Food and Agriculture Organization of the United Nations

SUDAN
NATIONAL FOREST INVENTORY

FINAL REPORT

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Sudan's Forests National Corporation (FNC)
Khartoum, 2021

REQUIRED CITATION:
Forests National Corporation (FNC). 2021. *Sudan National Forest Inventory: Final Report*. Khartoum.

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ACRONYMS AND ABBREVIATIONS

FAO	Food and Agricultural Organization of the United Nations
FCPF	Forest Carbon Partnership Fund
FNC	Forests National Corporation
FREL	Forest Reference Emission Levels
FRL	Forest Reference Level
GEF	Global Environment Facility
GFOI	Global Forest Observation Initiative
GHG	Greenhouse gas
HCENR	High Council for Environment and Natural Resources
ICA	International Consultation and Analysis
LULUCF	Land Use, Land Use Change, and Forestry
MRV	Measurement, Reporting, and Verification
NAMAS	Nationally Appropriate Mitigation Actions
NC	National Communications
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NGGI	National Greenhouse Gas Inventory
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RMU	REDD+ Management Unit
RPGD	Range and Pasture General Directorate
RSSA	Remote Sensing & Seismology Authority
SESA	Strategic Environmental and Social assessment
TOR	Terms of Reference
UNFCCC	United Nations Framework Convention on Climate Change

ACKNOWLEDGEMENTS

The National Forest Inventory (NFI) is a significant step towards monitoring and development of Sudan's forests. It has provided instrumental data in the context of REDD+, but its scope and outputs extend to polices and management of the forest and natural resources sectors. Moreover, it supports policy actions and planning that promote national forest conservation, and strengthen political commitment and action at the states and national levels.

Commitment, dedication, determination and hard work were the key elements in handling the challenges and difficulties in carrying out the NFI inventory involving extensive land coverage. In this regard, the FNC acknowledges the hard work of the field crews, data management teams, national and international experts and related stakeholders and institutions (listed in Annex 4).

Thanks are due to the FNC Directors in the HQs and the State Managers for facilitating and providing enabling means to conduct the NFI activities. The knowledge and field experience of the FNC experts, from past NFIs, had contributed to the successful completion of this NFI and related activities. In addition, experts from the FAO, universities, forest research centers and other institutions contributed significantly with ideas and constructive thoughts during the several discussions, consultations and validation meetings.

The FNC is particularly grateful to the staff of FAO Sudan country office in Khartoum, FAO Regional Office for Near East and North Africa in Cairo and FAO's HQs in Rome for the technical support, services and management in accordance to the terms of the technical agreement between the Republic of Sudan and the FAO titled "Support for the Design of the MRV System in the Framework of REDD+ Readiness in the Republic of the Sudan". Thanks as well to the technical committees, and to the REDD+ PMU for the logistical support to the project. In addition, the FNC would like to express its gratitude to the World Bank who funded this project under its Forest Carbon Partnership Facility (FCPF).

The FNC extends genuine gratitude to the many individuals who contributed in this output, right from initiation and preparation activities through the data collection, management, cleansing and analysis of data, and up to the preparation of this final report. Particularly, the FNC is grateful to Matthias Lichtenberger (CTA), Salah Yousif (National Project Coordinator), Selmi Khemaies (International consultant), Elyass Daak (national consultant) and Marco Piazza (FAO HQ) for their crucial inputs and involvement in the field work and general project activities. Thanks are extended to Asdrúbal Calderon (International consultant) who supported the data analysis and Essam Warrag for overall coordination and inputs to the final report. Also, thanks are due to Talaat Abdel Magid, Fath Al aleem Mohie eldin for their contribution and writing of the report. The role and contribution of the Late FNC GM Mohamed Ali Elhadi is highly acknowledged.

Mr. Osman Omer Abdalla

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EXECUTIVE SUMMARY

Sudan's forest and woodlands are estimated to have decreased at a slow but steady rate, approximately 175.000 ha/year, during the last two decades (FAO's Forest Resources Assessment Report 2020). Conversion of natural forests to cropland and pasture had the biggest direct impact. In addition, fuelwood consumption has been a major driver of forest degradation, as it constitutes up to 80 % of the national energy supply. Other significant drivers include grazing of domestic animals in woodlands, with devastating effects on tree seedlings and smaller trees, and fire, frequently used in rural land management.

Sudan is committed to implementing REDD+ in the context of the UNFCCC by putting in place policies and actions to reduce emissions from deforestation and forest degradation. It has sought and received international support to prepare for and implement REDD+, notably receiving funding assistance from the World Bank's Forest Carbon Partnership Program (FCPF) and technical support from FAO. The National Forest Inventory of Sudan (NFI) is among a series of other activities aimed at reaching the agreed outcome of "The Government of Sudan has the data and capacities to monitor, report and verify REDD+ activities". The support included the overall strengthening of national government institutions and the institutionalization of the MRV system. In addition to the establishment of a satellite land monitoring system with the production of up-to-date land cover maps; the development of Sudan's Forest Reference Emission Level (FREL) and the strengthening of the GHG inventory and reporting process for the AFOLU sector.

The NFI fills an important gap in Sudan's capacity to monitor and report the status of its forests, and is instrumental in providing data in the context of REDD+. However, its scope and importance reaches a wider range of aspects and sectors. A multipurpose NFI is primarily a national asset and as such aims at providing valuable information for informing policy processes in line with the idea of "better data, better decisions". In addition, the planning and implementation of an NFI yields a number of by-products, including the overall strengthened capacity of relevant national institution and the improved capacity (technical, equipment, methodologies) of staff including those at subnational stations. An NFI is a significant logistical and organizational effort and its success highly depends on the effort of dozens of field crew members that worked tirelessly, often in very challenging conditions.

