater Khartoum.

The use of mercury in gold extraction is both a health and an environmental hazard. Artisanal gold mining contributes much more to the country's economy than the big mining companies. High prices for gold on the international market are encouraging farmers and others to leave their trade and take up mining. Much more needs to be done to discourage the use of mercury

among the miners and encourage safer alternatives. E-waste is a fast-growing problem in Sudan. Electronic devices such as mobile phones contain hazardous materials and should be disposed of appropriately by garbage collectors who are trained to handle such products. This rarely happens. Information on e-waste is scarce, which makes it difficult to draw up policies to tackle the problem.

The growing number of two-stroke rickshaws in Sudan's urban areas is creating a serious environmental problem due to the poor blending of gasoline with lubricating oil. The emissions caused by the incomplete combustion of gasoline and oil contain dangerous chemicals and particulate matter. New policies and proper enforcement are required to phase out the import and use of two-stroke engines.

References

REFERENCES

1. Abbas, M. and May, A. (2014). *Conventional Mining in River Nile State*. Presented at the Ministry of Mineral Conference. Khartoum, Sudan.
2. Alamin, A. (2010). Electronic waste management in Khartoum state, Unpublished report.
3. Allam, H. (2010): E-waste Management in the Arab Region: Status and Opportunities (Power-Point). Centre for Environment and Development for the Arab Region and Europe, Cairo, Egypt.
4. Ali, S. (1999). *Greater Khartoum: The Horizontal Expansion and its Impact on the Development of Settlement* (in Arabic). Unpublished MA Thesis, Geography Department University of Khartoum, Sudan.
5. 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 Sudanese Standards and Metrology Organization.
6. Appleton, J.D. and Williams, T.M. (1998). Mitigation of mining related mercury pollution hazards: Project Summary Report. *British Geological Survey, Overseas Geology Series Technical Report WC/98/034*. Nottingham: United Kingdom. Retrieved from http://www.bgs.ac.uk/research/international/dfid-kar/WC98034_col.pdf
7. 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>
8. Calkins, S. (2014). Gaining an access to land: everyday negotiations and ethnic politics of Rashaida in Northeastern Sudan. In J. Gertel, R. Rottenburg and S. Calkins (Eds.). *Disrupting territories: land, commodification and conflict in Sudan*. (pp. 180–205). Woodbridge: James Currey.
9. Codan Limited (2016). *Codan Annual Report*. Adelaide, Australia. Retrieved from: <https://codan.com.au/wp-content/uploads/2017/04/27-2016-Codan-Annual-Report-23.09.2016.pdf>
10. Collins, T. (2012). Sudan pins economic hopes on gold prospects. *Sudan Tribune*, 26 July. Retrieved from: <https://sudantribune.com/Sudan-pins-economic-hope-on-gold.43373>
11. Extractive Industries Transparency Initiative (2016). Artisanal and Small-Scale Mining. Retrieved from <https://eiti.org/ASM>
12. Elsamani, Y. (2015). *Minerals Potential and Resources in Sudan*. Presented at the meeting of 17th African OILGASMINE Conference, Khartoum, Sudan.
13. Eltayeb, G. E. (2003). Urban Slums Reports: The case of Khartoum, Sudan. Retrieved from https://www.ucl.ac.uk/dpu-projects/Global_Report/pdfs/khartoum.pdf
14. Gamma, A. (2012). Technical Report on Informal Management of Used Paper and E- waste in Sudan. Higher Council for Environment and Natural Resources United Nations Industrial Development Organization.
15. Ibrahim, M.S. (2015). *Artisanal Mining in Sudan – Opportunities, Challenges and Impacts*. Presented at the 17th Africa OILGASMINE Conference, Khartoum, Sudan. Retrieved from: <https://unctad.org/meetings/en/Presentation/17OILGASMINE%20Mohamed%20Sulaiman%20Ibrahim%20S4.pdf>
16. Ibrahim, Y. (2018). *Case Study of Design of a Mercury Closed System for Use by artisanal Miners*. Unpublished MSc report, Faculty of Engineering. University of Khartoum, Sudan.
17. Jalal, A. (2006). *Pollution by 2-stroke Engines*. Presented at the Nigerian Conference on Clean Air, Clean Fuels and Vehicles, Abuja, Nigeria.
18. Lassen, C., Warming, M. and Maag, J. and Jønsson, J. B. (2016). *Mercury trade and use for artisanal and small-scale gold mining in Sub-Saharan Africa*. United Nations Environment Programme. Retrieved from: <http://cegem.com/wp-content/uploads/2016/02/Mercury-Sub-Saharan-Africa-Trade-Report-12-December.pdf>
19. Mahmoud, E.F (2018). *E-Waste Management in Sudan*. Presented at the ITU/UNU/ISWA Training Workshop on “Electronic Waste—Statistics” Khartoum, Sudan. Retrieved from: <https://www.itu.int/en/ITU-T/Workshops-and-Seminars/gsw/201804/Documents/Eiman.pdf>

20. Mine Engineer (2012). Mercury Amalgamation. Retrieved from: <http://mine-engineer.com/mining/minproc/MercAmal.htm>
21. Ministry of Minerals (2015). *Minerals Wealth Development and Mining Act*.
22. Ministry of Minerals (2017). Artisanal Mining Activities. A report by the General Administration for Mineral Resources. (in Arabic)
23. Mudd, G. M. (2007). Global Trends in Gold Mining: Towards Quantifying Environmental and Resources Sustainability. *Resources Policy*, 32, 42–56.
24. Nimir, H. and Saeed, M. (2018). *Evaluation of Electricity self Generation in Khartoum State*. Study under preparation, Department of Petroleum and Natural Gas Engineering, University of Khartoum, Sudan.
25. Onour, I. (2018). *The Cost of Mismanagement of Gold Production in Sudan*. School of Management Studies, University of Khartoum, Sudan.
26. Sahu, S. and Srinivasan, N. (2008). Mobile phone waste: Current initiatives in Asia and the Pacific, *TECH MONITOR, Special Feature: E-waste Management*. 32–38
27. Said, J. (2014). *Workshop on Effect of E-Waste on Environment*. Khartoum, Sudan.
28. Smith, R. B., Fecht, D., Gulliver, J., Beevers, S., Dajnak, D. (2017). Impact of London's road traffic air and noise pollution on birth weight: retrospective population based cohort study. *British Medical Journal*, 359, Retrieved from: BMJ 2017;359:j5299
29. Tong, D., Li, P., Chen, V., Lamsal, L., Lee, P., Tang, Y., Kim, H., Kondragunta, S., and Stajner, I. (2016). Impact of 2008 Global Recession on Air Quality Over United States: Implications for surface Ozone levels from changes in NOx emissions. *Geophys. Res. Lett.*, 43 (1), 9280–9288.
30. Tyrab, E., Abd Elrahim, M., Elbagir, M. Y, and Kodi, M. A. (2016). Human mercury exposure associated with artisanal gold miners in Sudan. *Int J Earth Environ Sci*, 1, 118.
31. UN Environment Programme (2007). Electronic Waste. Vol. 1. Inventory Assessment Manual. Retrieved from: <http://greene.gov.in/wp-content/uploads/2018/01/E-waste-Vol-I-Inventory-Assessment-Manual.pdf>
32. UN Environment Programme (2016). GEO-6 Regional Assessment for Africa. United Nations Environment Programme, Nairobi, Kenya. Retrieved from: http://wedocs.unep.org/bitstream/handle/20.500.11822/7595/GEO_Africa_201611.pdf?sequence=1&isAllowed=y
33. UN Environment Programme (2017). *Global mercury supply, trade and demand*. United Nations Environment Programme, Chemicals and Health Branch. Geneva, Switzerland. Retrieved from: https://wedocs.unep.org/bitstream/handle/20.500.11822/21725/global_mercury.pdf?sequence=1&isAllowed=y
34. Yager, T. Y. (2015). The Minerals Industry of Sudan in 2015, *U.S. Geological Survey Minerals Year Book*. 41.1–41.5
35. Zettl, E., Lassen, C., Maag J., and Potrykus, A. (2015). *Ratification of the Minamata Convention by the EU: Complementary assessment of the mercury export ban*. Retrieved from: <https://ec.europa.eu/environment/chemicals/mercury/pdf/20150609ExpBanComplAssess.pdf>



9

Policy Analysis

9.1 INTRODUCTION

Sudan's environmental strategy stems from its constitution, its various strategic and development plans over the past few decades, its response to droughts and other environmental crises, and its commitments under multilateral environmental agreements, including the United Nations Millennium Development Goals and Sustainable Development Goals.

Its environmental policies are aimed at rehabilitating, conserving and protecting the country's natural resources, while also regulating the economic activities that have an impact on those resources, such as mining, agriculture, forestry, fisheries and tourism. Meanwhile its social policies, which target issues such as poverty and population growth, seek to deal with some of the root causes of Sudan's environmental problems.

The challenge is to drive increased production in agriculture, livestock, fisheries, water, manufacturing, petroleum and gas, mining, trade, infrastructure, transport and construction while at the same time to maintain or improve the quality of soil, air, watersheds, forests, rangelands and pastures, wildlife, marine and freshwater fisheries, and biodiversity.

While there have been successes, in general environmental protection in Sudan has been held back by gaps and overlaps in certain policies and by the unintended consequences of others, as well as by a lack of policy coordination and weak enforcement and implementation. For example, the policy of increasing the area under irrigated agriculture, which involved huge investments in new dams and canals, led to the removal of large areas of forest, rangeland and pasture (Ministry of Environment, Natural Resources and Physical Development 2015; Hassan and Tag Consultants 2018; Sullivan and Nasallah 2010).

9.2 ENVIRONMENTAL POLICY LANDSCAPE

The government's environmental policies cut across many different sectors, including natural resources, biodiversity, climate change, poverty reduction and economic development. Protecting the environment requires engagement from all sections of society. For example, to adapt to climate change, achieve

sustainable development or improve the country's resilience against natural disasters, the government must address issues in health, agriculture, water harvesting, community forests, communal pastures, coastal zones and much more.

Some policies are aimed at tackling deep-seated economic stresses, while others offer "band aid" solutions to immediate environmental concerns; some act as incentives to boost economic production, while others seek to protect against environmental degradation.

Among the major strategies and plans that have shaped the country's environmental strategy are the 10-Year Development Plan 1960–1970, the consecutive Five-Year and Seven-Year development plans of the 1970s, the National Economic Salvation Programme 1992–1993, the 10-Year National Comprehensive Strategy 1992–2002, and the 25-Year Development Strategy 2007–2031. The latter was reformulated into the Three-Year Economic Recovery Programme 2012–2014 after the secession of South Sudan, and continued into the Five-Year Economic Reform Programme 2015–2019 (Ministry of Finance and National Economy 2015a)

The 2005 Comprehensive Peace Agreement and the Interim National Constitution have had a big impact on Sudan's environmental strategy. They specified the need to develop policies and laws to resolve land use and land tenure problems, and offered insights for achieving a clean environment and protecting the country's biodiversity, among other things. Since then the government has produced the National Action Plan on Desertification Control 2006, the National Adaptation Programme of Action 2007 under the United Nations Framework Convention on Climate Change (UNFCCC) (Ministry of Environment and Physical Development 2007), various versions of the Sudan Interim Poverty Reduction Strategy Paper (International Monetary Fund 2013; Ali and Hassan 2016), the National Biodiversity Strategy and Action Plan 2015–2019, and the Sudan National Adaptation Plan 2016 (Ministry of Environment, Natural Resources and Physical Development 2016).

A history of environmental legislation in Sudan is shown in Table 9.1 while Annex 1 contains a more comprehensive list of Sudan's economic and natural resources policies that have implications for the environment.

9.2.1 Macroeconomic policies

Macroeconomic policies aim to address issues that affect the whole economy, including many that are at the root of environmental degradation. They are largely monetary and fiscal policies designed and implemented by the Central Bank of Sudan and the Ministry of Finance and Economic Planning.

Some of Sudan's current macroeconomic policies date back to the economic liberalization programme of 1992–1993, and more recently to the economic reform programme of 2012–2014, which was later recast as the Five-Year Economic Reform Programme 2015–2019 (Ministry of Finance and National Economy 2015a). The economic liberalization policies of the early 1990s transformed the economy from a state-controlled economic system into a market-based one (Ministry of Finance and National Economy 1992; World Food Programme 2018). They involved halting inflation, reducing government expenditure, increasing government revenues, extending credit lines, privatising state enterprises, floating Sudan's currency and eliminating subsidies on basic goods such as sugar, fuel and energy.

These reforms were critical in framing the country's present macroeconomic policies. They had both positive and negative impacts on the economy, and consequently on the environmental situation in Sudan. For the most part, they did not provide the necessary stability to encourage investment into the country.

9.2.2 Economic policies

Many of Sudan's economic policies have a direct effect on the environment and sustainable development, particularly those directed at agriculture, livestock, oil exploration and artisanal gold mining.

The principal aims of Sudan's agricultural policy have been to improve the country's food security and increase export earnings. The policies have supported the expansion of public irrigation schemes, modelled on the schemes in Gezira, and private sector rain-fed mechanized schemes in the eastern and central regions of the country (Khalifa et al. 2012; Elsiddig 2013; FAO 2016). The private sector mechanized schemes emphasize mono-cropping of sorghum at the expense of the traditional ecological farming practices that are applied in most parts of the country.

The objective of the livestock policy has been to increase earnings from live animal and meat exports. The sustainable supply of live animals depends on them being able to graze on natural pastures, an organic approach that avoids the need for growth hormones. The policy aims to rehabilitate, conserve, protect and sustain pastures and rangelands to allow them to support an optimal number of animals. In 2010, the Range and Pasture Administration was brought into the jurisdiction of the Ministry of Livestock Resources; previously it had been under the Ministry of Agriculture, and at another time the Ministry of Livestock Resources and Fisheries.

Sudan's policies on oil production and gold mining have resulted in the clearing of large areas of forest and rangeland for drilling and mining operations. This has had serious socio-economic and environmental consequences. Oil drilling, for example, has contaminated large areas of water, forests and pastures in West Kordofan (Pantuliano and Egemi 2009). Artisanal gold mining, which takes place in more than ten states and employs more than one million people, has caused serious damage to the environment (Ministry of Finance and National Economy of Sudan 2015b); in the Butana area it destroyed pastures and pushed out livestock farmers, forcing them to graze their animals on the crop lands in Gedaref State (Food and Agriculture Organization 2013).

Oil companies are required to pay two per cent of their revenues to the state in which they are working. This policy has not yet been imposed on gold miners. The environmental and social impacts of gold mining are covered by the Mineral Wealth and Mining Act 2015, as well as by other more general legislation such as the Environmental Protection Act 2001, the Environmental Health Act 2009, the Child Act 2010 and the Labour Act 1997.

9.2.3 Natural resources policies

Sudan's natural resources policies aim to reduce the impact of development on forests, wildlife, biodiversity, soil and water resources, and to increase the resilience of natural ecosystems to climate change.

The modified forestry policies that came into force in 1986 were designed to protect, rehabilitate, conserve and develop the forest sector (Elsiddig 2013). One of the objectives was to expand the area under forest reserve to 20 per cent of the country's total area.

Another was to recognize new forms of forest tenure including private, communal and institutional forests, to add to the existing forms of tenure which included public forests and forest reserves (UNEP and UKaid 2020). There was also an intention to plant five per cent of the country's irrigated land and ten per cent of its rain-fed schemes with tree belts according to the Forest Act 1989 (Ministry of Agriculture and Forests 2000).

The Sudan National Forestry Policy Statement of 2006 broadened the scope of the country's forest policy, covering poverty reduction, food security, desertification, reforestation, conserving biodiversity, land use planning, industrialization and the economic valuation of forest products and services (FAO 2006). However, the policy statement is silent on important issues such as drinking water for animals, grazing for livestock and wildlife, and the effects of climate change (UNEP and UKaid 2020).

Sudan's wildlife directives and policies emphasize the conservation of habitats, the development of national parks, and the protection of wild animals – especially endangered species – against illegal hunting (Ministry of Environment, Natural Resources and Physical Development 2015). For example, the Environment Protection Act 2001 forbids the destruction of wildlife habitats and the poaching of animals, and prohibits the introduction of genetically modified organisms.

Sudan's national water resources policies of 1992, 2000, 2006 and 2011 have marked a continual improvement in the management of watersheds of Sudan (UNEP 2012; UNEP and UKaid 2020); Ministry of Irrigation and Water 1999; Ministry of Justice 2020). The policies aim to ensure enough supplies of water for agriculture, industry, health, energy, transportation and domestic uses (Ministry of Environment, Forestry and Physical Development 2013). The 2011 policy addresses the streamlining of the UN Millennium Development Goals into national policies and plans.

Biodiversity policies are decided jointly by the Ministry of Environment, Natural Resources and Physical Development and the Higher Council for Environment and Natural Resources. The National Biodiversity Strategy and Action Plan of 2000 and 2015 aim to stop the deterioration of the country's biological resources, preserve the genetic resources of its flora and fauna, and incorporate Sudan's obligations under the 1992 United Nations Convention on Biological Diversity into national strategies. They also address the critical problem of mismanagement of natural resources, and the expected effects of climate change (Ministry of Environment and Physical Development 2007; Elsiddig 2013; Republic of Sudan 2015). Another objective is to synchronize natural resources policies across the different sectors.



Growing broad bean (Vicia faba) between tree belts is a good example of implementation of forest policies. Photo credit © Osman Ali

Table 9.1 A history of environmental legislation in Sudan, 1901–2018

Period	Remarks
1901	Endorsement of the first Forest Act
1901	Land Registration Act
1905	Amendments of the 1901 Forest Act
1908	Amendments of the 1908 Forest Act
1917	Land Settlement and Registration Ordinance
1925	Land Settlement and Registration Ordinance
1932	Endorsement of the Forest Policy Statement
1932	Enactments of provincial and central forests ordinances
1939	Endorsement of the Royalty Ordinance
1939	National Park Ordinance (amended 1986)
1948	Reform of the Provincial Forest Act to delegate power to the local level
1954	Freshwater Fisheries Act to protect the freshwater fisheries of the Sudan and to regulate and control fishing (amended in 1988)
1959	Reform of the Provincial Forest Act to centralize the approval of establishing new sawmills
1959	Amendments of the Royalty Ordinance to halt tree felling
1960	Water-hyacinth Control Act for the control and prevention of the spreading of water-hyacinth in rivers and waterways in Sudan
1961	Endorsement of Provincial Administration Act and reform of the Central Forest Act
1970	Unregistered Land Act
1974	Both central and provincial forest acts were reformed to allow more protection to forest resources
1975	Environmental Health Act
1977	Labour Act
1980	Endorsement of the Regional Government Act
1981	Endorsement of the Local People Government Act
1984	Civil Transaction Act. The Act repeals the 1970 Unregistered Land Act and maintains the principles of usufruct rights
1986	Wildlife Conservation and National Parks Act
1989	Enactment of the Forest Act 1989
1990	Irrigation and Drainage Act. All irrigation and drainage activities require a licence from the Ministry of Irrigation
1991	Native Administration Acts of 1991 and 1998
1991	Federal-decentralization system of governance

Table 9.1 continued

Period	Remarks
1995	Water Resources Act
1995	Freshwater Fisheries Act
1998	Petroleum Wealth Act
1999	Investment Encouragement Act. This was initiated in the 1980s and amended several times, most recently in 2011 and 2013
2001	Environment Protection Act (amended in 2020)
2001	Pharmaceuticals and Poisons Law
2002	Forests and Renewable Natural Resources Act
2003	Local Government Act (updated from 1989 Act)
2005	Interim National Constitution of the Republic of Sudan; includes protection of natural resources
2007	Integrated Water Resource Management Policy and Strategy
2009	Combat Desertification Law
2009	North Darfur State Environmental Protection Act
2010	North Darfur State Land Use Act
2012	The State of Khartoum Law for Environmental Protection
2013	North Darfur State Desertification Control Act
2015	North Darfur State Tree-belts and Wind Breakers Act
2015	Rangelands Regulation and Forages Resources Development Act
2015	The Mineral Resources and Mining Act
2015	National Bio-safety Law No. 15
2015	Decree of Council of Ministries No. 283 – bans cutting of forest trees, develops protocol and plan for great afforestation campaign
2016	Dinder – Jebel Al Dair National Park Law
2016	North Kordofan State Law of Protection and Promotion of the Urban Environment No. 17
2016	Regulation for Groundwater Control
2016	Regulation for Surface Water Control
2016	North Kordofan State Law of Protection and Promotion of the Urban Environment No. 17
2017	Development of Mineral Resources Law
2018	Blue Nile State Law requiring farmers to plant trees on ten per cent of rain-fed agricultural land and five per cent of irrigated land, in line with the provisions of the federal law

Source: Hassan and Tag Consultants (January 2018)

The biodiversity strategy has had limited success. The increasing livestock population, oil drilling and mining have exacerbated land degradation and the loss of biodiversity in many parts of Sudan. There are many policy gaps. For example, there is no plan yet to deal with alien invasive plants such as mesquite shrubs (Ministry of Environment, Natural Resources and Physical Development 2015).

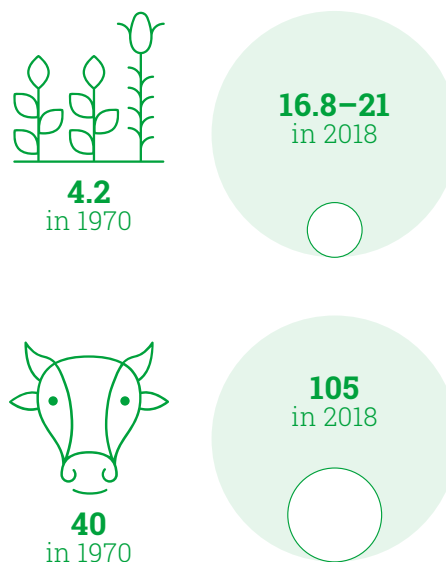
Pollution and waste are major problems in Sudan. Municipal solid waste, industrial waste, medical waste and electronic waste are not properly controlled and are a threat to human health and the environment in urban and rural areas. Another issue is the use of unlicensed chemical pesticides and fertilizers, as well as the illegal dumping of chemicals. Air pollution is covered by the Environment Protection Act 2001, which requires industries with potentially polluting emissions to carry out an environment and social impact assessment and abide by health and sanitation laws.

While dealing with waste and pollution will be costly, the potential growth of the recycling sector in Sudan could present some lucrative opportunities.

9.3 ASSESSING SUDAN'S ENVIRONMENTAL POLICIES

Between 1970 and 2018, Sudan's agricultural land increased from 10 million feddans (4.2 million hectares) to 40–50 million feddans (16.8–21 million hectares), and its livestock numbers from 40 million to 105 million (Central Bank of Sudan 2015). Over this period, the government has invested in irrigation dams, hydropower projects and water harvesting programmes (FAO 2015a). These long-term policies for growth and development still shape the pattern of land use in the country. To meet the needs of a fast-growing population, the government continues to prioritise food production, private sector investment in farming, the expansion of irrigated agriculture, oil exploration and gold mining.

Agricultural land and livestock (million hectares and million)



This focus on agriculture, oil and mining has resulted in deforestation, degradation of forests and range-lands, and widespread pollution of land, water and air (see Section 9.3.2 below). Many of these threats will remain as long as the government fails to address people's economic insecurity. For example, one reason for the degradation of pastures is that pastoralists are being forced to graze their animals in increasingly small spaces because of oil exploration, mining operations and the expansion of croplands.

In other areas, Sudan has adequate protection policies but is failing to apply them effectively. The threats to biodiversity from wildlife poaching, uncontrolled fishing, coastal pollution and the introduction of new plant species and the loss of indigenous ones will continue unless the government commits its planning and financial resources towards adopting and implementing its National Biodiversity Strategy and Action Plan.

Ineffective policies and the mismanagement of natural resources are compounded by climate change. This is already reflected in recurrent droughts, desertification, deforestation, overgrazing of pastures, degraded biodiversity, reduced crop and food production and increased crop and animal pests. These often result in poverty and food insecurity, especially among rural communities. More land is becoming unsuitable for crop production or animal grazing, and some land has been so degraded that dust storms are becoming common.

Sudan is party to several international and regional conventions. Among the most important is the UNFCCC, which came into force in 1994. In 2007, the country produced its National Adaptation Programme of Action, which among other things highlighted its vulnerability to climate change and identified ways to adapt (Ministry of Environment and Physical Development 2007). In 2016, Sudan prepared a further National Adaptation Plan, which shifted the focus for climate change adaptation to sustainable agricultural development. Sudan also developed its Intended National Determined Contributions (INDC) in the framework of the Paris Declaration of 2015 and its ratification by the government of Sudan in August 2017.

Sudan is a signatory to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which restricts the trade in endangered species such as the Greater Kudu (*Tragelaphus strepsiceros*) and Rock hyrax (*Procavia capensis*) (Abdelhameed et al 2013); the Convention on Biological Diversity (CBD), which aims to both conserve biodiversity and promote its sustainable use; and the Ramsar Convention on Wetlands (Sudan has several designated Ramsar sites, including Dinder National Park). The country's commitment to CITES and CBD in particular have helped address the gaps in its wildlife laws (UNEP 2012; Ministry of Justice 2020). A comprehensive list of the international conventions to which Sudan is a party is found in chapter 2.

9.3.1 Impact of selected environmental legislation

Land tenure laws

One of the most important areas of legislation for both agriculture and the environment is land tenure and land use.

The use of land for agriculture is covered by Presidential Decree No. 34, while the use of land for residency and other purposes is covered by the Land Settlement and Registration Ordinance 1925, the Unregistered Land Act 1970 and the Civil Transaction Act 1984 (Sullivan and Nasallah 2010).

These land laws have allowed recognition of tribal and individual usufruct rights – the right to enjoy another person's property without abusing it – and inheritance rights, as well as opening the way for compensation for land appropriated by the state (World Food Programme 2018). Most land use for traditional farming and grazing operates under the usufruct system. The complexity of the country's land tenure and land use laws have made it difficult to allocate land for private sector investment (World Food

Programme 2018), and to distinguish between the rights of local communities and those of the public and private sectors (Sullivan and Nasallah 2010). This issue was addressed in the 2005 Comprehensive Peace Agreement.

Native Administration Act

Another prominent piece of legislation in Sudan is the Native Administration Act 1991 and 1998, which authorizes traditional leaders and local communities to guide the conservation and protection of forests, pastures and livestock corridors. The Local Government Act 1998 further strengthened this act by establishing rural courts and giving judicial powers to native leaders, which enabled them to work with local governments, the Forests National Corporation, the Range and Pasture Administration, and state wildlife and agriculture departments (Ministry of Environment, Forestry and Physical Development 2013).

Federal and state governance

In 1991, the responsibility for environmental policy in Sudan was divided between the federal and state governments (UNEP 2012; FAO 2015a). This was a significant milestone in the country's policy landscape. The federal government is responsible for policy design and the state governments are responsible for administering and executing those policies. The Local Government Act 1989 and 2003 entrusts local governments with the conservation and sustainable use of natural resources at a community level. Typical roles include the management of drinking water points, reforestation, the provision of services to agriculture and the management of livestock grazing (UNEP 2012; Ministry of Environment, Forestry and Physical Development 2013).

This division of responsibility between the federal and state government has brought challenges. Institutional roles sometimes overlap or are poorly coordinated: for example, the legislation proposed the establishment of local consultative councils to administer and manage the country's environmental resources, but their functions overlapped with those of existing federal government departments. In addition, local law enforcement and policy implementation have been poorly funded by the central government.

Water resources

Sudan's water laws cover the country's rivers, basins and catchment areas, as well as groundwater resources (FAO 2015a; Ministry of Justice 2020; UNEP 2012). The main aim is to provide equity and transparency in water services. However, effective management depends on functional institutions, which are often non-existent.

Some states and localities have built their own institutions to allow them to maintain and govern their water supplies (UNEP 2012; FAO 2015b). This has created confusion in cases where states share water resources; for example, South and North Kordofan States and White Nile State all share the seasonal water stream of Khor Abu Habil. Too often, state-level institutions have no clear mandate, are short of human resources or are poorly funded (Ministry of Environment and Physical Development 2007).

Environmental impact assessments

The Environment Protection Act 2001 harmonizes different environmental laws, including laws covering biodiversity protection, pollution control, public environmental awareness, and environmental and social impact assessments (Ministry of Environment, Forestry and Physical Development 2013). Despite federal and state legislation stipulating the need to conduct environmental impact assessments, too often they are carried out without following guidelines and regulations, and monitoring and follow-up are ineffective. This has led to several incidents of chemical pollution along the banks of the Nile.

Wildlife, national parks and forests

The Wildlife Conservation and National Parks Act 1986 covers the conservation, protection, development and management of game animals and national parks. It lists protected species and provides regulations on hunting licences, hunting seasons and permissible hunting methods. The act does not cover the conservation of plants and trees or the protection of marine species. It also ignores community participation in management plans (Ministry of Environment, Natural Resources and Physical Development 2015).

The Forests and Renewable Natural Resources Act 2002 provides the framework for the management and protection of forests and renewable natural resources, including pastures and rangelands. The act stipulates that trees should be left standing on five per cent of irrigated agricultural land and ten per cent of rain-fed agricultural land (Ministry of Environment, Forestry and Physical Development 2013; Elsiddig and Abdel Magid 2012), though these targets are lagging due to a lack of adequate enforcement measures.

9.3.2 Unintended consequences of environmental legislation

In its efforts to achieve economic growth, the Sudanese government adopted policies that promoted the expansion of agriculture, livestock, oil exploration, gold mining and construction. This has had unintended consequences for the environment, including deforestation, encroachment into rangelands and pastures, destruction of protected areas, loss of biodiversity, and pollution of soil, water and atmosphere.

The expansion of agriculture, mining and other developments has intensified competition for land and water between crop farmers and pastoralists, and some pastoralists have been forced to take their herds into marginal lands (Sullivan and Nasallah 2010). This competition for resources also affects wildlife, with large numbers of game animals being driven out of their natural habitats and into grazing lands. Some species have become endangered as a result (UNEP 2008).

Other examples of policies having unintended negative consequences include the introduction of mesquite, which was planted during the 1983-1984 drought to stop desert encroachment and ended up spreading and threatening the country's agriculture and biodiversity (Ministry of Environment, Natural Resources and Physical Development 2015); and the hosting of internally displaced persons and refugees, which in some areas has resulted in deforestation or the destruction of forest biodiversity (Elsiddig 2013; Hassan and Tag Consultants 2018).

9.3.3 Policy gaps and overlaps

Despite a long list of laws, there are still gaps and overlaps in Sudan's environmental policies. For example, the country does not have a clear policy to combat land degradation and desertification. In the 1970s and 1980s, the government introduced the Desert Encroachment Control and Rehabilitation Programme and various soil conservation, reforestation and resource protection programmes. Although the Combat Desertification Law of 2009 included the establishment of the National Council for Combating Desertification (NCCD), NCCD was established in 2018 only to be dissolved in 2020. Moreover, there is a lack of an intersectoral approach that integrates forestry activities and land use into the social, economic and developmental processes of the country (Saad et al. 2018).



*The introduction of mesquite (*Prosopis juliflora*) to stop desert encroachment, which ended up spreading and threatening the country's agriculture and biodiversity, is one example of policies having negative consequences. Photo credit © Osman Ali*

Sudan also lacks clear policies to deal with drought and climate change, despite the country facing many cycles of drought over the last decades. The 1983–1984 droughts resulted in large numbers of internally displaced people from North Kordofan moving to Khartoum for shelter and refuge. The government is committed to international conventions on climate change, but as yet there are no local measures in place to reduce the risks (UNEP 2012; Elsiddig 2013).

There is an absence of appropriate and coherent policies on natural resource management. This largely stems from a lack of participation by affected groups in policy creation. For example, forest policies are often drawn up by forest staff. This results in policies that are focused on the protection of forests and the planting of trees, and that fail to address the rights of communities to use the forests. Similarly, the design of agricultural policies often excludes representatives of rangelands and pastures, resulting in policies that do not address the daily needs of those communities. Many of these policy gaps and overlaps are due to the lack of a clear distinction between the roles of federal and state institutions (UNEP 2012; Ministry

of Environment, Natural Resources and Physical Development 2015). When it is not obvious who is responsible for formulating policy, the outcome is either a policy that does not work, or no policy at all.

9.3.4 Policy coordination

Some environmental policies in Sudan suffer from a lack of coordination between the government bodies responsible for planning and implementing them. The poor coordination is found at both federal and state levels, and particularly between federal and state institutions.

The staff responsible for designing and implementing environmental policies are spread among multiple governmental agencies, specialized authorities and consultative institutions. These include the Ministry of Environment, Natural Resources and Physical Development, the Tourism Administration, the Higher Council for Environment and Natural Resources, the Ministry of Agriculture and Forests, the Ministry of Water Resources, Irrigation and Electricity, the Council for Water Resources, the Ministry of Livestock

Resources and Fisheries, the Range and Pastures Administration, the Ministry of Interior, the Wildlife Administration and the Attorney General (FAO 2015a).

Between them these agencies cover a range of concerns, including crop production, animal health, forestry, rangelands and pastures, fisheries, wildlife and irrigation. Each agency has its own legislative advisory department, specialized research division and technology transfer department. If they found a way to coordinate better, the policies they all work on would be significantly more effective.

9.3.5 Enforcement and implementation

Much environmental legislation is prepared at the federal level and implemented at the state level. Too often federal institutions do not take the interests and limitations of states and local communities into account when formulating policy (UNEP and UKaid 2020). Policies are poorly executed, partly because of budgetary constraints, partly because of a lack of qualified personnel (Elsiddig 2013). This explains, for example, the failure to raise the production of gum arabic to 500,000 tonnes and exports to 300,000 tonnes per year, as stipulated in the Five-Year Economic Reform Programme 2015-2019; to enforce the plan to plant five per cent of the country's irrigated land and ten per cent of its rain-fed schemes with tree

belts; and to meet the Forests National Corporation's target of covering 20 per cent of the country's land area with forests by planting 6.58 million hectares of trees (as Table 6.6 in Chapter 6 shows, the total area planted during 2002–2017 was only 3.61 million feddans or 1.52 million hectares).

9.3.6 Potential for upscaling and replication

Some natural resource policies have had a positive impact on the environment and society, resulting in them being scaled up and replicated. These successes have been in the areas of forestry, rangelands and pastures, wildlife and water resources. They include the introduction of liquified petroleum gas stoves into rural areas to reduce the cutting of forest trees for firewood; the rehabilitation of the degraded Nabag Reserve Forest in South Kordofan State; the revitalization of gum arabic production and marketing in various localities in Blue Nile, Sennar, White Nile, North and South Kordofan states; and the carbon sequestration project in Kordofan region (see Boxes 1 and 2). An ongoing project worth mentioning is Sudan Sustainable Natural Resources Management Project (SSNRMP) which started in 2018. The has three components: Institutional and Policy Framework, Community based sustainable management of rangelands, forests and biodiversity and Project Management, Monitoring and Evaluation (World Bank 2020).