This report provides a comprehensive account of the NFI process, its methodological approach, and presents a set of detailed key results. The sampling approach was designed in accordance to Sudan's land characteristics and focused on forests and woodland areas. Sampling intensity was set according to biophysical considerations as well as budget and time constraints, while aiming at acceptable levels of uncertainty for key variables. The whole country was classified into five strata, mainly from North to South, according to vegetation zones. Sampling Units (SUs) were systematically determined in each Stratum for a total of 968 SUs which were visited in the field, and portion of other SUs classified as inaccessible for security or logistical reasons. The employment of a dedicated Quality Assurance/Quality Control (QA/QC) field crew ensured higher reliability of the data collection process. The establishment of a database maintained at the Headquarters of FNC followed the extensive data collection process. Data cleansing and analysis yielded the results presented in this

report. All results are herein presented as aggregated by land use class (FAO FRA and National classes), strata and administrative levels (States).

The results provided estimates of total area by forests (15.85%), other wooded land (13.24%), inland water (0.32%), and the rest as others land and deserts (70.4%). Results are also presented for a number of measures of forest stocking: density (trees/ha), regeneration, basal area, gross volume and bole (merchantable) volume. Tree species and biodiversity indicators are also presented and the species registering the highest mean volume are: Acacia seyal var seyal, Anogeissus leiocarpus, Balanites aegyptiaca, Albizia amara and Combretum ghasalense.

The estimates on biomass and carbon content are particularly useful as baselines for further work related to REDD+ and carbon offsetting initiatives. In addition, the multipurpose approach adopted in this NFI allows to present statistics on the major products obtained from the forest that include plant food, fodder, fire-wood and wood charcoal.

The National Forest Inventory constitutes a major effort of the Government of Sudan and its relevant agencies. The new database contains a wealth of information that should be accessed and made available for further analysis with a cross-sectoral approach. Besides its importance for international reporting commitments, the new set of data is a valuable source for forest managers and decision makers to develop evidence based management decisions. The overall improved capacity of various national institutions also ensures the sustainability of the process which should be seen as an ongoing effort. The NFI plots were designed to be permanent sample plots, which are geo-referenced and should be re-visited during future inventories.

The NFI of 2021 constitutes a major step forward and adds to the existing national experience on field sampling and measurements methodology. The capacity of FNC staff was strengthened on a variety of skills related to forest and land monitoring. All these elements result in a better placement of the Government of Sudan in its fight against the detrimental effects of climate change and the protection of its natural resources which still provide the source of livelihood for a large portion of Sudan's population.

FOREWARD

The Republic of Sudan, as part of the international community, is committed to contributing to mitigation actions in the forest sector by undertaking: Reducing emissions from deforestation and forest degradation; Conservation of forest carbon stocks; Sustainable management of forests; and Enhancement of forest carbon stocks. Sudan's forests and woodlands are valuable natural resources with significant direct and indirect products, services and environmental roles. The forestry sector will continue to receive governmental support for afforestation and conservation activities, reduce deforestation and degradation, increase vegetation cover and conserve the biodiversity. The Ministry of agriculture and Forestry values the output of the National Forest Inventory as an important step towards sustainable management of forests and natural resources. The extensive information and baseline data are essential to project, analyze, assess and research, the growth and yield related to natural and planted forests, as well as estimation of a removed tree characteristics. The NFI will provide the ministry with clear guidance to policies and actions to develop the Sudan's forest sector. The NFI recommendations and guidelines will receive utmost attention and considerations, and will be shared with the related governmental departments and units.

The Ministry of Agriculture and Forestry, we acknowledges the FAO and Forests National Corporation (FNC) roles in shouldering the responsibility of planning and carrying out the NFI numerous activities. Sincere thanks are extended to Mr Babagana Ahmadu (FAO-SDN Representative) and his assisting team and experts in FAO Khartoum, Cairo, and HQ-Rome. In addition, thanks are extended to the FNC MD and staff in the FNC-HQ, States, forest circles, and divisions. Finally the ministry recognizes the contribution of the previous ministers who witnessed the NFI stages.

Minister of Agriculture and Forestry

INTRODUCTION

The Sudan diverse forests and woodlands spread over a number of ecological zones according to rainfall, soil and topography. Their vital environmental roles, socioeconomic services and products have significant importance in support to the livelihoods of rural population and the national economy. The area estimates of the Forests and woodlands signal a decreasing trends due to many factors contributing to deforestation and forest degradation. Many drivers contribute to forest degradation in Sudan e.g. expansion of agricultural and pasture lands at the expense of natural forests, in addition to fuelwood consumption, which constitutes up to 80 percent of the national energy supply.

Sudan is joining the global efforts to reduce emissions from deforestation and forest degradation by putting in place policies and actions of REDD+ in the context of the United Nations Convention on Climate Change. It has received international support to prepare for and implement REDD+, notably from the World Bank's Forest Carbon

Partnership Program (FCPF). The National Forest Inventory of Sudan (NFI) is among a series of other activities aimed at reaching the agreed outcome of

"The Government of Sudan to monitor, report and verify REDD+ activities". The support package, made possible through support from the World Bank's FCPF, included the overall strengthening of national government institutions and the institutionalization of the MRV system. In addition to the establishment of a satellite land monitoring system with the production of up-to-date land cover maps; the development of Sudan's Forest Reference Emission Level and the strengthening of the GHG inventory and reporting process for the AFOLU sector.

The multipurpose NFI is a national asset and as such aims at providing valuable information for informing policy processes in line with the idea of "better data, better decisions". It is an important step towards monitoring and reporting the status of Sudan's forests and woodlands, and is instrumental in providing data in the context of REDD+.

Moreover, its scope and importance extends to a wider range of aspects and sectors. Planning and implementation of the NFI yields a number of by-products, including the overall strengthening capacity of relevant national institutions and the improved capacity of forestry staff at all levels.

The main focus of forest policy is sustainable utilization of the forest resources to meet the needs for wood products, especially for fuels, building poles, and food supplements

The reliable information, data and results generated from National Forest Inventory (NFI) include areas of forests and wood land, growing stock, biomass, carbon content, wood and non-wood products, carbon, protected areas, use of forests for recreation and other services. They are essential for establishing reference point data for future

measurement monitoring, verification purposes. In addition, they provide forest resource related information for national policy, strategy processes and forestry planning on forests conservation, governance and management at all levels. FAO, at the request of its

member countries, regularly monitors the world's forests and their management and uses through the Forest Resources Assessment Program.

With the changed role of forests, the scope of NFIs has broadened and new variables for assessment have been introduced to address both national needs and the need for common reporting at the international level. The needs emerge from international conventions and policy processes, such as the Kyoto protocol addressing climate change.

The NFI is the first of the three pillars of a NFMS, and forms an important component of the REDD+ MRV. The NFI will provide the first-hand data required to develop emission factors and growth models needed for estimating the changes in carbon stock as a result of management interventions. Within Sudan, the NFI has been supported by the FAO. This support includes assistance in the design of the NFI (following the Forest Resource Assessment processes) and training Open Foris to analyze the required data [1].

1 Geoff Roberts and Mohamed Osman. 2017. Support for the Design of the MRV System in the Framework of REDD+ Readiness in the Sudan- Institutional arrangement and gap analysis. REDD+ Sudan, FAO.

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CHAPTER 1
GENERAL ASPECT OF SUDAN

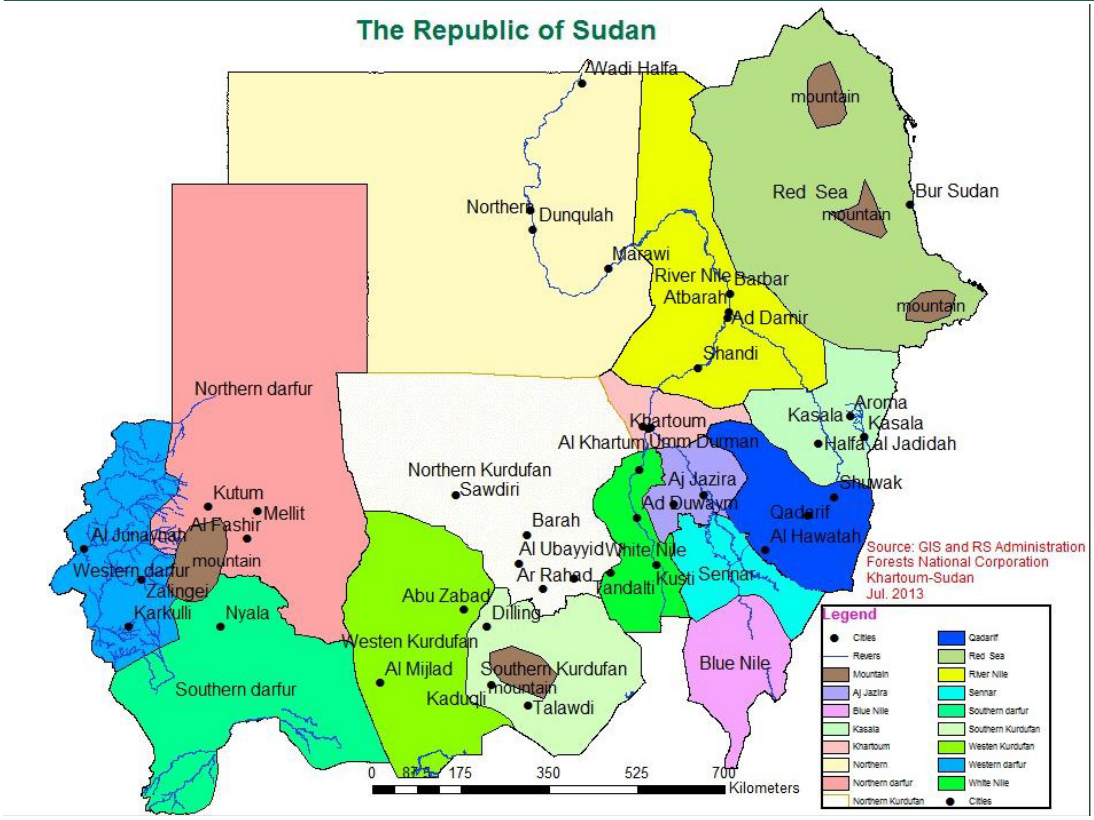
1.1. Location and terrain

Located in North Eastern Africa, the Republic of Sudan (RoS) is bound by Egypt, The Red Sea, Eretria, Ethiopia, Republic of South Sudan (RSS), Central African Republic, Chad and Libya, with an estimated total of 1.882 million km2 (Figure1). It lies between latitudes 100 and 220 N and longitudes 220 to 380 E. The highest point in the country is Jebel Marra; 3,024 meters above sea level (m.a.s.l.) and the lowest is the Red Sea. The most salient geographical features are the Nubian and Bayuda Deserts in the north, the Nile Valley, Jebel Marra, Nuba, and Ingessena& Red Sea Hills.

The Blue Nile and White Niles originates in the Ethiopian Highlands and the Equatorial Lakes, respectively. The two unite at Khartoum and with their tributaries form the River Nile that runs north to the Mediterranean Sea. Mean annual temperatures vary from 260C to 320C across the country.

The northern part of the country is mostly desert and semi desert with average annual temperatures around 30o C and average annual rainfall about 150 mm/year. The central area is semi-desert to savannah with average annual temperatures that are around 27o C, and rainfall averaging to about 200 mm/year. Rainfall, which supports the great majority agricultural activity, is erratic and varies significantly from the northern to southern ranges of the country.

Figure 1.1 Sudan map



1.2. Population

The population of the Republic of Sudan was estimated in 2019 at 42.81 million, a significant increase from 34.85 million in 2013, ranking the country as number 35th worldwide. The current population density is 64.0 people per square mile (24.7 people per square kilometer). Although the density is small, it has more than quadrupled in the past 50 years[2], and skewed by a large empty desert areas. The population lives in rural areas (63%), nomadic lifestyle (7%) and urban areas (30%), with concentration along the River Nile and its tributaries and around agricultural and forest areas. The concentration patterns indicate direct dependency on the natural environment for subsistence and rival over limited local resources. Overall life expectancy is 59 years, being 58 years for men and 61 years for women. Furthermore, 43%, 53% and 3% of the population are in the age groups of 14-0, 65-15 and 65+; respectively. Literacy estimates shows that males are more literate than women (71% and 51%, respectively).