Box 9.1: Examples of natural resource policy successes

Introduction of liquified petroleum gas stoves into rural areas.

Practical Action in North Darfur supplied 8,980 liquified petroleum gas stoves, which reduced firewood consumption by 50–70 per cent, improved the quality of indoor air, and allowed households to reduce their monthly spending on firewood by up to 65 per cent.

Rehabilitation of the degraded Nabag Reserve Forest in South Kordofan in 2004.

The Forest National Corporation introduced an agro-forestry system and raised community awareness on the economic value of agro-forest management. The community and private sector planted 2,018 hectares with acacia trees and distributed 0.6-3.0 hectares to more than 70 per cent of households for growing of high value crops (beans, cowpeas, sesame, maize and rosella). This increased the average income of households by 145 per cent (Elsiddig and Abdel Magid 2012).

Revitalizing the Sudan Gum Arabic Production and Marketing Project.

Supported by multi-donor trust fund and the International Fund for Agricultural Development. Formed gum arabic production associations from communities in localities in the Blue Nile, Sennar, White Nile, North and South Kordofan states. Constructed 14 water yards, water stations and 4 hafirs. Established 12 warehouses for storage of gum arabic. Purchased 16 tractors for agricultural operations. Conducted training and workshops on microfinance, financial management and agro-forestry. Increased beneficiaries from 9,571 to 11,346 during 2004–2011, including women who constituted up to 25 per cent of members of the project (IFAD 2009; Elsiddig and Abdel Magid 2012).



Introduction of LPG stoves in rural areas to reduce the cutting of trees for firewood. Photo credit © UNDP

Box 9.2: Forest carbon sequestration projects

The Range and Pastures Administration, with support from the United Nations Development Programme, carried out two carbon sequestration programmes in Kassala and North Kordofan states. The Gireigikh Community Rangeland carbon sequestration project in North Kordofan promoted climate change adaptation, biodiversity conservation and the re-vegetation of degraded lands. It encouraged the adoption of sustainable rotation grazing practices, restored the balance between grazing animals and the carrying capacity of pastures, helped increase the absorption of carbon gas emission into soil and plants, supported the growing of drought-tolerant crops, and planted native trees and tree belts that stopped sand encroachment and protected the croplands of 30 farms (Elsiddig and Abdel Magid 2012; Ministry of Environment, Forestry and Physical Development 2013).

9.4 CONCLUSION

While Sudan has a long history in environmental policy-making, more effort is needed to streamline its policies and ensure that federal and state institutions cooperate to implement them properly. While some policies have proved ineffective – either because they are poorly implemented or weakly enforced – there have also been a number of success stories.

To reverse the general trend towards environmental degradation, the government will need to increase funding for environmental protection and improve the

ability of its institutions to enforce its laws. Currently its development policies seem to favour agriculture, oil and mining, to the detriment of human health and environmental protection.

Meanwhile, the government's efforts to collaborate with other countries in setting the global environmental agenda should be applauded. Its response to climate change, which is focused on increasing Sudan's ability to adapt, should help reduce the country's vulnerability and increase its resilience to conditions that are beyond the country's control and capacity.

References

REFERENCES

1. Abdelhameed, S.M., Eljack, A.O. and Abdelbagi, H.M. (2013). Jebel Al Dair Management Plan. WSRMP/IFAD. 124p.
2. Ali, S.E. and Hassan, F.M.A. (2016). The Sudan Interim-Poverty Reduction Strategy Paper Status Report: a joint World Bank and Sudan's Ministry of Finance and Economic Planning. Retrieved from: <http://documents.worldbank.org/curated/en/980991479985933855/The-Sudan-Interim-Poverty-Reduction-Strategy-Paper-Status-Report-a-joint-World-Bank-Group-and-Sudan-s-ministry-of-finance-and-economic-planning-assessment>
3. Central Bank of Sudan (2015). *55th Annual Report 2015*. Retrieved from: https://cbos.gov.sd/sites/default/files/Central%20Bank%20of%20Sudan%20Annual%20Report%202015_0.pdf
4. Elsiddig, M. and Abdel Magid, T. D. (2012). Development Strategy of the Traditional Rain-fed Agriculture, *Forestry Sector*. Report number: 12. Retrieved from: https://www.researchgate.net/publication/309727094_Development_Strategy_of_the_Traditional_Rain-fed_Agriculture_forestry_Sector
5. Elsiddig, A. M. (2013). Consultation to support the development of the National Action Plan for implementation of the Great Green Wall initiative (GGWI). FAO Sudan.
6. Food and Agriculture Organization (2006). Sudan National Forestry Policy Statement 2903-A.
7. Food and Agriculture Organization (2013). *Range and Pasture Situation in Butana Area, Gedaref State, Sudan. State Ministry of Animal Resources*.
8. Food and Agriculture Organization. (2015a). Sudan's National Action Plan for the Great Green Wall Initiative Finalized with FAO Support. Retrieved from: <http://www.fao.org/neareast/news/view/en/c/326285>
9. Food and Agriculture Organization (2015b). *A tool for institutional and policy evidence-based analysis of agriculture water management (AWM) in Sudan*. Partnership for Agricultural water for Africa (AgWa) and Food and Agriculture Organization (FAO) of the United Nations. Retrieved from: http://www.fao.org/fileadmin/user_upload/agwa/docs/IA_Sudan_Final.pdf
10. Food and Agriculture Organization (2016). Sudan National Agriculture Investment Plan (SUDNAIP) 2016–2020. Retrieved from: http://www.fao.org/fileadmin/user_upload/agwa/docs/NIP_Sudan_Final.pdf
11. Hassan and Tag Consultants (2018). *In-depth analysis of Drivers of Deforestation & Forest/Range Degradation*. Retrieved from: <https://www.reddplussd.org/phocadownload/Drivers%20of%20Deforestation%20&%20ForestRange%20Degradation.pdf>
12. International Fund for Agricultural Development (2009). Revitalizing the Sudan Gum Arabic Production and Marketing Project. President's Report. Retrieved from: <https://www.ifad.org/en/web/operations/project/id/1100001476/country/sudan>
13. International Fund for Agricultural Development (2013). *Republic of the Sudan: Country strategic opportunities programme*. Retrieved from: https://www.ifad.org/documents/38711624/40235553/sudan_cosop2013.pdf/f946886d-b51f-43f9-a4b5-a90ec59a2f12
14. International Monetary Fund (2013). *Sudan Interim-Poverty Reduction Strategy Paper*. Retrieved from: <https://www.imf.org/en/Publications/CR/Issues/2016/12/31/Sudan-Interim-Poverty-Reduction-Strategy-Paper-41025>
15. Khalifa, F., Mohamed, A. A, Al Faki, H. H., Hamid, H. I., Ibn Ouf, M. O., Adam, M. O., Omer, M. O. and Egaime, O. A. (2012). Agricultural policies in Sudan, the present and the Future, *Rakaiz Al Marifa for Research and Studies*. (in Arabic).
16. Ministry of Agriculture and Forests (2000). Forestry Outlook Study for Africa (FOSA) Sudan. Retrieved from: <http://www.fao.org/3/a-ab574e.pdf>
17. Ministry of Finance and National Economy (1992). *Ten Years National Comprehensive Strategy 1992–2002*. Khartoum, Sudan.
18. Ministry of Finance and National Economy (2015a). The Five-Year Programme for the Economic Reform 2015-2019. Ministry of Finance and National Economy. (1992). Volume one. Retrieved from: <https://www.cabri-sbo.org/en/documents/the-five-year-programme-for-economic-reform-2015-2019>

19. Ministry of Finance and National Economy of Sudan (2015b). *Impact of traditional mining of gold on the social and economic life in Sudan and on the environment*. Retrieved from: <http://www.gras.gov.sd/files/Mining%20Final.pdf>
20. Ministry of Environment, Natural Resources and Physical Development (2015). *National Biodiversity Strategy and Action Plan (NBSAP) 2015-2020*. Khartoum, Sudan. Retrieved from: <https://www.cbd.int/doc/world/sd/sd-nbsap-v2-en.pdf>
21. Ministry of Environment and Physical Development (2007). *National Adaptation Programme of Action (NAPA)*. Khartoum, Sudan. Retrieved from: <https://unfccc.int/resource/docs/napa/sdn01.pdf>
22. Ministry of Environment, Forestry and Physical Development (2013). *Sudan Sustainable Natural Resources Management Project, Integrated Land Management Action Plan (SSNRMP)*. Retrieved from: <http://documents.worldbank.org/curated/en/384871468129613741/pdf/RP15030SUDAN0S000PUBLIC00Box379856B.pdf>
23. Ministry of Irrigation and Water Resources (1999). *Sudan National Water Policy*. Khartoum, Sudan. Retrieved from: <https://www.ircwash.org/sites/default/files/824-SD99-18175.pdf>
24. Ministry of Justice.(2020). Sudan's Laws (1903-2015). Retrieved from: https://www.moj.gov.sd/sudan_laws
25. 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. Retrieved from: <https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/4168.pdf>
26. Republic of Sudan (2015). National Action Plan for the Implementation of the Great Green Wall for the Sahel and Sahara Initiative. Retrieved from: http://www.grandemurailleverte.org/images/DOCUMENTATIONS/SOUDAN/Sudan_action_plan_document.pdf
27. Saad, A, Seedahmrd, A.M., Ahmed, A. and Eldoma, A.M (2018). Combating desertification in Sudan: Experiences and Lessons Learned. A paper presented at Conference: Public private partnerships for the implementation of the 2030 Agenda for Sustainable Development. At: Geneva, Palais de Nations. Retrieved from: https://www.researchgate.net/publication/325105898_COMBATING_DESERTIFICATION_IN_SUDAN_EXPERIENCES_AND_LESSONS_LEARNED
28. 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*. Retrieved from: <https://www.usip.org/sites/default/files/resources/SR242SullivanNasallah.pdf>
29. UN Environment Programme (2008). "Wildlife and Protected Area Management." In *Sudan: Post-Conflict Environmental Assessment*. 250–273. Nairobi: United Nations Environment Programme.
30. UN Environment Programme (2012). *Environmental Governance in Sudan: An Expert Review*. Nairobi: United Nations Environment Programme. Retrieved from: http://wedocs.unep.org/bitstream/handle/20.500.11822/22127/UNEP_Sudan_environmental_governance_review_2012.pdf?sequence=1&isAllowed=y
31. UN Environment Programme and UKaid (2020). *Lessons Learned and Good Practices in Natural Resources Management*. Retrieved from: https://postconflict.unep.ch/Sudan/NRM_2020_EN.pdf
32. World Bank (2020). Sudan Sustainable Natural Resources Management Project (SSNRMP). Additional financing (Phase 2). Retrieved from: <https://projects.worldbank.org/en/projects-operations/project-detail/P161304>
33. World Food Programme (2018). Sudan Country Brief. Retrieved from: <https://reliefweb.int/sites/reliefweb.int/files/resources/WFP-0000102288.pdf>



10

Scenarios and Policy Options

10 Scenarios and Policy Options

10.1 INTRODUCTION

Sudan's current and future development is largely dependent on its rich and diverse natural capital. The country's 1.88 million km² (Sudan National Survey Authority 2018) provides plentiful arable land, rangelands, freshwater resources and minerals. Sudan's population, estimated to be 44.4 million in 2020 (Central Bureau of Statistics 2018), is made up of many different cultures and is dependent on many different livelihoods.

Despite these resources, Sudan continues to suffer from multiple economic, political, social and environmental crises, including violent conflicts, political instability, poverty and economic underdevelopment, natural resource depletion and environmental degradation. These crises are caused by a mix of human and natural dynamics such as weak governance, high population growth, drought, desertification, deforestation, land degradation and climate change and variability.

Sudan's future development path will be determined by a number of key drivers. Foremost among these are its population dynamics. Sudan's population is projected to increase to 57.3 million by 2030, with a growth rate averaging 2.4 per cent per year (Central Bureau of Statistic 2018). The resulting rise in demand for food, water, housing and other services, as well as a projected increase in the number of people migrating from rural areas to cities, could put more pressure on natural resources and lead to significant environmental change.

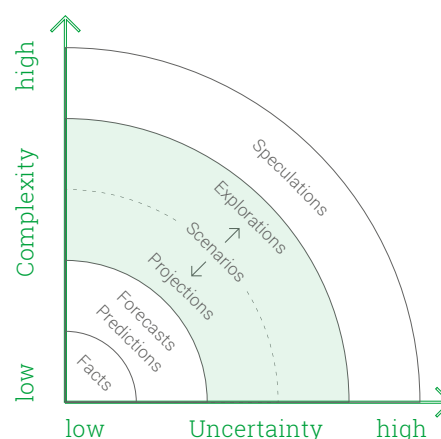
Given its location in arid and semi-arid zones, Sudan is likely to be seriously affected by climate change. Preserving its water reserves and other natural resources will be crucial. However, achieving sustainable development will be difficult unless the country resolves its violent conflicts and settles long-running disputes over land tenure. Much will depend on the country's economic growth, per capita incomes, export earnings from the extraction of natural resources, and the agricultural sector, which accounts for around 40 per cent of Gross Domestic Product (GDP) (Central Bureau of Statistic 2018).

10.2 IMAGINING THE FUTURE

Sudan's current development path is likely to have far-reaching negative consequences not only for the state of its environment but also for its economy. This final chapter explores policy options for a sustainable and peaceful future for Sudan. It focuses on two scenarios: "Business as Usual"; and "Bending the Curve", which represents an alternative pathway towards sustainable development.

Scenario building is a way to investigate the unpredictability of future developments and can be used to devise robust policy options. Scenarios are plausible and often simplified descriptions of how the future may develop, based on a coherent and internally consistent set of assumptions about key driving forces and relationships (Henrichs 2009; Mugabe et al 2010). As demonstrated in Figure 10.1, scenarios are not facts; neither are they predictions, forecasts, projections, explorations or speculations. They are descriptions about how the future might unfold. A scenario is somewhere between a projection, which is closer to the facts, and an exploration, which is of higher uncertainty and complexity.

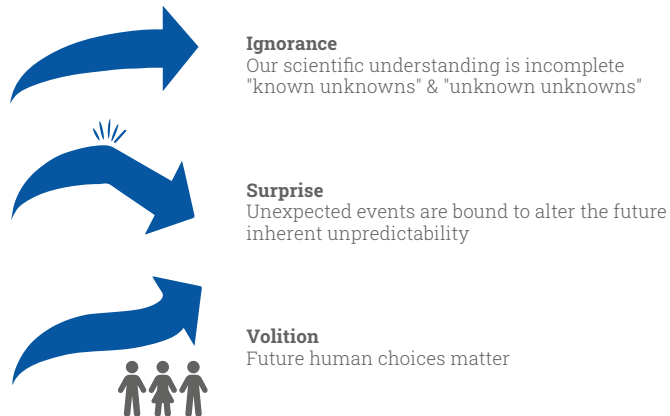
Figure 10.1 Situating scenarios within complexity and uncertainty (Henrichs 2009)



Theorists, policy-makers and decision-makers constantly have to look to the future. As depicted in Figure 10.2, looking into the future involves three key sources of uncertainty: (i) ignorance of our scientific understanding; (ii) inherent unpredictability because unexpected events are bound to alter the future; and (iii) future human choices.

10 Scenarios and Policy Options

Figure 10.2 Key sources of future uncertainty and complexity (Henrichs 2009)



One of the challenges of imagining a future scenario is to identify the key forces likely to drive change. These forces are the main factors that will influence the way a system develops, as depicted in Figure 10.3.

Driving forces tend to be demographic, policy, economic, social-cultural, political, legal, technological and environmental factors (Henrichs 2009). These and other factors combine together to produce a future scenario (Figure 10.4). Scenarios are always specific to their context. The critical question for this report is what are the most relevant scenarios for Sudan.

Figure 10.3 General scenario dynamics of an environmental system (UNEP 2006)

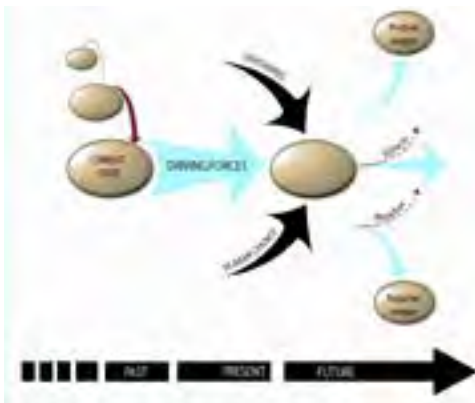
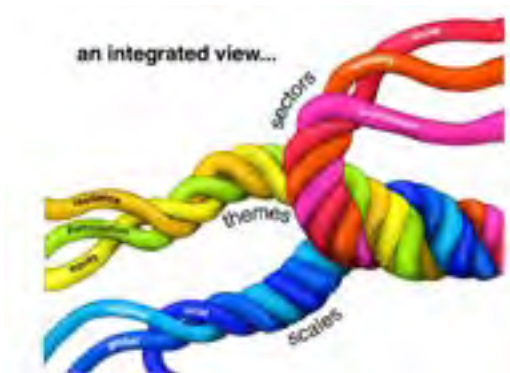


Figure 10.4 Scenario building and its integrated components (Swart 2009)



10.3 DRIVERS OF CHANGE IN SUDAN

Many factors drive environmental change in Sudan. The key ones include demographic dynamics, economic development and growth, climate change and variability, technology and innovation, urbanisation, and governance and institutional arrangements.