The population is a combination of indigenous Nilo-Saharan- speaking Africans and descendants of migrants from the Arabian Peninsula. The main ethnic groups are Sudanese Arabs (Approx. 70%), Fur, Beja, Nuba and Fallata. Due to the process of Arabisation common throughout the rest of the Arab world today, Arab culture predominates in Sudan. The greater majority of adheres to Islam. The official language is Arabic, and English is widely used together with several local dialects in Northern, S. Kordofan, Kassala, Darfur and Red Sea States.

1.3. Forestry in the Sudan

Forestry activities started in the Sudan in 1901, when the Indian forester, Mr. C.E. Moriell was commissioned to tour and investigate the state of forests in the country. As a result of his report the Woods and Forests Ordinance was promulgated in 1901 and the Department of Woodlands & Forests was established the same year. The Ordinance was replaced in 1908 by the First Forest Act. Adoption and implementation of administrative and legislative measures continued ever since. The most salient of these are the endorsement of Sudan's Forest Policy in 1932, the Central & Provincial Forest Ordinances (1932), the Local Government Act of 1972, Regional Government Act 1980, the amendment thereof in 1985, the revision of Forest Policy in 1986 and creation of the Forests National Corporation (FNC) and Revision of Forest Act in 1989[3].

1.4. Vegetation types

The country is ecologically divided into five vegetation zones according to rainfall patterns from North to South:

1. Desert: (0-75 mm of precipitation),
2. Semi-desert: (75-300 mm),
3. Low rainfall savannah on clay and sand: (300-800 mm),
4. High rainfall savannah (800-1500 mm),
5. Mountain Vegetation: (300-1000 mm).

Sudan is endowed with a wide range of ecosystems and species diversity. The ecological zones extend over a wide range from the desert in the extreme north to the savannah. According to the recently published, Land Cover Atlas of Sudan, FAO (2012), Forests together with Rangeland represent 35.6% of the total country area. Sudan is rich in biodiversity within diverse environmental systems making it endowed with flora and fauna which are being subjected to a number of threats as a result of natural factors and human activities.

The land cover is classified as follows:

1. Productive and unproductive forest lands constitute 34.0% of the country area,
2. Shrubs and desert scrub make up 17.0%,
3. Wildlife reserves 5.0%,

2 - World Population Prospects (2019 Revision);

3 - Bayoumi A. Badi, K. H., Ahmed E. A, and Abdel Magid T D (2000). A century of Sudanese Forestry. Second edition published by Forests National Corporation. The first edition was published by Arab Organization for Agricultural Development;

4. Cropped areas make up 6.0%,
5. The flood areas, swamp surface and the montane regions constitute 5.0%,
6. Other land use types make up the remaining 33.0%.

The country is the center of origin of many agricultural crops, fruit trees, forest trees, medicinal plants and pasture species. The wetlands along the River Nile valley (Maayas) are an important and outstanding ecosystem in Sudan vegetation; it is a unique freshwater ecosystem rich in biodiversity and it is an important home for migrating birds from all over the world.

1.5. Socioeconomic and environmental importance of forestry

Forests play an important social economic and environmental roles by the goods and services they provide to support livelihood. Approximately 63% of the population is rural and considered forest dependent, essentially for fuelwood as main source of energy and for round timber as building material. In addition to wood products, the rural population uses the forest for grazing, as source of bush meat (wildlife hunting) and for food in the form of tree leaves, fruits, honey and tubers. They also use tree shade for social functions and other recreational purposes, (FOSA, 2001). Non-wood forest products are collected for domestic as well as for commercial purposes, among these, Sudan is the leader country in Gum Arabic production. The formal National Accounts show a limited (1-2%) contribution of the forestry sector to the GDP, which equals the value of wood produced from government forest reserves or registered in the form of royalty collection. However, the socioeconomic values and contributions of forests to other sectors are significant. There are also socio economic benefits from gum Arabic collection that go beyond the simple cash value of the gum. Millions of people are involved in its harvesting and cleaning and, because it is an activity that is carried out during the dry season, it does not make demands on the farmer when he needs to tend other crops. It, therefore, helps the farmers and their families to stay in their land instead of search for work in urban areas. One of the important ecological roles of forests is the provision of carbon sinks. However, the National Communication Report concluded that the forestry sector contributed around 75 % of the national CO2 emissions. On-site and off-site wood burn resulted in such high contribution of forestry sector as a result of forest conversion. Forest trees also contribute some 30% of the animal feed per annum and that share can reach 70% in extremely dry years. Sudan depends mainly on forestry sector as energy source. Forests used to contribute by a total of 4.11 million ton of oil equivalent (TOE) representing 70 - 81% of energy supply in the country (FNC, 1995).

The forests and woodlands are under considerable pressure by domestic consumption as well as by the large flows of refugees from neighboring countries. The estimated one million refugees in Sudan are concentrated in camps, and are exerting pressure and degradation in the surrounding forests and range.

1.6 Forest Governance and Institutional Organization

Land and forest management in Sudan is the concern of numerous ministries and agencies:

1. Ministry of Agriculture and Forestry (Forests National Corporation (FNC),
2. Ministry of Animal Resources and Fisheries (Range and Pasture General Directorate (RPGD). One of the tasks of the RPGD is to formulate policies and regulations that can protect pastures, plans and programs to improve and manage range resources,
3. Ministry of Finance and Economic Development,
4. Ministry of Justice,
5. Ministry of Industry and Trade,
6. A number of academic centers with expertise in forests and forest management (Agricultural Research Corporation, Forest Research Centre, Higher Council for the Environment and Natural Resources, Ministry

of Higher Education & Science Research, National Research Centre, Academia, and Remote Sensing and Seismology Authority (RSSA). The objectives of the RSSA are to achieve the needs of research projects by using the latest developments in the field of space information. The RSSA has developed land cover and use maps in accordance with the FAO's Land Cover Classification System.