10.3.1 Demographic dynamics

Human population is the most important driving factor of environmental change. With an estimated population of 44.4 million and an average population density of 23 people per km², Sudan is considered sparsely populated. In reality the population density tends to follow the distribution of key resources such as water, arable land and urban settlements. The country's highest population density is in central Sudan along the River Nile and the lowest is in the desert and semi-desert areas of northern Sudan (Central Bureau of Statistics 2018). 36 per cent of the population lives in urban areas. 42.6 per cent is under the age of 15, 47.4 per cent is between 15 and 24 years old while 5.2 per cent is over 60 years old (Ministry of Finance and Economic Planning 2016). This makes Sudan's population relatively young.

A long history of adverse climate and the recurring violent conflicts in Sudan, South Sudan and neighbouring countries have resulted in a sizeable population of internally displaced persons (IDPs), refugees and returnees (Sudanese who have returned to the country but have no home). In 2018, the International Organization for Migration reported that there are approximately 2.2 million IDPs, 695,000 refugees from neighbouring countries and 105,000 returnees across Sudan (International Organization for Migration 2018). 390,000 Sudanese refugees live in camps or urban settings in neighbouring countries, in particular Egypt, Chad, Uganda, Kenya and Ethiopia. There are also between 1.2 and 1.7 million Sudanese economic migrants living mostly in the Gulf States, Europe, North America and neighbouring African countries (International Organization for Migration 2011), who contribute substantially to the country's economic development through financial remittances.

10.3.2 Economic development

The Sudanese economy is largely agrarian, with crops and livestock the main pillars of economic activity and livelihoods. Extraction of different types of natural

resources, especially minerals, is also key. The manufacturing sector is underdeveloped, contributing just 2.6 per cent to GDP, while the services sector contributes 57.8 per cent (Central Intelligence Agency 2019). Agriculture and livestock contribute 39.6 per cent to GDP (World Bank 2018b) and employ about 80 per cent of the workforce. Agriculture could contribute significantly more with sound economic development policies, more investment and better governance.

Contribution of sectors to GDP

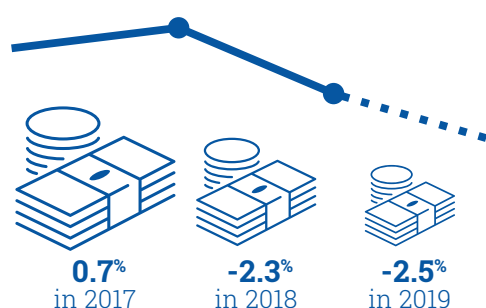


Although Sudan has a rich diversity of natural resources, it has tended to exploit only one resource at any one time. From the 1950s to the 1980s, cotton was the single main source of export revenues. After the discovery of oil in the mid-1990s, the Sudanese economy shifted its dependency to oil revenues, which accounted for over half of the government's total revenues and 95 per cent of its exports.

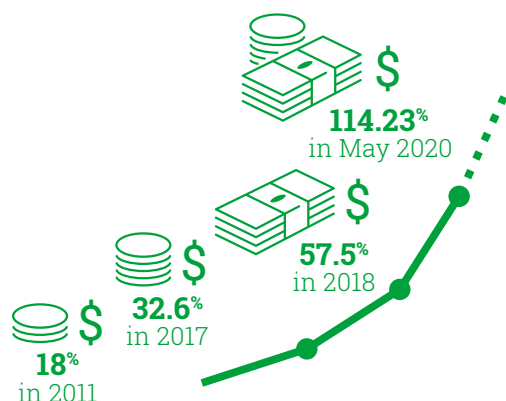
The secession of South Sudan in 2011 caused Sudan to lose three-quarters of its oil revenue, which resulted in severe and multiple economic shocks (International Monetary Fund 2017). The annual change in the growth rate, measured as real (inflation-adjusted) GDP, for the years 2017, 2018 and 2019 was 0.7 per cent, -2.3 per cent and -2.5 per cent respectively; it is likely to remain negative in the near term (International Monetary Fund 2020). The country's trade figures took a similar hit: Sudan has been recording a trade balance deficit since 2012. The 2018 deficit was 217.57 million USD, reaching 527.4 million USD in 2020 (International Monetary Fund 2020). The secession also affected inflation. The annual rate of inflation increased from 18 per cent in 2011 to 32.6 per cent in 2017, and then sharply to 57.5 per cent in 2018 (Central Bureau of Statistics 2018). A press release by Central Bureau of Statistics in May 2020 showed that the rate of inflation has soared to 114.23%.

10 Scenarios and Policy Options

Annual change in the growth rate
(measured as real GDP)



Annual rate of inflation



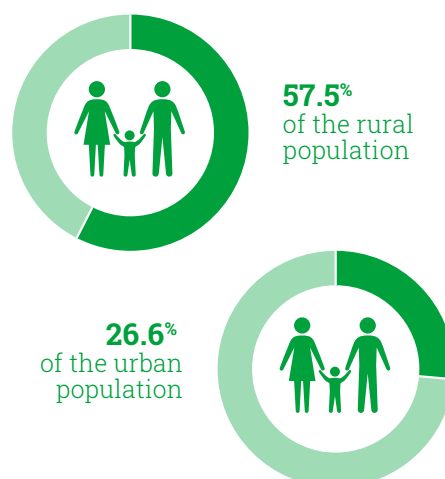
In 2013, two years after the secession of South Sudan, the country's economy was further impacted by the conflict in South Sudan between government forces and rebel factions. The conflict led to the shutdown of most oil fields in South Sudan. The situation was made worse by the decline in international oil prices; by the United States of America's economic sanctions on Sudan, which were lifted in October 2017; and by ongoing conflicts in South Kordofan, Darfur and Blue Nile states. The weak economy, compounded by a lack of basic infrastructure and the reliance by much of the population on subsistence agriculture, resulted in an increase in poverty levels in Sudan. 46.5 per cent of the population is living below the poverty line (Ministry of Finance and Economic Planning 2016)

Despite attempts by the government to increase the development of revenues from non-oil sources such as gold mining and agriculture, Sudan's economy continues to decline or stagnate. One problem is that since as far back as independence, economic

development and resources have been concentrated on the more developed regions in central and northern Sudan at the expense of underdeveloped regions in the western, southern and eastern parts. One study revealed that 51 per cent of the country's total development expenditure in 2012/2013 was allocated to Khartoum State, while only 0.2 per cent and 0.7 per cent went to the peripheral states of Blue Nile and West Darfur (Al Naeem 2015). As a result of this biased policy, most rural regions remote from the centre remain underdeveloped despite being rich in natural resources and having sizeable and productive populations.

Rural regions also suffer most from poverty, with 57.5 per cent of the rural population living below the extreme poverty line, compared with 26.6 per cent of the urban population (African Development Bank 2017). Urban communities now account for 36 per cent of Sudan's population, so addressing urban poverty is essential.

Population living below the extreme poverty line



Many of Sudan's economic problems, as well as social disruption, increasing poverty rates and political instability, can be ascribed to a large extent to the failure to fully exploit natural resources, as well as to sharp regional and social disparities in development opportunities. The result is that Sudan continues to rank far down the United Nations Human Development Index, 167 out of 189 countries (UNDP 2018).

10.3.3 Climate change and variability

Long-term climate change and short-term climate variability are the greatest development challenges of our time. Over the last century, Sudan, as part of the Sahelian zone, has experienced long alternating periods of wet and dry seasons: the 1910s were dry, the 1920s to the 1950s were wet, and it has been relatively dry, save a few wet years, since the mid-1960s (Trilsbach and Hulme 1984; van Arsdale 1989; UNEP 2007; Komey 2012). Lately Sudan has been experiencing frequent droughts, rising temperatures and low rainfall, and as a result water scarcity during dry seasons is becoming an increasing concern. The longer-term impacts of climate change include agricultural failures and a reduction in productivity, famine and food insecurity, famine degradation of fertile land, desertification, deterioration of natural resources and the associated negative effects on trade, market prices, migration and conflicts.

The boundary between semi-desert and desert has shifted an estimated 50 to 200 km southwards since rainfall and vegetation records were first kept in the 1930s, a trend that is expected to continue due to the steady decline in rainfall (Hulme 1990; Komey 2012). Although climate change could affect hydroelectric power and solar energy production, these sustainable energy sources could also be used to lessen its impact.

Despite the significant threat Sudan faces from climate change, the government has paid it little attention in its plans for economic development and natural resource governance. One example of that is the failure over the past two decades to maintain the country's meteorological records, which have been published since the 1950s. Effective resource management requires timely and accurate information about the state of natural resources, yet both the number of recording stations and the quality of data have deteriorated due to institutional failure and the impact of conflicts (Komey 2012).

10.3.4 Governance

The World Bank defines governance as the exercise of political authority and the legal use of institutional resources to manage society's problems and affairs. Good governance requires the proper functioning of government institutions with the ability to create and implement sound policies, laws, rules, regulations and customs (United Nations Development Programme Oslo Governance Centre 2010). Governance involves not just the state, but community organizations, civil

society groups, the private sector, the business community and international institutions (Nyariki et al 2010).

As it stands, Sudan's performance in environmental governance is unlikely to lead to sustainable development. The country's institutions, laws, policies and regulations on environment and natural resource management suffer from a number of problems. Foremost among these are:

- i. Lack of a comprehensive national natural resource governance framework;
- ii. Lack of a national land use strategy;
- iii. Institutional instability and weak enforcement of policies and law;
- iv. Contradictions and overlapping of laws, institutions and policies; and
- v. Lack of political will and commitment to enforce environmental laws.

This section will now deal with each of these in turn.

Lack of a comprehensive national natural resource governance framework

Sudan has never produced a comprehensive governance framework guiding the use of its natural resources. Instead, each sector – agriculture, animal resources, mining, water, forestry, and so on – has its own policies for natural resource management. These policies impact natural resources in different ways, and there is no overall vision.

Lack of a national land use strategy

As with natural resources, there is no overarching strategy governing the use of land in Sudan. As a result, competing ministries and institutions, in collaboration with different United Nations agencies such as UNDP, UNEP, IFAD and FAO, allocate and use land in their own ways, and the country's land use strategy is fragmented. For example, the following policies and laws each have their own vision for how land should be used: the National Plan for Development and Utilization of Water Resources 2014, the National Biodiversity Strategy and Action Plans of 2000 and 2015, the Sudan National Forest Policy of 2006, the Rangeland Act 2015, and the Agricultural Land Use Investment Law 2015.

Institutional instability and weak enforcement of policies and law

The institutions responsible for managing Sudan's environment and natural resources are generally weak and ineffective. An example of this is the failure to enforce the rule laid down in the Forest Act 1989 that five per cent of irrigated schemes and ten per cent of

mechanized rain-fed schemes should be planted with tree belts. Similarly, the deforestation that is happening in many parts of the country is partly due to the inability of state forestry departments to police the forests and enforce the law.

One of the problems has been the political fluidity and instability in Sudan which has meant constant change in government institutions at federal, state and locality levels. For three decades, natural resources and environmental issues have oscillated between different ministries, which has made it difficult to implement any long-term strategies or policies. The decision in September 2018 to abolish the Ministry of Environment, Natural Resources and Physical Development and demote the environment and natural resources portfolio from ministerial to council level for the first time since 1994 does not bode well, for it indicates that this sector is no longer top priority for the government. Furthermore, this change is likely to impede Sudan's efforts to attain the goals set out in the United Nations' Agenda 2030 for Sustainable Development. In April 2020, a new Higher Council for Environment and Natural Resources was established as the national environment authority.

Contradictions and overlapping of laws, institutions and policies

Sudan has passed numerous laws in its efforts to achieve sustainable management and exploitation of its natural resources (see Chapter 2, and Chapter 9 Annex 1). These include the Environmental Conservation Act 2001, the Mineral Resources and Mining Act 2015, the Law of Forests and Renewable Natural Resources 2002, the Range and Pasture Law 2015, the National Parks and Protected Areas Act 1986, and the Investment Act 2013, to name just a few. However, because of the lack of an overarching environmental policy framework, many of these laws overlap or contradict each other, or contradict other national laws and policies.

For example, the rapid growth of artisanal gold mining in Sudan is undermining most of those laws, including the Mining Wealth Law 2007. Although gold mining is an extremely important source of national revenue, current mining practices are having a catastrophic impact on the environment and natural resources. As well as altering the shape of the landscape and polluting ecosystems with chemicals like mercury and cyanide, artisanal gold mining has penetrated protected reserves, undermining the National Parks and Protected Areas Act 1986. The Songo artisanal gold mine inside Radom National Park in South Darfur is an illustration of this.

Another case where an economic activity is undermining the sustainable use of natural resources is the expansion of mechanized rain-fed farming schemes. These have resulted in deforestation and degraded soil, which contradicts the Law of Forests and Renewable Natural Resources 2002. In 2012, Gedaref state passed the Prevention of Agriculture North of 110 45' law, which is designed to prevent the spread of mechanized farming schemes beyond latitude 110 45' N where traditional rain-fed farming and livestock grazing better suit the lighter soil and lower rainfall. Despite this law, mechanized farming is still practised there.

Lack of political will and commitment to enforce environmental laws

Behind the weak enforcement and poor implementation of environmental laws lies a lack of political will. One sign of this is the government's willingness to allow foreign investors to acquire land in Sudan for agribusiness (Cotula et al 2009; Centre for Human Rights and Global Justice 2010; Deng 2011). A study by the World Bank found that from 2004 to 2009, Sudan transferred nearly four million hectares to foreign companies investing in agribusiness, the highest figure among all the countries it looked at (World Bank 2010). Another study, which investigated 102 cases of land grabbing in 21 countries in Africa and Asia, revealed that more of these cases took place in Sudan (20 cases) than anywhere else (GRAIN 2011). More recent data shows that Sudan has allocated about 1.3 million hectares to twelve global investors (GRAIN 2016).

It appears that the Sudanese government is not adhering to some of the key principles for responsible agro-investments outlined by the World Bank in its 2010 report on this issue (World Bank 2010), including the following:

- ➔ Recognizing and respecting existing rights to land and associated natural resources;
- ➔ Ensuring transparency, good governance and accountability of all stakeholders within a proper legal system;
- ➔ Investors are to ensure that projects respect the rule of law, reflect best practices and are economically viable;
- ➔ Investors adhere to corporate social responsibility; and
- ➔ Investment must be sensitive to environmental sustainability.

10 Scenarios and Policy Options

Without proper arrangements that ensure the sustainable use of natural resources, these agri-business investments are likely to have negative implications for Sudan's environment.

10.4 FUTURE SCENARIOS

This section considers two possible scenarios for a future Sudan. The first scenario – Business as Usual – considers what might happen if the country continued on its current development path. The second scenario – Bending the Curve – envisages a change of direction towards the United Nations Sustainable Development Goals (SDGs) and the 2030 Agenda for Sustainable Development. In each case, we reflect on the themes explored at length in the previous chapters – atmosphere, land, water, biodiversity, persistent environmental issues and emerging environmental issues – as well as the likelihood of Sudan achieving the goals of the Agenda 2030 for Sustainable Development.

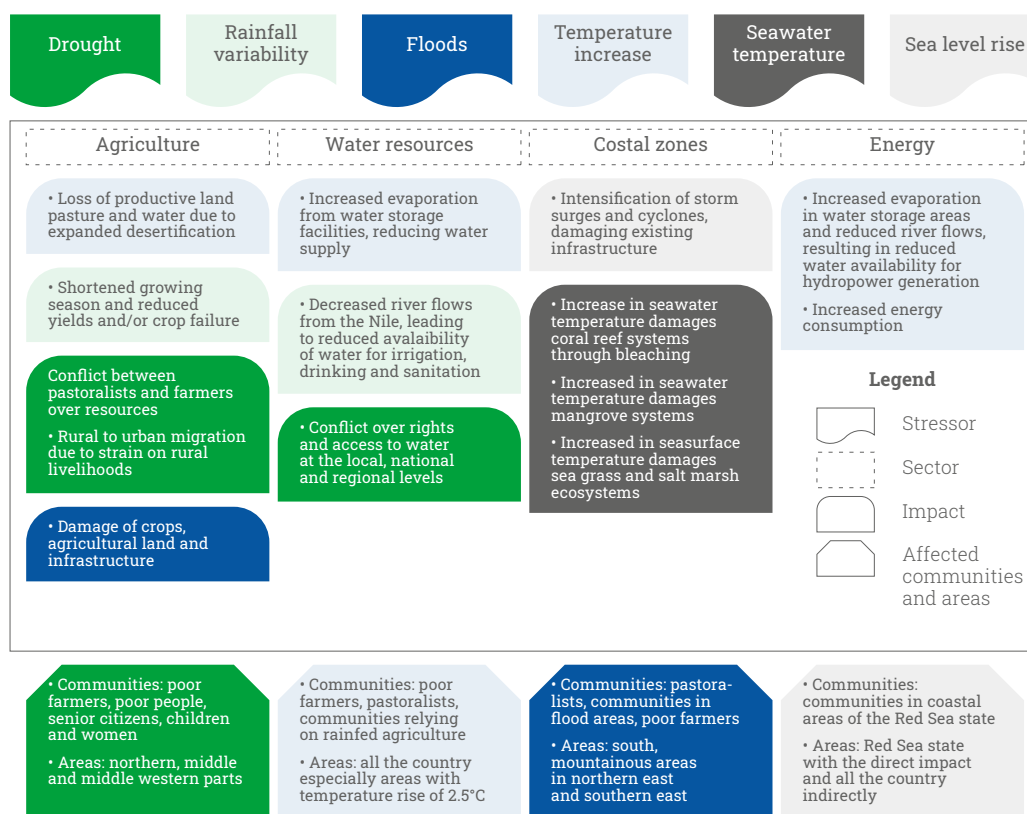
10.4.1 Business as usual scenario

Atmosphere

Air pollution has recently become an issue of great concern in Sudan. The country has many laws on environmental pollution – the Environmental Health Act 2009, the Labour Act 1997, the Pesticides and Pest Control Products Act 1994, the Environment Protection Act 2001, among others – yet none of them contains standards for air quality. With urbanisation, industry and transport systems set to grow, air pollution is likely to get worse, particularly with weak institutions, ineffective policies and the lack of law enforcement.