1.6.1 Forests National Corporation

One of the missions of the Forests National Corporation (FNC) is to develop public policies, rules and methods for safeguarding and protection of the forest resources. The FNC also has the role of technical supervision of the forests and raising awareness about forest issues, as well as undertaking studies and planning of forests. In addition, it is responsible for afforestation and reforestation projects including developing gum Arabic and other small forest products, and for implementing the policy objective of increasing the area of reserved forests to at least 20% of the country's area. The FNC is currently responsible for the development and implementation of the Sudan's REDD+.

1.6.2. Forest Policies

The first forest policy for the Sudan was enacted in 1932 with a main objective to protect and reserve country forests resource, and carefully separated the forest-related responsibilities between the central authority and the local authorities. The policy included directives on afforestation and logging activities in and outside of reserved areas. Also, stated the prohibited actions in forests and outlined privileges and rights of the population in and surrounding the forests.

In 1986, the revision of the 1932 policy was made to accommodate the constitutional, political, administrative, environmental and socio-economic changes. The second policy of 1986 was the basis for forestry sector strategy, and it recognized and encouraged establishment of private, community and institutional forests (includes irrigated forest plantations in agricultural schemes). The policy stressed the role of people participation and forestry extension in the areas of forest plantation, management and protection. It provided clear directions to raise the total areas of natural forests, wildlife reserves, and range lands. The main objectives were to reserve 20 percent of the total area of the country, manage the forest resources on sustainable basis, institutional strengthening and capacity building. In addition, attention was paid to resolve inter-sectoral conflicts, which have been a major cause of deforestation. The FNC continued to be the custodian of all forests in the country in administering the enforcement of the forest law and levying fees on forest products (Bayoumi et al. 2000).

In 2006 a new forest policy proposal was formulated through extensive stakeholders' consultation process by the project (TCP/SUD/2903 Revision of Forest Policy, Legislation and Institutional Reorganization in collaboration with FNC, Sudan). The drivers for the review of the forest policy include; Reduction of poverty, improvement of people's livelihood, amelioration of physical environment and combating desertification.

The 2006draft forest policy was reviewed in 2015 emphasizing that, the National Policy for Sudan's Forests is" Statement of the intentions of the Government of the Sudan reflects the Government's firm commitment to guide or direct the management of forest resources in the Sudan to maintain the supply of forest products and services to meet the needs of the current generation without compromising the needs of future generations of these products and services". New items were introduced, such as conservation of forest genetic resources, biodiversity, trans-boundary movements of forest products and benefit sharing.

1.6.3. Legislation

The first recognized forest law was issued in 1901, and the Forest Act of 1932 divided the responsibilities of forest administration between the central and provincial authorities. In 1939 a royalty order was enacted for collecting royalties from forest products produced outside the forest reserves to discourage people from cutting trees

outside the forest reserves. A new forest law was issued in 1989, which enacted the Forests National Corporation (FNC) and legalized people's participation in forest management and made provision for private, community, corporate (institutional), and public forests. The Forests Act 1989 has, since its promulgation, been repeatedly praised as the most important piece of legislation in Sudan. It recognized, under the FNC technical supervision, new types of forest ownership: private, community and institutional forest reserves to be managed by owners, committees and institutions respectively, in addition to the national and regional forest reserves. The control over tree cutting outside the reserves was tightened by the requirement of permits from the FNC.

1.6.4. Forest National Corporation Act, 1989

The establishment of the FNC was a significant change in the forestry administration. The outcome of the act with the assistance of the international contributions, led to the establishment of the FNC, which is a parastatal service-oriented and independent body corporate. It has functional freedom and flexible procedure in retaining revenue to meet its recurring expenses, namely wages, salaries, operation and maintenance.

1.6.5. Forests and Renewable Natural Resources Act 2002

The Forests and Renewable Natural Resources Act, 2002 (FRNR), provides the framework for the management and protection of forests and renewable natural resources encompassing pasture and range as well as the framework governing the managerial system of the forestry sector. Although, it is binding but not fully administered, and the FNC has not levied fees for browse or grazing resources used by livestock in forest reserves. Furthermore, the Act required the establishment of a Forests Police Force, which is beyond the entire FNC budget and was not established. The Act obliges investors in agricultural schemes to leave not less than 10% of the total area of a rainfed project and not less than 5% of the area of an irrigated project as shelter belts and protective wind breaks.

In 2015, the FRNR, 2002 was revised to provide for joint forest management, benefit sharing, community forestry, and recognize indigenous culture and peoples, protection of genetic resources. Also, the "reconciliation mechanism" and the natural resources police have been revoked. The multi-sectoral approach of the 2002 Act has also been repealed and all measures related to range and pastures in the 2002 Act have been disregarded. Still this revised act of 2015 was not sanctioned (Abdelmagid and Shareef 2018).

1.6.6. Review of Past Forest inventories in Sudan:

Extensive efforts were made to study the extent of the forest resources in the Sudan. The state of forests cover was conducted by national studies and surveys, and from global estimates. The surveys can be summarized as follows:

- The first geographical distribution of vegetation in the Sudan was made by plant botanist Schweinfurth in 1868. This descriptive effort was based on rainfall variations as a deciding factor of plant distribution between the different vegetation zones.
- The second attempt was made by the Sudan Government Botanist F.W. Andrews in 1948, who considered rainfall and soil type variations as the main factors affecting forest type distribution with topographical changes having a lesser effect. Andrews's work was further developed by Smith in 1949 that provided special emphasis to the effect of soil variation and soil texture on plant distribution.
- The third effort was given by Harrison and Jackson in 1958 "the Ecological Classification of the Vegetation of the Sudan". They recognized five main divisions of plant types but presented the "area dimension" for each type for the first time in the Sudan plant classification history. Their results were extensively cited and used for about half a century.

- A number of studies were conducted through the fifties of last century (Lewis 1953, Ferguson 1954). The Forests Department conducted various surveys in the Central and Eastern regions mainly for the preparation of Working Plans in reserved forests. In 1977-1979 when Southern Sudan's forests were run independently by the Southern Forests Administration (under the Addis Ababa Accords) ODA funded a survey for the Imatong forests on the Ugandan boarder as part of the utilization program implemented in the area.
- In 1957, Hunting made aerial photographs of West Darfur and were used to map forest types. Similarly tree inventory was made in selected random sampling from images which give clear portrait on the volume of forest resources and productivity.
- Abbas et al (1976), led by a team of specialists, conducted a pilot forest inventory 1050 km2 in the Lucca region, based on satellite imagery combined with limited aerial photography to test the feasibility of technology in conducting a forest-wide resources inventory.
- Stillingwerf (1965) undertook aerial survey over Bahr al-Ghazal for the purpose of selecting sites for the Russian sawmill. The flight route was determined in the light of aerial photographs covering 917,000 square kilometers of Vuba, Mahogany and Bay forests lies north and west of Wau.
- In 1975, the Ministry of Agriculture of the Southern Region requested the services of the British Ministry of Overseas Development to make aerial photography of the tropical Imatong Mountains, in preparation for a joint venture to exploit planted Cupressus forests and forest restoration. In light of this, a British / Sudanese company has rehabilitated the saw-mills and their sources of hydropower, housing facilities and other facilities in Ketri, Kilo and Atepol. The same British Ministry also used aerial photographs to make an inventory of forest resources (800 acres) in the Telanga area on the slopes of the Imatong, and gave the volume of the growing stock for forests.
- In 1982 the National Energy Administration (NEA) conducted a forest resource survey using satellite images produced by US Landsat 1 Multi-Spectral Scanner (MSS) for the period 1972 -1975. The study was implemented by the staff of the Forests Administration assisted by local experts from the University of Khartoum, the Forestry Research Institute and the Regional Remote Sensing Facility (Nairobi). A composite vegetation map, divided into thirteen strata and one sub-stratum (forestry plantations), was designed for the years covered. The crown cover of each forest stratum ranged between 80 – 30%. The map showed marked reduction of forests in the Central and Eastern provinces of Kassala, Blue Nile and White Nile when compared to earlier maps and more recent images.
- In 1983-1984 CIDA conducted an aerial photography that covered Blue Nile and Bahr el Ghazal Provinces, which are high potential

areas, using randomly selected plots to determine the tree standing volume. The area covered was relatively small and the operation was considered relatively expensive.

- In 1987 extensive survey was conducted by FAO project GCP/SUD036/NET via Lund University to cover an area of 580000 km2 in AlGadarif, Kassala and other areas in central Sudan. The project used Landsat Thematic Mapper (TM) but with limited field data to determine the size of the woody biomass in the surveyed area.
- The Sudan Reforestation and Anti Desertification project (SRAAD) funded by Sudan Government and the United States Agency for International Development (USAID) also utilized TM data but used a much higher number of field plots and visual interpretation of imageries. Location of sample plots in the field was carried out using the global positioning system receivers (GPS) to within +_20m. The use of these devices helped to avoid the locational problems faced by the previous inventories. SRAAD project used a systematic sampling design on a 7 km x 7 km grid. The outputs of the project were stand and stock tables for the surveyed areas and image woody vegetation distribution maps. The project used both image analysis and geographic information system (GIS) technology (Anon1990). The project which started in 1989 continued even after the American support for the project was which drawn in 1990 and completed two map sheets. Field data for six map sheet in Darfur were collected but it was very regrettable that all these data were missing after the termination of the project.
- The FNC conducted a National Forests Inventory (NFI) (1995-1997) to assess the available wood supply as compared to the

demand. This was done after completing an energy consumption survey in 1995, which presented the country's demand size for wood energy, the 1995-1997 Inventory was carried out by the FNC in collaboration with the FAO through a project supported by the Government of the Netherlands. The basis of the methodology is the measurement of fixed area plots on a systematic grid throughout the area to be inventoried. It was estimated that 8000 plots will be required to cover the area surveyed by the forest products consumption study. However the total numbers of plots enumerated in the national inventory were 6160 plots. The plot size was 20 x 100 meters with a regeneration sub –plot of 1 by 10 meters and the plot orientation was East-West. Plot descriptors followed SRAAD model and diameter at root collar (DRC) for most tree species, tree height and crown diameter were measured. The final report reviews the NFI objectives; methodology used and results in the form of tables, charts, graphs and maps. The results cover such parameters as land cover, land use, land condition, crown closure, volume of woody material, number of species, stock and stand tables, regeneration and a comparison of harvest level (annual allowable cut) and consumption (Table 1.1).

- The Africover project was launched in 1997 and covered 10 Nile Basin and East African countries including the Sudan. The project used TM coverage and the produced maps were visually interpreted. Ground validation was limited to some areas in Western Kordofan, Southern Darfur and Red Sea Provinces and scattered samples in central Sudan. The initial area calculations using the map legends resulted in a forest cover of 25.895 ha (or 31.746 million ha after calibration as reported by FNC to FRA 2005) which is approximately 10 - 12 % of the country area and OWL of 17 % 0f the area.