Sudan has been experiencing the effects of climate change for some time, including increasing temperatures, rainfall variability, droughts and floods. Average temperatures are projected to increase by up to 3°C by 2050, rainfall is projected to decrease by 4 per cent per decade, and Sudan will experience increased frequency of both droughts and floods (United States

Figure 10.5 Climate stressors and their potential impact on sectors, areas and communities (modified from Siddig et al. 2018)



Agency for International Development 2016). Figure 10.5 summarizes the potential effects of the major climate stressors, including drought, rainfall variability, floods, temperature increases, seawater temperature increases and sea level rise on natural resources and communities in Sudan.

In a country where agriculture is a major contributor to GDP and people's livelihoods, and where 93 per cent of cultivated land is rain-fed, the impact of climate change is critical to future development paths. Climate change increases the vulnerability of certain communities, such as poor farmers, pastoralists and others that rely on rain-fed agriculture. Without policies that help them adapt, it will be extremely difficult for Sudan to attain the goals of Agenda 2030 for Sustainable Development.

Land

Disputes over land tenure and rights of ownership, access and use of land have been at the heart of many conflicts in Sudan. The problems are partly due to the country having two land tenure arrangements: a statutory system, based on civil laws and institutions, and a customary system, which derives from tribal territorial rights. The two systems have never been integrated, which has created a confused legislative environment. The result is recurring tensions, violent conflict and civil war.

Urban settlement, agriculture, livestock, industry and mining all require land. Demand for land increases with economic development and population growth. With the secession of South Sudan in 2011, the country lost 24.7 per cent of its land area (Sudan National Survey Authority 2018). Under the business as usual scenario, Sudan's population will continue to grow at 2.8 per cent per year, increasing from the estimated 44.4 million in 2020 to 57.3 million in 2030 (Central Bureau of Statistic 2018).

At the same time, Sudan's agricultural productivity is decreasing. In the 2017–2018 growing seasons, the country recorded the lowest sorghum yield in Africa: 225 kg per feddan compared with 2,142.86 kg per feddan in Egypt, 837.78 kg per feddan in Ethiopia, 489.72 kg per feddan in Nigeria, 416 kg per feddan in Mali and 400 kg per feddan in Burkina Faso (USA Agricultural Department 2018)¹. As the population grows and productivity goes down and the country loses more land to degradation, the amount of food produced per capita will decrease, particularly without

more appropriate farming technologies and management systems. Worse, farmers will be forced to encroach onto fragile and marginal lands and ecosystems, further diminishing productivity and accelerating environmental deterioration.

Despite some attempts towards land reform, little has been achieved. For example, the Interim National Constitution of 2005 called for the establishment of land commissions at federal and state levels, but this has not happened because of a lack of commitment by the federal government. Only the Darfur Land Commission was formed based on the Darfur Peace Agreement in 2006. It seems clear that under current policies and without effective land reforms, Sudan will not meet its global and national goals for food security, poverty and zero hunger under the SDGs, and peace and political stability will remain out of reach.

Water Resources

Despite substantial water resources such as rivers, seasonal streams, lakes and aquifers, Sudan is classified as a water-scarce country. This is due to several factors, including its failure to use its water resources effectively, limited water harvesting, a decreasing storage capacity in its reservoirs due to siltation and the accumulation of debris, pollution, unregulated economic development, poor water governance and climate change. The demand for water is rising in many sectors including domestic consumption, agriculture, industry and hydropower, and is bound to increase more rapidly as urbanisation and rural development grow. The country's per capita water availability is estimated around 700 m³ per person per year based on the 2020 projected population of 44.4 million and the Falkenmark Indicator (White 2012), which is significantly below the "water stress margin" of 1000 m³ per capita.

The scarcity of water presents many challenges. As Chapter 5 demonstrates, only 58.7 per cent of people in Sudan have access to safe drinking water (69.4 per cent in urban areas, 51.6 per cent in rural areas), while 40 per cent of basic schools suffer water shortages. Water scarcity threatens food security and energy generation. In rural areas away from the Nile, lack of access to safe water is hindering socio-economic development and environmental conservation. It also causes conflict between pastoralists and farmers that can escalate to a serious level, as demonstrated in Darfur.

¹ 1 hectare = 2.38 feddan.



Sudanese, especially women, will continue suffering finding sufficient clean water. Photo credit © UNDP

One of the policy solutions to the water problem in Sudan is the Zero *Attash* or Thirst programme, which began in 2016 and aims to ensure that everyone in rural parts of the country is within 500 metres of a reliable water supply by the year 2020. However, it has not yet materialized, and its activities are almost on hold following the popular political movement that ended the previous regime in 2019. Under the business as usual scenario, Sudan's water stress condition is expected to become more acute and is likely to impede its progress towards meeting the SDGs, 14 of which are related to water in one way or another.

Biodiversity

After years of desertification and cycles of droughts, many biodiversity-rich areas in Sudan are under threat, with an unknown number of flora and fauna species disappearing. Many activities related to economic development, such as overgrazing, overcultivation, mechanized farming and artisanal gold mining, have had far-reaching negative impacts on biodiversity.

Deforestation due to mechanized farming is rife in Gedaref, Blue Nile, Sennar, South Kordofan and South Darfur states. Sudan's forest area declined steadily from more than 40 per cent of the country's area in the 1950s to 27 per cent at the beginning of the millennium, before declining further to 10.3 per cent in 2015 due to agricultural expansion and the rising demand for wood for energy and construction. The loss of biodiversity and ecosystem services as a result of deforestation affects people's health, livelihoods and food security. It also threatens the country's sustainable development.

Persistent Issues

The most serious persistent environmental problems in Sudan are desertification, pollution from pesticides, and various types of waste (solid, plastic, medical, industrial and wastewater).

Despite the government's efforts to combat desertification, the problem is getting worse at the expense of farming and grazing land, fertile soil, vegetation cover and water sources. Over the last two decades, desertification has been accelerating (Laki 2009). Recently, the Secretary-General of the National Council for Combating Desertification warned that there is an increase of the desertification in the Sahara Desert by 10 per cent (Alshrooq Network 2019).

Pesticides are used in almost all major agricultural schemes in Sudan. Despite their usefulness, pesticides have caused great harm to the environment due to poor quality control and the lack of controls on their

transportation, storage and use. Stored pesticides regularly leak into the environment because of deteriorating storage facilities, with serious effects on human health and air and water quality. Given the ineffectiveness of current policies and the lack of institutional control, pesticides will continue to be a threat to Sudan's environment.

Due to population growth and changing production and consumption patterns, the quantity of all types of waste produced in Sudan is on the increase. Sudan suffers from limited waste disposal facilities, weak enforcement of laws, and a lack of institutional capacity to deal with solid waste. Sanitation, sewage and wastewater facilities are lagging behind the growth of settlements. This is likely to have an increasing impact on the environment, particularly in the Greater Khartoum area and other urban centres. If the situation prevails, it will be difficult to achieve SDGs in the areas of good health, clean water and sanitation, sustainable cities and communities, life below water and life on land.

Emerging Issues

Artisanal gold mining is becoming a key driver in Sudan's economy. It is encouraged by the government as a way of filling the drop-in oil revenues that followed the secession of South Sudan. Despite the economic gains, the sector is poorly organized and regulated and as a result it is having a far-reaching impact on Sudan's environment, human health and local livelihoods. The lack of control has resulted in increased competition over land, the proliferation of community-based conflicts, land degradation, the loss of agricultural and pastoral land to mining, disturbance of the ecosystem, and pollution of water, air, soil and rangelands.

Artisanal gold miners are exposed to numerous health and safety hazards, largely due to the use of mercury in the leaching and washing process. Mercury is poisonous to humans and other species: chronic exposure damages the neurological system causing sensory, motor and cognitive disorders. There are no training or public awareness campaigns to promote a more responsible use of mercury. Furthermore, millers and crushers at the mining sites are at risk of inhaling siliceous dust particles which leads to respiratory problems and diseases. Mine workers often have to drink polluted water. Nearby surface and ground waters are threatened by pollution with mercury and cyanide acid drainage (El Tohami 2018). The goals and targets under Agenda 2030 can hardly be achieved under such conditions.

10.4.2 Bending the curve scenario

Atmosphere

Sudan's policies to combat air pollution and climate change, such as the National Adaptation Programme of Action and the National Adaptation Plan, are inadequate to address the major issues of increasing temperatures, rainfall variability, drought and crop failure. To respond effectively to climate change and atmospheric and air pollution, the government should adopt policies that address the following issues:

- ➔ A management system for water resources that delivers safe drinking water while enhancing agricultural productivity;
- ➔ Guaranteed food security for both humans and animals;
- ➔ A national land use plan that guides all development;
- ➔ The appropriate use of natural resources;
- ➔ The closing of any gaps in legislation related to environmental protection and natural resource governance; and
- ➔ A national early warning system to ensure timely and appropriate responses to climate change.

Under this new policy scenario, Sudan would accelerate investments in clean energy, reduce indoor air pollution caused by the use of biomass fuels, mitigate the impacts of climate change by meeting its current target for planting tree belts, and improve water use efficiency in food production.

Land

Alternative policies on land tenure, ownership and access rights are badly needed. In the Bending the Curve scenario, the government would harmonize the country's two land tenure systems and carry out the commitment laid out in the Interim National Constitution of 2005 to establish land commissions at federal and state levels. It would also enable the registration of all unregistered land in Sudan and give legal recognition to those with land rights under the traditional customary system, including the ability to access agricultural funding from banks. A restitution law that allowed refugees and IDPs to return to their land in conflict-affected regions would help Sudan meet its targets for ensuring peace and political stability under the Agenda 2030 for Sustainable Development.

Water Resources

Under the Bending the Curve policy scenario, Sudan would introduce integrated water resources management to coordinate the management of water and other resources and ensure that the country's abundant supplies of water were made available to those who need them. Water harvesting techniques would be enhanced and scaled up. Managed like this, water resources would play a key role in boosting the economy and improving people's quality of life.

To achieve this, the government would carry out the following actions:

- ➔ Assessment of the Zero *Attash* or Thirst programme to identify and correct the policies and institutional weaknesses that have held back this initiative;
- ➔ Review all laws, institutions and enforcement mechanisms related to water resource management; and
- ➔ Introduce a new national water policy that would bring water resources under one institution instead of its current fragmentation among different ministries and departments.

With the new suite of policies, Sudan would achieve its targets under the SDGs, including those for safe drinking water, sanitation and food security. It would also benefit from stronger regional cooperation through the Nile Basin Initiative, resulting in a more transparent and equitable distribution of water from the Nile River.



Modern efficient irrigation techniques are encouraged in the future agricultural scenarios in Sudan. Photo credit © UNEP

Biodiversity

Much of Sudan's rich and diverse biodiversity has been affected by civil war, climate change, drought, overgrazing, the imprudent use of natural resources, the expansion of mono-crop agriculture at the expense of natural forests, poaching and wildlife smuggling. More effective national policies are needed to ensure that institutions at all levels prioritize biodiversity when implementing the country's development plans in coordination with the country's National Biodiversity Strategy and Action Plan. Expanding the area of land and water under protection would ensure that Sudan achieved its targets under the Convention on Biological Diversity.

Persistent Issues

The following alternative national policies are needed to deal with Sudan's major persistent environmental problems of desertification, pesticides and waste:

- ➔ Strengthen the institutions responsible for dealing with persistent issues and improve their technical and financial resources;
- ➔ A national legal framework, backed by a strong monitoring system and law enforcement mechanisms, to ensure compliance over the management of persistent issues; and
- ➔ A mechanism to ensure that the management of persistent problems is integrated into national development plans.

With the right policies in place, Sudan should be able to slow down the southwards advancement of the Sahara Desert, rehabilitate all areas contaminated with persistent organic pollutants, and stop the import of all banned pesticides.

Emerging Issues

To address major emerging environmental issues such as artisanal gold mining, the following alternative policies are suggested:

- ➔ Put in place well-equipped institutions with the capacity to enforce laws and policies relating to oil and gold mining companies;
- ➔ Ensure that oil and mining companies comply with their corporate social responsibilities, including providing compensation to any communities or individuals affected by their activities;
- ➔ Make it mandatory for companies to carry out environmental and social impact assessments and to integrate the findings in all their economic activities; and
- ➔ Introduce a total ban on the use of mercury in gold mining so that Sudan meets its obligations under the Minamata Convention on Mercury.

10 Scenarios and Policy Options

Under the Bending the Curve scenario, the government would also address other emerging environmental issues, for example by introducing a national environmentally friendly mass transport system to force polluting rickshaws off the roads and boosting investment in clean forms of energy such as solar, wind and hydropower in place of electric generators.

10.4.3 Business as Usual versus Bending the Curve

Table 10.1 summarizes how the Bending the Curve scenario, with its coordinated policies and legal frameworks, would shape the future of sustainable development in Sudan. It is expected that the alternative policies would “bend the curve” by reversing current negative trends on some key issues and reshaping the country’s direction on population, the economy, environment, equity/equality, technology, conflict, and urbanisation (Figure 10.6).



Sudan's future energy policies should boost investment in clean forms of energy such as the solar energy station in North Darfur.
Photo credit © UNEP

10 Scenarios and Policy Options

Table 10.1 Business as Usual versus Bending the Curve

Key Issue/Factor	Business as Usual scenario Current state (no change in policies)	Bending the Curve scenario Future state (change in policies)
Population	<ol style="list-style-type: none"> 1. High population growth rates 2. Massive rural-urban migration 3. High birth rates and high mortality rates 	<ol style="list-style-type: none"> 1. Moderate population growth rates 2. Decreasing rural-urban migration 3. Moderate birth rates and low mortality rates
Economic Growth and Development	<ol style="list-style-type: none"> 1. Low economic growth rates (economic inefficiency) 2. Widening regional and social inequity and disparities in national development (economic inequality) 3. Dependency on single or few natural resources 4. Non-agricultural based economic investments 5. Primary and raw material exports 6. High and rising poverty rates 7. Rising deficit in balance of trade 8. Recurring food insecurity and insufficiency associated with pressure on environment and natural resources 9. Poor performance in the implementation of the SDGs, resulting in Sudan lagging behind on the Human Development Index 	<ol style="list-style-type: none"> 1. High to moderate economic growth rates (economic efficiency) 2. Socially and spatially balanced and equitable development (economic equality) 3. Broad-base and diversified economic production sources 4. Agricultural-based smart economic investments 5. Processed or manufactured exports 6. Low and decreasing poverty rates 7. Decreasing deficit and eventually surplus in balance of trade 8. Food security and sufficiency given priority in national economic strategy 9. Review and strengthen institutions, policies and mechanisms relevant to the SDGs while improving Sudan's Human Development Index ranking
	<ol style="list-style-type: none"> 1. Federal environment and natural resources policy framework run by sector-led ministries that don't coordinate 2. Environment and natural resources policy framework at state and locality levels run by institutions that do not coordinate 3. Competing regimes and overlapping regulations, laws and legislations related to environment and natural resource governance 4. Weak culture of public awareness of environmentally sound development at individual, societal and institutional levels 	<ol style="list-style-type: none"> 1. Coordinated environment and natural resources policy framework run by multi-stakeholders 2. Coherent and coordinated institutional policy framework at state and locality levels 3. Establishment of coherent and integrated environment and natural resources governance framework 4. Promotion of a culture of environmentally sound development






















10 Scenarios and Policy Options

Table 10.1 continued

Key Issue/Factor	Business as Usual scenario Current state (no change in policies)	Bending the Curve scenario Future state (change in policies)
Land Tenure System and Rights	<ol style="list-style-type: none"> 1. Dualism land tenure with statutory and customary systems, and no legal recognition of land rights based on customary ownership 2. Absence of comprehensive national land use map which leads to misuse of environment and natural resources 3. Increasing numbers of poor and landless individuals and communities resulting in more pressure on environment and natural resources and increase in violent conflicts 4. Lack of political will and commitment to establish land commissions at federal and state levels even though enshrined in the Interim National Constitution of 2005 	<ol style="list-style-type: none"> 1. Harmonization of land regulations and laws and integration of customary rights into statutory law according to the best international experiences and practices 2. Development of comprehensive national land use map to guide sustainable use and management of environment and natural resources 3. Policy reform to empower the poor and landless to access productive land and natural resources for their livelihoods and food security, with a resulting reduction in poverty and violent conflict 4. Establishment of land commissions at federal and state levels to lead the process of land reform
Climate Change and Variability	<ol style="list-style-type: none"> 1. Frequent droughts, rising temperatures and rain shortages with negative consequences for population, economy, natural resource capital and the entire environment 2. Agricultural failures and reduction in productivity resulting in food insecurity and famines 3. Degradation of fertile land, desertification and deterioration of natural capital 4. Climate-driven migrations and conflicts 	<ol style="list-style-type: none"> 1. Development and introduction of comprehensive and integrated national strategy for mitigation of and adaptation to climate change and variability 2. Adoption of drought-resilient crops and improved agricultural technologies and farm management techniques 3. Land reclamation, revitalization of the National Action Programme to Combat Desertification, and sustainable use of natural resources 4. Rehabilitation of climate-affected areas
Political State of Affairs	<ol style="list-style-type: none"> 1. Perpetual political disarray, associated with multiple contests and disputes over the fundamentals of a modern state, e.g. national identity and national permanent constitution 2. Protracted and recurring civil wars and violent conflicts due to many interwoven factors and motives 3. Weak political will and commitment towards some international conventions related to sustainable use and management of environment and natural resources 	<ol style="list-style-type: none"> 1. National consensus through genuine and inclusive dialogue on issues such as the sharing of wealth and power, political governance and socio-cultural diversities 2. A just, inclusive and lasting peace agreement that addresses the causes of civil wars and violent conflicts nationwide 3. Review and reinforcement of Sudan's membership in key international and regional organizations and agreements related to sustainable environment and natural resource management

10 Scenarios and Policy Options

Figure 10.6 Expected changes in direction in response to alternative policies under Bending the Curve scenario (Komey)

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

10.5 POLICY OPTIONS FOR FUTURE SUSTAINABLE DEVELOPMENT

10.5.1 Policy options

One thing this report has demonstrated is that Sudan is lagging behind in its efforts to meet its commitments under the SDGs. The key question is what alternative policies would help Sudan achieve a more sustainable future. Table 10.2 highlights some specific policy options that would steer the country closer to the SDG targets, as part of the Bending the Curve scenario.