Table 1.1 Results of NFI 1995-1997

Activity	
Start of NFI	March 1995
Completion of NFI	July 1997
Total surface area of Sudan	250 060 000 ha
Area targeted by NFI	95 000 000 ha
Total area inventoried	92 270 000 ha
Total area inventoried % of target	65.5%
Total area inventoried of Sudan %	24.9 %
Total number of tree and shrub species encountered in inventoried area	84 species
Total area of forest with crown closure > 10 % in inventoried area	4 940 000 ha
Total volume of woody vegetation in inventoried area	166 752 600 m3
Total average volume / ha in inventoried area	2.49 m3
Total annual allowable cut inventoried area (calculated as 7% of total volume)	11 672 682 m^3
Total annual wood consumption of people in inventoried area (1995)	16 522 112 m^3
Total area constituted as forest reserves in the inventoried area	7 112 703 ha
Total area of forest under forest management Plans in inventoried area	116 274 ha

CHAPTER 2
THE NFI PROJECT

2.1 Background

Pervious assessments and inventories of Sudan's forests resources were limited in scope in spite of an enormous wealth of vegetation and tree cover across the ecological zones. Forest based small industries constitute a main pillar to the national economy as well as to local economies, and provide 15% of job opportunities in the country. In addition, more than five million farmers earn their living depending on Gum Arabic production. Forests contribute to 30% of the fodder requirements of the national animal herd.

Although forests are important carbon sinks, the National Communication Report (1998) indicated that the forestry sector contributed 75 % of Sudan's CO^2 emissions. On-site and off-site wood burn resulted in such high contribution of forestry sector as a result of forest conversion The overall objective of Sudan's national implementation strategy for climate change is to promote sustainable development paths that improve Sudan's adaptive capacity and limit the growth in GHG emissions through integration of climate change issues and concerns into national policies, strategies and development plans.

As such an up to date and complete national forest monitoring is of an utmost importance as a basic information requirement for integrated rural development planning, poverty alleviation measures, climate change, REDD+ and assessing forest cover change. The institutional, policy, strategy and legislation frameworks is encouraging and favourable for the development of the sector, and constitute a strong empowerment towards improved forestry practices in Sudan, provided that they are supported with up-to-date information based on a lasting monitoring system as foreseen in the Forests and Renewable Natural Resources Act 2002.

The government mobilized substantial resources and the FAO provided technical assistance and guidance to carry out this NFI. The NFI contribute to the sustainable natural resources management and utilization; mainstream the benefits in the national economy and policies and provide mechanism to evaluate effectiveness of the REDD+ strategies in reducing Greenhouse Gas emissions. The FAO technical assistance provided the required technical assistance, capacity building, and procurement of equipment's.

2.2 NFI Objectives and outputs

The main objective of this NFI is to improve carbon and forest information, and that capacities are built for periodical assessment and updates as follows:

1. Design and set up of a long-term monitoring system of the forests and woodlands through a network of permanent plots located across the country.
2. Collect national data on the context of REDD+ on forest and other land cover area, growing stock, biomass and carbon, state and quality of the forests and trees outside of forests, social economic information about use and management of forest products and services.
3. Establish a database to store and manage the field information for analysis and dissemination.
4. Improve the technical capacities and capabilities of professionals and relevant national institutions in NFIs.

2.3 Support

The NFI is one of the products of the technical assistance agreement for the design of MRV system in Sudan, among other related outputs of the technical assistance agreement. The

World Bank's FCPF has supported the country in adopting the REDD+ in the readiness phase since 2015. The FAO has provided support as a technical organization in the field of MRV and NFMS. The FAO role was to implement a Technical Assistance Agreement signed in August 2016 by FAO and FNC. In addition, the REDD+ received national support and collaboration from internal institutions like the education, research, ministries, private sector, and national experts (Figure 2.1).

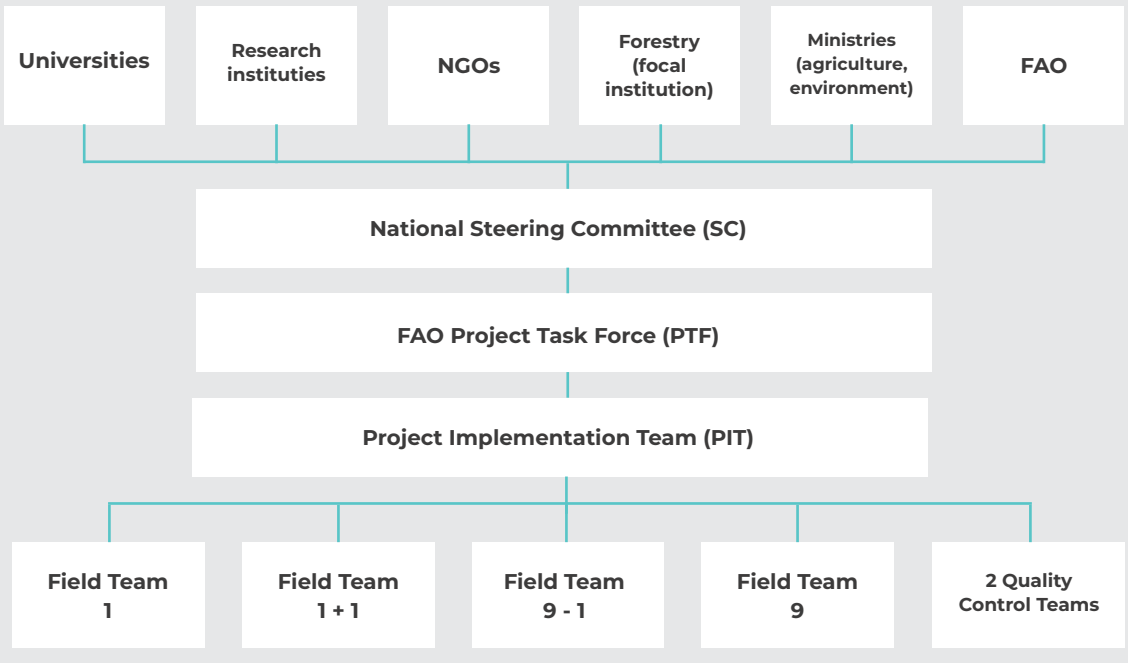
2.4 Project Management

The FNC is the focal institution of the project that is led by a full time national project coordinator (NPC) as well as the Project Implementation Team (PIT). The team consists of members from participating national institutions to coordinate, execute and monitor the project activities. The (PIT) is supervised by the FAO Project Task Force (FAO-TF) and the National Steering Committee (SC) whose mandate is to oversee the NFI activities. Field teams in collaboration with PIT are responsible for field data collection. Quality control teams to verify some randomly selected sampling units' data collected by the field teams to assess their quality. The organizational structure is included in Integrated Field Data Collection Manual. (Figure 2.1) illustrates the organizational structure of the project.