10 Scenarios and Policy Options

Table 10.2 Future alternative policy options and their relevance to the SDGs (Komey)

Factors	Specific Issues	Policy Options	Targeted SDGs
Population and Demographic Dynamics	<p>High illiteracy rate</p> <p>Slow and weak progress towards gender equality in national policies, plans and education</p> <p>Environmentally destructive consumption and production</p>	<p>Promotion of literacy</p> <p>Acceleration of gender and youth mainstreaming in national policies, plans and education</p> <p>Promotion of environmentally friendly consumption and production</p>	<p>Quality Education (4)</p> <p>Gender Equality (5)</p> <p>Responsible Consumption and Production (12)</p>
Land and Agricultural Development	<p>Land tenure dualism associated with conflicts</p> <p>Competing, overlapping and uncoordinated land policy frameworks. Less focus on agricultural investments and infrastructure</p> <p>Increasing number of landless people, particularly rural women and poor households</p>	<p>Increase agricultural productivity through changes in funding, appropriate technologies and marketing</p> <p>Undertake land and institutional reforms</p> <p>Harmonization and integration of land tenure systems</p> <p>Policy shift in national investment and development towards agricultural sector</p>	<p>No Poverty (1)</p> <p>Peace, Justice and Strong Institutions (16)</p> <p>Gender Equality (5)</p> <p>Responsible Consumption and Production (12)</p>
Economic Growth and Development	<p>High dependency on natural resources</p> <p>Low productivity and production</p> <p>Low economic growth</p> <p>Sustained deficit in balance of trade</p> <p>High and rising unemployment among the youth</p> <p>Weak economic institutions associated with misappropriation of economic resource and natural capital</p>	<p>Diversification of economic production among different sectors and regions</p> <p>Policy, institutional and legal reforms of economic sector</p> <p>Review and revitalization of agricultural sector</p> <p>Promotion of agro-business and agriculture-related manufacturing and processing industries</p>	<p>No Poverty (1)</p> <p>Zero Hunger (2)</p> <p>Good Health and Well-being (3)</p> <p>Decent Work and Economic Growth (8)</p> <p>Reduced Inequalities (10)</p> <p>Peace, Justice and Strong Institutions (16)</p>

10 Scenarios and Policy Options

Table 10.2 continued

Factors	Specific Issues	Policy Options	Targeted SDGs
Urbanisation and Rural Development	<p>Massive and sustained rural to urban migration</p> <p>Urban-biased development policies, particularly in physical and social services (roads, water, education, health)</p> <p>Lack of national strategy that integrates rural and urban production functions</p>	<p>Balanced and integrated development</p> <p>Establishment of national land agency to coordinate national physical planning</p> <p>Shift focus towards rural development and investments</p> <p>Adoption of urban physical strategy that curbs unplanned settlement without services</p>	<p>Sustainable Cities and Communities (11)</p> <p>Peace, Justice and Strong Institutions (16)</p> <p>No Poverty (1)</p> <p>Decent Work and Economic Growth (8)</p> <p>Reduced Inequalities (10)</p> <p>Clean Water and Sanitation (6)</p>
Governance and Institutions	<p>Weak and non-coordinated national governance frameworks</p> <p>Absence of enforcing mechanisms and regulations</p> <p>Lack of good governance, transparency and accountability</p>	<p>Introduction of policies aimed at strengthening institutions</p> <p>Promotion of principles of good governance, transparency and accountability</p>	<p>Peace, Justice and Strong Institutions (16)</p> <p>Partnerships for the Goals (17)</p>
Technological Changes and Innovations	<p>Weak or no national policies that encourage promotion of appropriate technologies</p> <p>Weak or no academic or training institutions that promote innovation and industrial research and development</p> <p>Lack of comprehensive and consistent policies that promote collaboration between public and private institutions</p>	<p>Initiation of national policies that guide and promote technological changes and innovations in different sectors particularly in agriculture and agro-industrial activities</p> <p>Introduction of national policies that make research and development a top priority in national development strategy</p> <p>Implementation of consistent policies that promote collaboration between public and private institutions in technology and innovations</p>	<p>Industry, Innovation and Infrastructure (9)</p> <p>Responsible Consumption and Production (12)</p> <p>Decent Work and Economic Growth (8)</p>

10 Scenarios and Policy Options

Table 10.2 continued

Factors	Specific Issues	Policy Options	Targeted SDGs
Climate Change and Variability	<p>Sudan is lagging behind in achieving the Climate Action SDG (13)</p> <p>Climate change and variability are some of the main causes of declining natural capital, agricultural productivity and food insecurity in Sudan</p> <p>Climate resilience and adaptation initiatives and projects in Sudan are mostly driven and funded by external donors or agencies</p>	<p>Acceleration and intensification of adaptation and resilience measures such as drought-resistant and early maturing crop varieties, crop husbandry practices, soil and water management and agro-forestry</p> <p>Promote the spread and adoption of promising technologies by increasing agricultural extension services</p> <p>Acceleration of Sudan's engagement with the Climate Action SDG (13)</p>	<p>Climate Action (13)</p> <p>Life on Land (15)</p> <p>Life below Water (14)</p> <p>Responsible Consumption and Production (12)</p> <p>No Poverty (1)</p>
Environment, Natural Resources and Biodiversity	<p>No national environment and natural resource governance framework in Sudan</p> <p>Different components of environment and natural resources are scattered across different government sectors, driven by competing policies and plans, and with no integration</p> <p>Most initiatives and projects aimed at sustainable management of the environment and natural resources are externally driven and/or funded</p> <p>Too little attention is paid to conservation of biodiversity, especially threatened ecosystems and species</p>	<p>Initiation of an inclusive national exercise to establish a natural resource governance framework for Sudan</p> <p>Strengthening and reinforcement of natural resource policies at federal, state, local and community levels (vertical alignment), as well as across different sectors (horizontal alignment)</p> <p>Establish a national institution, independent of all ministries, with legal and administrative power to initiate and enforce policies and regulations on biodiversity, natural resources and the environment</p>	<p>Clean Water and Sanitation (6)</p> <p>Affordable and Clean Energy (7)</p> <p>Responsible Consumption and Production (12)</p> <p>Life below Water (14)</p> <p>Life on Land (15)</p> <p>Peace, Justice and Strong Institutions (16)</p>

10 Scenarios and Policy Options

Table 10.2 continued

Factors	Specific Issues	Policy Options	Targeted SDGs
Equity and Equality	<p>Rising social, inter-regional and intra-regional disparities in development</p> <p>Increasing poverty rate associated with destructive exploitation of environment and natural resources</p> <p>Fragile state institutions associated with poor governance, socio-political disruption, conflict, injustice and inequality</p>	<p>Creation of national policies aimed at equitable socio-economic development and sustainable environmental and natural resource management</p> <p>Increase level of political commitment towards poverty reduction</p> <p>Establish a just and lasting peace and begin process of state-building and national integration</p>	<p>Gender Equality (5)</p> <p>Reduced Inequalities (10)</p> <p>Peace, Justice and Strong Institutions (16)</p>



Universities and research centers are the custodians of sustainable development-oriented scientific research. Photo credit © UNEP



With a new suite of policies, Sudan would achieve its target under the SDGs.

10.5.2 Sudan in 2030

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.

10 Scenarios and Policy Options

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 (*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 organize themselves into groups so that they can jointly use ore-processing facilities and organize 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 a significant decrease in rickshaws, 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. Meanwhile, land degradation has been controlled, desertified lands are reclaimed, afforestation programmes are implemented and the vegetation cover is increased. Stockpiles of obsolete pesticides are destroyed, while contaminated soils and water are remediated.



Sudan aspires to accelerate gender and youth mainstreaming in national policies, plans and education. Photo credit © Sari Omer



Sudan aspires to accelerate gender and youth mainstreaming in national policies, plans and education. Photo credit © Sari Omer

References

REFERENCES

1. African Development Bank (2017). Sudan Country Brief 2017–2019. Retrieved from: <https://www.afdb.org/en/documents/document/sudan-country-brief-2017-2019-98653>
2. African Development Bank (2018). Sudan Poverty Profile: Summary Results of the 2014-2015 National Baseline Household Budget Survey. Retrieved from: https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Brief-Sudan_Poverty_Profile_2014-2015_-_Key_Findings.pdf
3. Al Naeem, A. A. (2015). Institutional Reforms for Fiscal Federalism in Sudan. Paper presented at Workshop on “harmonization of Economic Reform in Sudan”. UNICONS Consulting for a Prosperous Sudan (in Arabic). Retrieved from: <http://unicons.org/Portals/0/Publications/Fiscal%20Federalism%20paper-final.pdf>
4. Alshrooq Network (2019). Warning of the danger of increasing rates of desertification in Sudan. Retrieved from <https://desertification.wordpress.com/2019/10/07/warning-of-the-danger-of-increasing-rates-of-desertification-in-sudan>
5. Assal, M. (2008). Urbanization and the future of Sudan. African Arguments. Retrieved from <https://africanarguments.org/2008/01/29/urbanization-and-the-future>
6. Central Bureau of Statistics (2018). Sudan Projected Population, Distribution by States, 2016 – 2022; Censuses and Social Statistics Department. Khartoum.
7. Central Intelligence Agency (2019). The World Factbook: Sudan. Retrieved from: <https://www.cia.gov/library/publications/the-world-factbook/geos/su.html>
8. Centre for Human Rights and Global Justice (2010). *Foreign Land Deals and Human Rights: Case Studies on Agricultural and Biofuels Investment*. New York: NYU School of Law.
9. Cotula, L., Vermeulen, S., Leonard, R., and Keeley, J. (2009). *Land Grab or Development Opportunity? Agricultural Investment and Land Deals in Africa*. IIED/FAO/IFAD: London/Rome.
10. Deininger, K., Byerlee, D., Lindsay, J., Norton, A., Selod, H. And Stickler, M. (2011). *Rising global interest in farmland: can it yield sustainable and equitable benefits?*. Agriculture and rural development. Washington, DC: World Bank. Retrieved from: <http://documents.worldbank.org/curated/en/998581468184149953/Rising-global-interest-in-farmland-can-it-yield-sustainable-and-equitable-benefits>
11. Deng, D. K. (2011). *The New Frontier: A Baseline Survey of Large-scale Land-based investment in Southern Sudan*. Oslo, Norway. Retrieved from https://reliefweb.int/sites/reliefweb.int/files/resources/6F0B144DA275260B8525785C0069D-B6A-Full_Report.pdf
12. El Tohami, A.E. A. (2018). Smart Artisanal Gold Mining from a Sudanese Perspective. *Biomedical Journal of Scientific & Technical Research*, 8 (5), 6700- 6706 Retrieved from: DOI: 10.26717/BJSTR.2018.08.001704
13. GRAIN (2011). *Land Grabbing and the Global Food Crisis*. [Paper presentation] Barcelona, Spain. Retrieved from <https://www.grain.org/article/entries/4164-land-grabbing-and-the-global-food-crisis-presentation?print=true>
14. GRAIN (2016). The Global Farmland Grab in 2016: How big, how bad? Retrieved from <https://www.grain.org/article/entries/5492-the-global-farmland-grab-in-2016-how-big-how-bad>
15. Henrichs, T. (2009). Environmental Scenario Analysis. METIER Training Course No 7- MODULE 1. National Environmental Research Institute University of Aarhus – Denmark. Retrieved from: https://www.peer.eu/files/user_upload/user_upload/opportunities/metier/course7/c7_environmental_scenarios_introduction.pdf
16. Hulme, M. (1990). *The changing rainfall resources of Sudan*. Transactions of the Institute of British Geographers. 15(1), 21-34.
17. International Monetary Fund (2017). Sudan Article IV Consultation Press Release: Staff Report and Statement by the Executive Director of Sudan. Country Report No. 17/3634. Retrieved from: <https://www.imf.org/en/Publications/CR/Issues/2017/12/11/Sudan-2017-Article-IV-Consultation-Press-Release-Staff-Report-and-Statement-by-the-Executive-45456>

18. 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>
19. International Organization for Migration (2011). Migration in Sudan, Country Profile. Retrieved from: https://reliefweb.int/sites/reliefweb.int/files/resources/D2ECC0D6226DF41D-C1257842003973F1-Full_Report.pdf
20. International Organization for Migration (2018). Sudan 2018. Humanitarian Compendium. Retrieved from <https://humanitariancompendium.iom.int/appeals/sudan-2018>
21. Kahn, H. and Wiener, A. J. (1967). *The Uses of Scenarios*. Hudson Institute. Retrieved from <https://www.hudson.org/research/2214-the-use-of-scenarios>
22. Komey, G. K. (2010). Land, Governance, Conflicts and the Nuba of Sudan. London: James Currey.
23. Komey, G. K. (2012). Climate change and recurrent conflicts: An interplay between nature and humans. *New Routes: A journal of peace research and action*. 17(2), 34–38.
24. Laki, S. L. (2009). Desertification in the Sudan: causes, effects and policy options, *International Journal of Sustainable Development & World Ecology*. 1 (3) 198–205.
25. Ministry of Finance and Economic Planning (2016). The Economic Exhibition – 2016.
26. Mugabe, P. H., Ochola, W. O. and Yemshaw, Y. (2010). Research in Natural Resource Management, in W. P. Ochola, P. Sanginga and I. Bekalo (Eds.), *Managing Natural Resources for Development in Africa: A Resource Book*. (pp. 449–506). IDRC, IIRR and RUFCA: University of Nairobi Press.
27. Nyariki, D., Sanginga, P., Yemshaw, Y. and Kakuru, W. (2010). Policy and Governance in Natural Resource Management, in W. Ochola, P., Sanginga, and I. Bekalo (Eds.). *Managing Natural Resources for Development in Africa: A Resource Book*. (pp. 391 –444). IDRC, IIRR and RUFCA: University of Nairobi Press.
28. Siddig, K., Davit Stepanyan, D., Wiebelt, M., Zhu, T. and Grethe, H. (2018). Climate Change and Agriculture in Sudan: impact pathways beyond changes in mean rainfall and temperature. Working paper 13 MENA. *International Food Policy Research Institute*. Retrieved from: <https://www.ifpri.org/publication/climate-change-and-agriculture-sudan-impact-pathways-beyond-changes-mean-rainfall-and>
29. Sudan National Survey Authority (2018). Sudan Survey Authority Report. Government of Sudan.
30. Swart, R. (2009). *Scenarios and international environmental assessments*. Part 2 Alterra. Wageningen, UR. Retrieved from: https://www.peer.eu/files/user_upload/user_upload/opportunities/metier/course7/c7_environmental_scenarios_assessments2a.pdf
31. Trilsbach, A. and Hulme, M. (1984). Recent Rainfall Changes in Central Sudan and Their Physical and Human Implications. *Transactions of the Institute of British Geographers*, New Series, 9 (3), 280–298.
32. United Nations Development Programme (2018). UN Human Development Report: Sudan. Retrieved from <http://hdr.undp.org/en/countries/profiles/SDN#>
33. United Nations Development Programme Oslo Governance Centre (UNDP OGC) (2010). The Development and Use of Governance Indicators in Africa: A comparative report. Retrieved from: https://www.undp.org/content/dam/undp/library/Democratic%20Governance/indicators_in_africa_idasa_2011.pdf
34. United Nations Environment Programme (2002). *Global Environment Outlook 3: Past, Present and Future Perspectives*. Nairobi, Kenya. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/8609/GEO-3%20REPORT_English.pdf?sequence=7&isAllowed=y
35. United Nations Environment Programme (2007). *Sudan Post – Conflict Environmental Assessment*. Nairobi, Kenya. Retrieved from:
36. https://postconflict.unep.ch/publications/UNEP_Sudan.pdf

37. United Nations Environment Programme (2006). *Africa Environment Outlook 2: Our Environment, Our Wealth*. Nairobi, Kenya. Retrieved from: <http://wedocs.unep.org/bitstream/handle/20.500.11822/9626/Africa%20Environment%20Outlook%202>
38. United Nations Population Division. (2019). World Population Prospects (2019). Sudan Population Review. Retrieved from: <https://www.worldometers.info/world-population/sudan-population>
39. United States Agency for International Development (2016). *Climate Change Risk in Sudan: Country Fact Sheet*. Washington, Washington DC. Retrieved from <https://www.climatelinks.org/sites/default/files/asset/document/2016%20CRM%20Fact%20Sheet-%20Sudan.pdf>
40. Van Arsdale, P. W. (1989). The Ecology of Survival in Sudan's Periphery: Short-Term Tactics and Long-Term Strategies. *Africa Today*. 36 (3/4), 65–78.
41. Wadi, E. I. (2011). Potential Environmental Impacts of Oil: Towards Sustainable Environmental Management of oil in Sudan. Retrieved from https://www.researchgate.net/publication/305991440_Potential_Environmental_Impacts_of_Oil_Towards_Sustainable_Environmental_Management_of_oil_in_Sudan
42. White. C. (2012). Understanding water scarcity Definitions and measurements. Global Water Forum. Retrieved from: <https://globalwaterforum.org/2012/05/07/understanding-water-scarcity-definitions-and-measurements/?pdf=3555>
43. World Bank (2010). *Worldwide Governance Indicators*. Retrieved from: <http://info.worldbank.org/governance/wgi/ind>
44. World Bank (2018a). The World Bank in Sudan: Overview. Retrieved from <http://www.worldbank.org/en/country/sudan/overview>
45. World Bank (2018b). Arable Land Hectare per Person. Retrieved from <https://data.worldbank.org/indicator/AG.LND.ARBL.HA.PC?locations=SD>

Annexes

ANNEX 1: Environmental implications of selected economic and natural resources policies

Policy	Goals, policy, targets	Environmental implications
Macroeconomic policies		
10-Year National Comprehensive Strategy (1992–2002) together with Liberalization Policy (1992–1993)	<p>Reform exchange rate and credit supplies.</p> <p>Remove subsidies on basic commodities.</p> <p>Increase tax revenues.</p>	Increased prices and cost of living especially for the poor, forcing them to exploit more natural resources, including clearing of land for agriculture and firewood.
25-Year Development Strategy (2007–2031)	<p>Increase GDP by 7 per cent per year.</p> <p>Increase export earnings as share of GDP.</p> <p>Reduce poverty by more than 50 per cent.</p>	<p>Expansion in mining leading to forest loss and encroachment into rangelands, pastures and wetlands.</p> <p>Deforestation and overgrazing due to expansion of agriculture.</p> <p>Competition between crop farmers and pastoralists over land and water resources.</p>
3-Year Economic Recovery Programme (2012–2014)	<p>Remove subsidies on fuel and electricity.</p>	<p>Increased prices and cost of living especially for the poor.</p> <p>Poor households exploiting more natural resources, especially forests as a substitute for energy.</p> <p>Increased use of cheap but low-grade fuels by rickshaws, resulting in increased air pollution.</p>
5-Year Economic Reform Programme (2015–2019)	<p>Prioritize private sector manufacturing and extractive industries for exports.</p> <p>Provide adequate finance for productive and basic services sectors.</p> <p>Provide adequate finance for security and defence.</p> <p>Gradual removal of subsidies.</p>	<p>Expansion of mining into forests, rangelands and pastures.</p> <p>Deforestation and overgrazing.</p> <p>Loss of biodiversity due to encroachment into sensitive ecosystems such as wetlands.</p>

ANNEX 1: continued

Policy	Goals, policy, targets	Environmental implications
Selected economic policies		
Agricultural policies	<p>Promote ecological balance of rain-fed agriculture, incorporating forests, rangelands and pastures, as well as water harvesting programmes.</p> <p>Carry out national land use mapping.</p> <p>Rehabilitate existing irrigation schemes.</p> <p>Adopt and expand efficient irrigation methods.</p> <p>Increase production and productivity.</p> <p>Improve food security and rural development.</p> <p>Expand water harvesting programmes in rain-fed area.</p> <p>Increase budget allocation to agriculture.</p> <p>Improve agricultural research and extension services.</p> <p>Make microfinance available to small farmers.</p> <p>Promote public-private investment in agriculture.</p>	<p>Increased the area under forests, rangelands and pasture.</p> <p>Improved the country's biodiversity.</p> <p>Improved crop management.</p> <p>Increased mixed farming of livestock and crops, and reduced pressure on forests, rangelands and pastures.</p> <p>Reduced competition and conflict over land between crop farmers and pastoralists.</p> <p>Allowed better land planning and management.</p> <p>Improved crop productivity per unit area, and reduced need for expansion of farmland.</p> <p>Reduced poverty and expanded livelihood opportunities, resulting in reduced deforestation, land degradation and desertification.</p> <p>Increased uptake of clean forms of energy, especially solar power.</p>
Livestock, rangeland and pasture policies		
The 10-Year National Comprehensive Strategy (1992–2002)	<p>Reform exchange rate, credit supplies and taxes.</p> <p>Remove subsidies on basic commodities.</p> <p>Increase exports of livestock.</p> <p>Reserve 25 per cent of land for pastures.</p> <p>Register 15 per cent of land as reserved land.</p> <p>Rehabilitate, conserve and protect natural resources.</p>	<p>Overgrazing and reduced carrying capacity of pastures.</p> <p>Lack of access to grazing land, water points and livestock routes.</p> <p>Introduction of invasive plants and grasses.</p> <p>Forest degradation.</p> <p>Conflict between livestock herders and crop producers.</p> <p>Increased carbon emissions.</p>
The 25-Year Development Strategy (2007–2031)	<p>Establish animal production industry to meet domestic and export market demands.</p> <p>Increase public finance to agriculture and livestock sectors to increase their relative share of GDP.</p> <p>Create capacities to become an international centre for producing and marketing hygienic red meat from livestock fed on natural fodder.</p> <p>Allocate 25 per cent of land for grazing and forests to benefit livestock and wildlife.</p>	<p>Competition over land and water.</p> <p>Conflicts of land tenure.</p> <p>Desertification, deforestation.</p> <p>Destruction of palatable plants and grasses, spread of invasive plants and grasses.</p> <p>Concentration of animals around water points, destroying the ecology.</p> <p>Increased gas emissions from animals.</p> <p>Livestock movement creates airborne dust pollution.</p>

ANNEX 1: continued

Policy	Goals, policy, targets	Environmental implications
Livestock, rangeland and pasture policies		
Ministry of Agriculture policies up to 1998 and 2010–2014	<p>Promote area and quality of pasture land, introducing good grass seeds and expanding irrigation systems.</p> <p>Introduce ecological rangeland and pasture land enclosures.</p> <p>Promote balance between carrying capacity of pastures and number of grazing animals.</p> <p>Transfer marginal lands into pastures.</p>	<p>Rehabilitation of marginal land would increase area under natural pastures, increase carrying capacity of rangeland and pasture, reduce overgrazing and degradation of pasture and reduce livestock damage to crops.</p>
5-Year Economic Reform Programme (2015–2019)	<p>Increase numbers of all livestock types.</p> <p>Integrate animals into crop rotation in the irrigated schemes.</p> <p>Increase capacity and quality of natural rangelands and pastures.</p>	<p>Increased grazing pressure on pastures.</p> <p>Reduced livestock damage to crops.</p> <p>Reduce friction between crop producers and pastoralists.</p>
Livestock and fisheries policies	<p>Expand livestock numbers and production for export.</p> <p>Improve range and pasture quality through use of improved seed and increased water supplies.</p> <p>Control epidemic diseases.</p> <p>Comply with international quality and sanitation measures for export of livestock, red meat and animal by-products.</p> <p>Improve fisheries resources to meet domestic and international demand.</p>	<p>Rehabilitation and reseedling programmes for pastures.</p> <p>Conservation and protection of pastures and improved grazing management.</p> <p>Increased production of livestock per unit area.</p> <p>Increased exports of livestock.</p> <p>Increased consumption of fish and reduced dependence on red meat.</p> <p>Reduced marine freshwater pollution.</p>
Petroleum policies		
25-Year Development Strategy (2007–2031)	<p>Increase crude oil production.</p> <p>Identify new reserves.</p> <p>Expand investment in oil sector.</p>	<p>Increased competition over land and water.</p> <p>Conflict over unclear land tenure arrangements.</p>
5-Year Economic Reform Programme (2015–2019)	<p>Provide security for investors engaged in exploration and production of oil resources.</p> <p>Decrease environmental contamination resulting from energy and mining activities.</p> <p>Increase and improve oil production levels.</p>	<p>Increased vulnerability to desertification and deforestation, causing reduced rangeland and pasture areas, overgrazing and land degradation.</p> <p>Increased pollution of soils, water and air, affecting health of humans and animals and threatening biodiversity.</p>

ANNEX 1: continued

Policy	Goals, policy, targets	Environmental implications
Mining sector policies		
25-Year Development Strategy (2007–2031) 5-Year Economic Reform Programme (2015–2019)	Expand exploration and exploitation of mineral resources. Comprehensive investment policy on mining and mineral wealth. Increased exports of gold.	Expansion of artisanal mining into rangelands, pastures and forests. Competition and conflict over land and water. Increased deforestation. Reduced area of rangelands and pastures, causing overgrazing and land degradation and threatening biodiversity. Pollution from toxic chemicals such as mercury.
5-Year Economic Reform Programme (2015–2019)	Expand exploration and exploitation of mineral resources. Comprehensive investment policy on mining and mineral wealth. Increased exports of gold.	Expansion of artisanal mining into rangelands, pastures and forests. Competition and conflict over land and water. Increased deforestation. Reduced area of rangelands and pastures, causing overgrazing and land degradation and threatening biodiversity. Pollution from toxic chemicals such as mercury.
Forestry policies		
Forest Policy (1932), modified in 1986 National Forestry Policy Statement (2006)	Encourage forest reserves and conservation. Recognize new forms of forest tenure (private, community and institutional forests). Target 20 per cent of the land area as forest reserves. Stress protective role of forests in rain-fed mechanized and irrigated schemes by planting green belts. Protecting, establishing and developing forestry resources in Sudan. Limiting cutting of trees in reserves areas 15% of rainfed scheme and not less than 5% of irrigated scheme to be used as forest. Reserving not less than 20% of Sudan area as forests.	Increased vegetation cover. Better use and management of forests. Protection of farms from wind erosion by tree belts. Increased volume and value of gum arabic revenues. Combating the dangers of desertification at the national level Conservation of biodiversity Climate change mitigation.

ANNEX 1: continued

Policy	Goals, policy, targets	Environmental implications
Wildlife sector policies		
10-Year National Comprehensive Strategy (1992–2002)	<ul style="list-style-type: none"> Reserve 25 per cent of land for wildlife. Register 15 per cent of reserved land. Rehabilitate, conserve and protect natural resources. 	<ul style="list-style-type: none"> Rehabilitate wildlife habitat. Enhance safe return and sustainability of wild animals. Protect parks against deterioration.
The 25-Year Development Strategy (2007–2031)	<ul style="list-style-type: none"> Allocate 25 per cent of land for grazing and forests to benefit livestock and wildlife. Promote tourism. Establish enclosures and new nature reserves. Conserve and invest in preserving wildlife. 	<ul style="list-style-type: none"> Balancing livestock-wildlife grazing would reduce overgrazing inside and outside parks. Recover biodiversity, protect and conserve plant and animal genetic material. Increased income for parks at national, state and locality levels.
Wildlife Policy 2014	<ul style="list-style-type: none"> Establish new protected areas. Develop strategic action plan for rangelands and pasture plants in semi-desert and low-rain savanna to strengthen resilience of communities against climate change. 	<ul style="list-style-type: none"> Rehabilitation, conservation and protection of wildlife. Community awareness and participation.
Water resources policies		
25-Year Development Strategy (2007–2031)	<ul style="list-style-type: none"> Develop water resources by increasing reservoirs, rivers and riverine storage capacity. 	<ul style="list-style-type: none"> Improved livelihoods of communities dependant on agriculture.
5-Year Economic Reform Programme (2015–2019)	<ul style="list-style-type: none"> Exploit groundwater and expand water catchments. Provide drinking water for people and livestock. 	<ul style="list-style-type: none"> Better health and hygiene for communities.
Water Resources Policy (2000 and 2007)	<ul style="list-style-type: none"> Protect water resources by preventing dams and irrigation canals from silting and spreading papyrus. 	
Sudan Policy and Strategy on Integrated Water Resources Management (2007–2022)	<ul style="list-style-type: none"> Strike a balance between supply and demand of water for irrigation and hydro-power generation. Regulate and coordinate water use to avoid conflict of interest. 	
National Plan for Development and Utilization of Water Resources (2014)	<ul style="list-style-type: none"> Involve the private sector and community in water service delivery. Promote role of women in water services and in backyard crop and animal production in remote rural areas. Increase Sudan's share of water from River Nile. 	

ANNEX 1: continued

Policy	Goals, policy, targets	Environmental implications
Biodiversity policies		
25-Year Development Strategy (2007–2031) The Interim National Constitution 2005 National Biodiversity Strategy and Action Plan 2015–2019	Boost domestic and international tourism. Establish enclosures and new nature reserves. Protect wildlife and biodiversity.	Increased revenues from tourism. Improved national parks services. Conservation of biodiversity and genetic resources.

Sources: Ministry of Finance and National Economy, the National Council for Strategic Planning, Ministry of Agriculture, Ministry of Livestock and Fisheries, Forests National Corporation, Wildlife Administration, Ministry of Water Resources, Irrigation and Electricity, the Interim National Constitution 2005, the Ministry of Environment and Physical Development, and the Higher Council for Environment and Natural Resources.

ANNEX 2: Technical Advisory Committee for the State of Environment and Outlook Report*

No.	Name	Designation	Position/Research area
1	Dr. Omer Mustafa Abdelgadir	Undersecretary MENRPD	Head
2	Dr. Hanna Hamdalla	MENRPD	Deputy Head
3	Dr. Gamal Mahmoud Hamid	National Council for Physical Development	Human settlements
4	Dr. Khitma Alawad Mohamed	HCENRs	Biodiversity
5	Dr. Ahmed Abdelkarim	Sudan Meteorological Authority	Atmosphere and Climate
6	Prof. Galal Eldin Eltayeb	University of Khartoum	Earth issues
7	Prof. Migdam Elsheikh	National Council for Research	Research
8	Dr. Ahmed Adam	Ministry of Water Resources	Water issues
9	Dr. Muawia Shadad	Sudanese Environment Conservation Society	CBOs
10	Representative of UNEP	UNEP	
11	Dr. Muna Abdelhafeez Daw Elbeit	MENRPD	ADAPT Focal Person
12	Mr. Abdelrahman Alkhaleefa	MENRPD	SoE Report National Coordinator
13	Colonel/ Mohamed Alfadi Eltahir	Economic Security	Member

*Appointed by the Minister of MENRPD



Technical Advisory Committee for the State of Environment Report and Environmental Outlook*

No.	Name	Designation	Position/Research area
1	Mr. Aboud Gaber Saeed	Secretary General of the National Council of Environment	Head
2	Dr. Bushra Hamed Ahmed Bashir	National Council of Environment	Deputy Head
3	Dr. Limya Abdelghfar	National Population Council	SDGs
4	Dr. Khitma Alawad Mohamed	HCENRs	Biodiversity
5	Dr. Ahmed Abdelkarim	Sudan Meteorological Authority	Atmosphere and Climate
6	Prof. Galal Eldin Eltayeb	University of Khartoum	Land issues
7	Prof. Migdam Elsheikh	National Council for Research	Research
8	Dr. Ahmed Adam	Ministry of Water Irrigation and Resources	Water issues
9	Dr. Muawia Shadad	Sudanese Environment Conservation Society	CBOs
10	Representative of UNEP	UNEP	Coordination
11	Dr. Safa Dahab	Omdurman Ahleya University	Universities
12	Colonel/ Mohamed Ahmed Eltayeb	Economic Security	Member
13	Dr. Osman Mirghani Ali	University of Khartoum	Technical Lead Author
14	Mr. Abdelrahman Alkhalifa	National Council of Environment	Report National Coordinator

*Appointed by the Secretary General of the National Council of Environment after the MENRPD was cancelled.

ANNEX 3: National Coordination Team

No.	Name	Designation
1	Mr. Abdelrahman Ahmed Ahmed Elkhalifa	National Coordinator
2	Ms. Azza Ahmed Eltyeib	Assistant
3	Ms. Aisha Seed Ahmed	Assistant
4	Ms. Amel Abdelrazig	Assistant



ANNEX 4: Lead Authors, SoE Chapters' Contributing Authors, Reviewers of SoE Chapters, UNEP National Reviewers, UNEP Non-Sudanese Reviewers

The SoE Technical Lead Author: Dr. Osman Mirghani Mohamed Ali

SoE Chapters' Lead Authors

No.	Chapter title	Lead Author
1	Socioeconomic Status and the Environment	(the late) Dr. Yagoub Abdalla Mohamed
2	Environmental Governance	Dr. Ahmed Mohamed Abusin
3	Atmosphere	Dr. Abdalla Khyar Abdalla
4	Land Resources	Dr. Omer Abdalla Egimi
5	Water Resources	Dr. Osman Eltom Hamad
6	Biodiversity	Prof. Talaat Dafalla & Dr. Salwa Mansour Abdelhameed
7	Persistent Environmental Issues	Dr. Eiman Alrasheed Diab & Ms. Sitnour Mohamed Alhassan
8	Emerging Environmental Issues	Dr. Hassan Beshir Nimir
9	Policy Analysis	Dr. Ali Abdelaziz
10	Scenarios and Policy Options	Dr. Guma Kunda Komey

SoE Chapters' Contributing Authors

Chapter No.	Chapter title	Contributing Author	Contribution field
1	Socioeconomic Status and the Environment	Ms. Rabab Baldo	Gender
2	Environmental Governance	Dr. Mohyeldeen Eltohami Taha	International agreements
3	Atmosphere	Ms. Sitnour Mohamed Alhassan	Air quality
4	Land Resources	Dr. Abdelatif Ahmed Ijaimi	Agricultural investment & large-scale land acquisition; urban land use
5	Water Resources	(the late) Dr. Moamer Eltayeb Ali	Marine ecosystems
7	Persistent Environmental Issues	Prof. Gamaa Abdelgadir Dr. Abdel Nasir Ibrahim Hanu	Waste Desertification
8	Emerging Environmental Issues	Mr. Motaz S. Saeed	Oil industry, electricity generation & artisanal mining



Reviewers of SoE Chapters

No.	Chapter	Reviewers	Contribution field
1	Socioeconomic Status and the Environment	Dr. Abdelhamid Bela Elnour	Faculty of Geographical and Environmental Sciences, University of Khartoum
2	Environmental Governance	Prof. El-Atta Hassan El- Batthani Dr. Mohamed Yousif Mabrouk	Department of Political Science, University of Khartoum NGOs – UN agencies Programme Coordinator/Manager
3	Atmosphere	Dr. Sumaya Ahmed Zakieldeen Mr. Najm Eldin Ghotbi Dr. Bashir Mohamed Alhassan Dr. Ahmed Mohamed Abdelkarim	Institute of Environmental Studies, University of Khartoum Climate Change programme, HCENR* Faculty of Engineering, University of Khartoum Sudan Meteorological Authority
4	Land Resources	Prof. Musa Adam Abdul-Jalil Prof. Abdelmagid Ali Elmobarak Elhaj	Department of Sociology and Social Anthropology, University of Khartoum Land & Water Centre, Medani Agricultural Research Station
5	Water Resources	Dr. Ahmed Mohamed Adam Saad Dr. Awatif Abdelgadir Beshir Mohamed	Ministry of Water Resources, Irrigation and Electricity-TAC** Faculty of Marine Sciences, Red Sea University & HCENR
6	Biodiversity	Dr. Dawi Musa Hamed Dr. Elhag Abugabr Elhag Dr. El Khitma El Awad Mohamed	Faculty of Sciences, University of Khartoum UNESCO Chair for Marine Sciences Convention on Biodiversity Coordinator-HCENR – TAC**
7	Persistent Environmental Issues	Dr. Ali Mohamed Ali Mahmoud Dr. Bushra Hamid Dr. Adil Mohamded Ali Seedahmed	POPs Programme, HCENR DG Environmental Affairs Directorate, Ministry of Environment – TAC** Sudan Environment Conservation Society
8	Emerging Environmental Issues	Dr. Awad Ibrahim Mr. Mohamed Ali Mr. Ismail Abdelrahim El Gizouli	Faculty of Environmental Sciences, Omdurman Ahleya University Freelance consultant on Energy and Climate Change; Member of ICCCP



Reviewers of SoE Chapters

Ch.	Chapter	Reviewers	Contribution field
9	Policy Analysis	Mr. Ismail Abdelrahim El Gizouli	Freelance consultant on Energy and Climate Change; Member of ICCCP
10	Scenarios and Policy Options	Dr. Somaya Elsayed	Ahfad University for Women
		Prof. El-Atta Hassan El- Batthani	Political Science, University of Khartoum
		Ms. Razan Mutasim Nimir	Sudan Environment Conservation Society
		Dr. Alfatih Ali Siddig	Freelance Consultant; Former Director of Poverty Unit–Ministry of Finance and National Economy
		Ms. Hanan Abdalla Mutawakil	UNDP
		Mr. Ismail Abdelrahim El Gizouli	Freelance consultant on Energy and Climate Change; Member of ICCCP
		Prof. Muwaia Hamid Shaddad	Faculty of Science, University of Khartoum Sudan Environment Conservation Society

* Higher Council for Environment and Natural Resources

** SoE Technical Advisory Committee

UNEP National Reviewers

No.	Reviewer	Title
1	Dr. Hamid Ahmed Omer	Senior IWRM Advisor of ADAPT! Project
2	Dr. Elamin Sanjak	Senior Natural Resources Management Advisor of ADAPT! Project
3	Ms. Huda Shafeeg	Gender Specialist-ADAPT! Project
4	Dr. Abuelgasim Abdalla Adam	Project Manager of East Darfur Project



UNEP Non-Sudanese Reviewers

No.	Reviewer	Title
1	Mr. Atila Uras	Sudan Country Programme Manager
2	Mr. Robbert Bekker	Sudan Senior Programme Advisor
3	Mr. Sorekai Doddi Chikkannachar Rajashekara	Programme Management Officer of ADAPT! Project
3	Mr. Rob Elsworth	Technical Advisor of ADAPT! Project
3	Mr. Robin Bovey	Former Sudan Country Programme Manager
4	Ms. Emily Massawa	Senior Climate Change Advisor of ADAPT! Project

UNEP Communication and Information Management Support

No.	Team member	Title
1	Mr. Maxime Paquin	Media and Communications Specialist/Geneva
2	Mr. Michael Bond	Copyeditor and Proofreader/Geneva
3	Ms. Xinyue Gu	Communications Officer/Geneva
4	Mr. Mikhail Fernandes	Communications Consultant/Geneva
5	Ms. Maria-Carolina Norgaard	Communications Intern/Geneva
6	Ms. Sara Eltigani	Communication Specialist/Sudan
7	Ms. Jumana Eltigani	Programme Assistant/Sudan
8	Mr. Tarig El Kheir	Information Technology Expert/Sudan



ANNEX 5: Regional consultation workshop participants

Attendance list of the Regional Consultative Workshop in Port Sudan, Red Sea State 17th/18th April 2018.

No.	Reviewer	State
1	Ms. Samia Ahmed Oshaikh	Red Sea
2	Dr. Abdulmonim Karamalla Jaiballa	Red Sea
3	Mr. Ashbou Ohaj Faki	Red Sea
4	Ms. Ikhlas Adam Mohamed	Red Sea
5	Mr. Musa Abdalla Issa	Red Sea
6	Ms. Afrah Ahmed Abdulwahab	Red Sea
7	Mr. Nasredin Mohamed Elamein	Red Sea
8	Mr. Motasim Ali Mokhtar	Red Sea
9	Dr. Somaya Kheder Mohamed	Red Sea
10	Ms. Manal Issa Adam	Red Sea
11	Ms. Abla Abdalaziz Magzoub	Red Sea
12	Mr. Bahaldin Ahmed Abdalla	Red Sea
13	Ms. Aisha Magzoub Mohamed	Red Sea
14	Mr. Elfatih Bakri Ahmed	Red Sea
15	Mr. Mohamed Taher Salih	Red Sea
16	Mr. Anwar Ibrahim Ahmed	Red Sea
17	Ms. Mona Mohamed Ali	Red Sea
18	Ms. Azahir Abusowar	Red Sea
19	Mr. Laila Ahmed Elhag	Red Sea
20	Mr. Mobarek Hamad Musa	Red Sea
21	Mr. Abdalla Osman Issa	Red Sea
22	Ms. Madena Eltahir Ahmed	Red Sea
23	Mr. Abdulrahman Mohamed Ahmed	Khartoum State
24	Ms. Azza Ahmed Eltayeb	Khartoum State
25	Ms. Hyam Ahmed Abdalla	Khartoum State
26	Dr. Salwa Abdelhameed Mansour	Khartoum State
27	Dr. Bushra Hamid Ahmed	Khartoum State
28	Dr. Osman Mirghani Mohamed Ali	Khartoum State
29	Mr. Mohamed Elfatih Ahaimer	Kassala
30	Mr. Yousif Mahmoud Mohamed Tom	Kassala



No.	Reviewer	State
31	Mr. Abubaker Mustafa Abbasher	Kassala
32	Mr. Hoaida Ahmed Ibrahim	Kassala
33	Ms. Eiman Abdurahman Hassan Bakhit	Kassala
34	Mr. Adil Ahmed Elgarashi	Kassala
35	Ms. Ahlam Eltaher Babiker	Kassala
36	Ms. Sana Hassan Ibrahim	Kassala
37	Mr. Wajd Omer Mohamed	Kassala
38	Ms. Samia Mohamed Ibrahim	Gedaref
39	Ms. Saneia Adam Abdalla	Gedaref
40	Mr. Ismail Elsaifi Ismail	Gedaref
41	Mr. Abdulgadir Abdulmoneim Mohamed	Gedaref
42	Mr. Majdi Abdalla Mohamed	Gedaref
43	Ms. Esmahan Nassir Tartor	Gedaref
44	Mr. Zahir Dafalla Abuagla	Gedaref
45	Mr. Abdulmoneim Hassan Osman	Gedaref
46	Mr. Mohamed Elamein Mahmoud	Red Sea
47	Mr. Hassan Abuo Sidig	Gedaref
48	Mr. Ibrahim Ali Abaker	Gedaref

Attendance list of the Regional Consultative Workshop in Nyala, South Darfur 13th/14th May 2018.

No.	Reviewer	State
1	Mr. Jafar Husein Madani	North Darfur
2	Mr. Khalid Mohamed Adam	North Darfur
3	Ms. Enass Najameldin Salih	North Darfur
4	Ms. Aseil Yousif Adam	North Darfur
5	Mr. Ismail Abdulrahman Hasaballa	North Darfur
6	Mr. Adam Ahmed Abdalla Daldom	North Darfur
7	Mr. Abdalla Basheir Adam	North Darfur
8	Mr. Ishag Ibrahim Hadi	North Darfur
9	Ms. Amna Ahmed Osman	North Darfur
10	Ms. Halima Mohamed Abdulraman	North Darfur



No.	Reviewer	State
11	Mr. Walied Ibrahim Abdulshafi	Central Darfur
12	Mr. Mohamed Ahmed Elmahdi	Central Darfur
13	Mr. Abdulhameed Mohamed Adam	Central Darfur
14	Ms. Zeinelabedin Adam Abdulrahim	Central Darfur
15	Mr. Abdelnasir Dodo Mohamed	Central Darfur
16	Ms. Mahasin Salih Osman	Central Darfur
17	Ms. Aziza Adam Ali	Central Darfur
18	Mr. Teifour Ali Teifour	Central Darfur
19	Mr. Zakaria Mohamed Ahmed	Central Darfur
20	Mr. Nasreldin Adam Ali	Central Darfur
21	Ms. Fatma Abdulkareem Elnor Salih	West Darfur
22	Mr. Abdulrazig Idreis Mahamadein	West Darfur
23	Ms. Fadwa Abdalla Hassan	West Darfur
24	Ms. Ayat Ali Ahmed Mustafa	West Darfur
25	Mr. Abdulhameid Ali Abutaroush	East Darfur
26	Mr. Hassan Adam Mahmoud	East Darfur
27	Mr. Hafiz Mohamed Hamad	East Darfur
28	Ms. Shadia Elshfea Adam	East Darfur
29	Mr. Abdalla Norain Omer	East Darfur
30	Ms. ZObeida Fedail Ababer	South Darfur
21	Mr. Hamid Mohamed Manzoul	South Darfur
22	Ms. Afaf Ahmed Ahamed hamid	South Darfur
23	Mr. Elsadig Adam Awat	South Darfur
24	Ms. Buthiana Ali Mohamed	South Darfur
25	Ms. Moawia Ahmed Mohamed	South Darfur
26	Ms. Nasreen Osman Ali (Ms)	South Darfur
27	Mr. Khalid Ali Adam Noreldin	South Darfur
28	Mr. Abdulrahim Suliman Abdalla	South Darfur
29	Mr. Yahya Abdu Abaker	South Darfur
30	Mr. Ahmed Omer Ali	South Darfur



No.	Reviewer	State
31	Mr. Hamid Mohamed Manzoul	South Darfur
32	Ms. Afaf Ahmed Ahamed hamid	South Darfur
33	Mr. Elsadig Adam Awat	South Darfur
34	Ms. Buthiana Ali Mohamed	South Darfur
35	Ms. Moawia Ahmed Mohamed	South Darfur
36	Ms. Nasreen Osman Ali (Ms)	South Darfur
37	Mr. Khalid Ali Adam Noreldin	South Darfur
38	Mr. Abdulrahim Suliman Abdalla	South Darfur
39	Mr. Yahya Abdu Abaker	South Darfur
40	Mr. Ahmed Omer Ali	South Darfur
41	Ms. Amani Elhadi Ali	South Darfur
42	Mr. Mohamed Yasein Ishag	South Darfur
43	Ms. Ikhlas Adam Norain	South Darfur
44	Ms. Nazik Marshoud Mohmoud	South Darfur
45	Mr. Abdulrahman Mohamed Taher	South Darfur
46	Ms. Samia Khalil Alhilo (Ms)	South Darfur
47	Mr. Musa Sabit dam	South Darfur
48	Mr. Badereldin Ali Musa	South Darfur
49	Mr. Hamid Elshareif Elsayer	South Darfur
50	Mr. Ibrahim Abdulrasoul Ibrahim	South Darfur
51	Mr. Bahaeldin Abdulgabar	South Darfur
52	Mr. Abduraman Mohamed Taher	South Darfur
53	Mr. Abdulrahman Mohamed Ahmed	Khartoum State
54	Mr. Azza Ahmed Eltyeib	Khartoum State
55	Mr. Osman Mohamed Tom	Khartoum State
56	Dr. Osman Mirghani Mohamed	Khartoum State
57	Dr. Osman Eltoum Hamad	Khartoum State



Attendance list of the Regional Consultative Workshop in Ed Damar, River Nile State 9th/10^h July 2018

No.	Reviewer	State
1	Dr. Sameer Ahmed Osman	River Nile
2	Mr. Ali Mustafa Humeida	River Nile
3	Mr. Mohamed Mukhtar Hussein	River Nile
4	Mr. Hasim Mohamed Ahmed	River Nile
5	Ms. Muwahib Abdelrahman Mahmoud	River Nile
6	Representative	River Nile
7	Mr. Ali Hamza	River Nile
8	Mr. Tag el Sir Ahmed Mohamed	River Nile
9	Mr. Hafsa Mahgoub	River Nile
10	Mr. Hassan Alamin Hassan	River Nile
11	Mr. Mu'taz Haj Nour	River Nile
12	Mr. Mujahid Mekki	River Nile
13	Mr. Abu Baker Osman	River Nile
14	Ms. Alaweya Gasmall Yousif	River Nile
15	Mr. Ahmed Sid Ahmed	River Nile
16	Ms. Lubna Fadul	River Nile
17	Mr. Saleem Mohamed Osman	River Nile
18	Ms. Nada Hassan Hussein	River Nile
19	Ms. Malaz Abdelrahman	River Nile
20	Mr. Abdelmoneim Sir Elkatim	River Nile
21	Ms. Fareeda Khaleefa Elsayed	River Nile
22	Mr. Essam Mohamed Zein	River Nile
23	Ms. Nazik Abdeen	River Nile
24	Ms. Nagwa Fadalla Babiker	River Nile
25	Ms. Kawther Alhassan Mohamed Ahmed	River Nile
26	Dr. Abdeen Babiker	River Nile
27	Dr. Abdelazim Tayfour	River Nile
28	Ms. Somaya Omer Albaloula	River Nile
29	Mr. Mohamed Ahmed Mohamed	River Nile
30	Mr. Yousif Elsheikh	River Nile



No.	Reviewer	State
31	Mr. Abdelkarim Ahmed Mohamed Ali	River Nile
32	Mr. Abdelhameed Osman	River Nile
33	Mr. Ahmed AL Rasheed Mohamed	River Nile
34	Mr. Yousif Abdalla Mohamed	River Nile
35	Mr. Hassan Ali Elhaj	River Nile
36	Mr. Mohamed Ahmed Abbas	River Nile
37	Mr. Hassan Satti	River Nile
38	Mr. Abdelaziz Abu Baker Abdu	Northern State
39	Mr. Mohamed Hassan Osman	Northern State
40	Ms. Tahani Malik Alamin	Northern State
41	Mr. Hisham Hassan Mahmoud	Northern State
42	Mr. Ibrahim Elnaeem Ibrahim	Northern State
43	Mr. Yagoub Ibrahim Mohamed Salih	Northern State
44	Dr. Elrasheed Fagiri	Northern State
45	Mr. Faisal Mohamed Abdelrazig	Northern State
46	Mr. Abdulrahman Mohamed Ahmed	Khartoum State
47	Ms. Azza Ahmed Eltyeib	Khartoum State
48	Mr. Osman Mohamed Tom	Khartoum State
49	Dr. Osman Mirghani Mohamed	Khartoum State
50	Dr Guma Kundi Komey	Khartoum State