2.5 Timeline

The timeline for the TA agreement was from August 2016-31 December 2018. The actual commencement of NFI activities of the NFI took place in April 2017, stopped for rainy season and continued in the 4th quarter of 2017. It continued for the year 2018 with intervals of the rainy season

Figure 2.1 Project organization



and stops of other reasons. So the final report of the NFI was scheduled to be delivered before 31 December 2018. With the extension of the TA till 2019, an intensification of the sampling made by 263 Sampling Units in the states of Darfur, Kordofan, and Central regions. Accordingly the timeline to deliver NFI results was extended to 31 December 2019. Another extension until December 2020 was agreed upon by the World Bank and the implementers, the Government of Sudan and FAO. Despite the additional outputs, the NFI results were ready before the end of 2020. Nevertheless, the report benefited from the extension as it allowed adequate time for reviews and validation of outputs.

CHAPTER 3
METHODOLOGY

This chapter gives brief accounts on the methodologies used by NFI in field data collection and analysis. Details are presented in the manual for integrated field data collection.

3.1 Preparatory phase

The preparatory phase began in 2017 with stakeholder consultations to review the FAO traditional methodology's relevance to Sudan conditions and requirements. It was then decided to use a systematic cluster sampling design, and field manuals were then developed. During this phase all the preliminary arrangements and preparatory works of the project were carried out that included a number of activities:

1. Development of a National Land Use Classification System that agrees with the Global Land Use classes (GLU) identified by FAO.
2. Fine-tuning of Forest and Tree Assessment Methodologies for field data collection.
3. Identification and training of team leaders and field crews for the field data collection.
4. Collection of maps to be used in the field during the field data collection.
5. Identification and recruitment of the local as well as international experts required for the implementation of the NFI.

3.1.1. Training of staff

In preparation for the field work, four Sudanese specialists were trained in the FAO HQ in April 2017, for the purpose of reviewing the sampling methodology, screening the Sampling Units and cancelling the empty units. The initial 1025 total Sampling Units, before intensification were thus reduced to 705 using Collect-Earth tool.

Training of field crews was conducted in the Dam City between Roseris and Ed Damazin cities for 15 days from 18/ April -2/May, 2017. The FNC was not able to involve other staff from range, wildlife, and soil fields due to financial limitation. Only four range officers were trained representing Kordofan, Eastern and Darfur teams. The range crews attended the field work in North Kordofan and discontinued. The number of trained crews included 27 persons, 5 head of technical sectors, 4 from range general directorate. Total number of teams was 9: one team for each of the Northern and the Eastern. Two teams for the central region, 2 teams for Kordofan region, and 3 teams for Darfur region.

The training in the field of sampling methodology referenced to the Field Sampling Manual of Sudan current NFI 2017-2019. The training included theoretical and practical applications in the forests around Ed Damazin, in addition to training in tablet use for direct data collection in the field. The training was facilitated by FAO Office at Ed Damazin and Blue Nile state Forest Director, and 3 FNC technical experts and FAO national RSS expert, and 5 heads of the regional technical sectors participated in the training.

Quality Assurance/ Quality Control engagement QA/QC: The universities of Khartoum and Kordofan were engaged in the QA/QC. In January 2018 training was conducted to more than 30 members of the two universities about the concept and procedures of QA/QC by the FAO-NFI consultant. The analysis and results of the QA will be attached to the NFI report.

3.1.2. Field equipment per team

In order to conduct the data collection in the field, each field team must carry the equipment that is listed in table 3.1.

Table 3.1 Equipment required for each field team

Equipment needed	Number required	Additional Comments
Measurement tools		
Precision compass (360°)	1	- High precision - In degrees - Water-proof and resistant
GPS receiver (Geographic Positioning System) and extra batteries	1	- Possibility to calculated average point - Optional antenna
Tree height and land slope measuring equipment	1	Clinometer with 15m, 20m and % scales to measure both tree height, in meters, and slopes, in percent
320cm/10m diameter tapes	2	- Graduated in meters - Diameter measurement on one side, distance measurement on the other side - Auto rewind
30-50m measuring tape or rope/ chain marked at every meter	1	Metric (Self-rolling)
Range finder with amplification	1	Optional
Digital camera+ Spare memory card + Extra batteries + charger	1	
30-50cm galvanized steel bars for plot marking	40	For plot marking
Colored flagging tape	Several rolls	Used for marking and retracing the access route
Machete	2	
File	1	
Water-proof bags	2	To protect measurement instruments and forms
Spade / Augers	1	For soil profiles and soil sample collection (optional)
Callipers / ruler	1	Metric For shrub stems and deadwood branches diameter measurements
Clothing		
Boots and waterproof outfits	For each permanent team member	Size to fit team members
Leather gloves	1-2 pairs	
Helmet	For each permanent team member	Optional, for are where there are risks for branches to fall

Equipment needed	Number required	Additional Comments
Documents, papers		
Clipboard	3	To take notes
Topographic maps and field maps	As necessary	
Field forms	As necessary	
Field manual	As necessary	
Notebooks	3	
Pens and markers	As necessary	
Hand calculator	1	
Flora and fauna species lists and identification keys	As necessary	On forestry, pasture, range, weeds, pests and others are relevant topics
Other equipment (camping, security, communication...)		
Flashlights and batteries	As necessary	
Knives	1	
Camping equipment and cooking utensils	1	Food if required
First aid kit	1	With phone numbers of hospitals / emergency
Cell phone and/or radio	1	For communication with supervision or in case of emergency

3.2 Data Collection

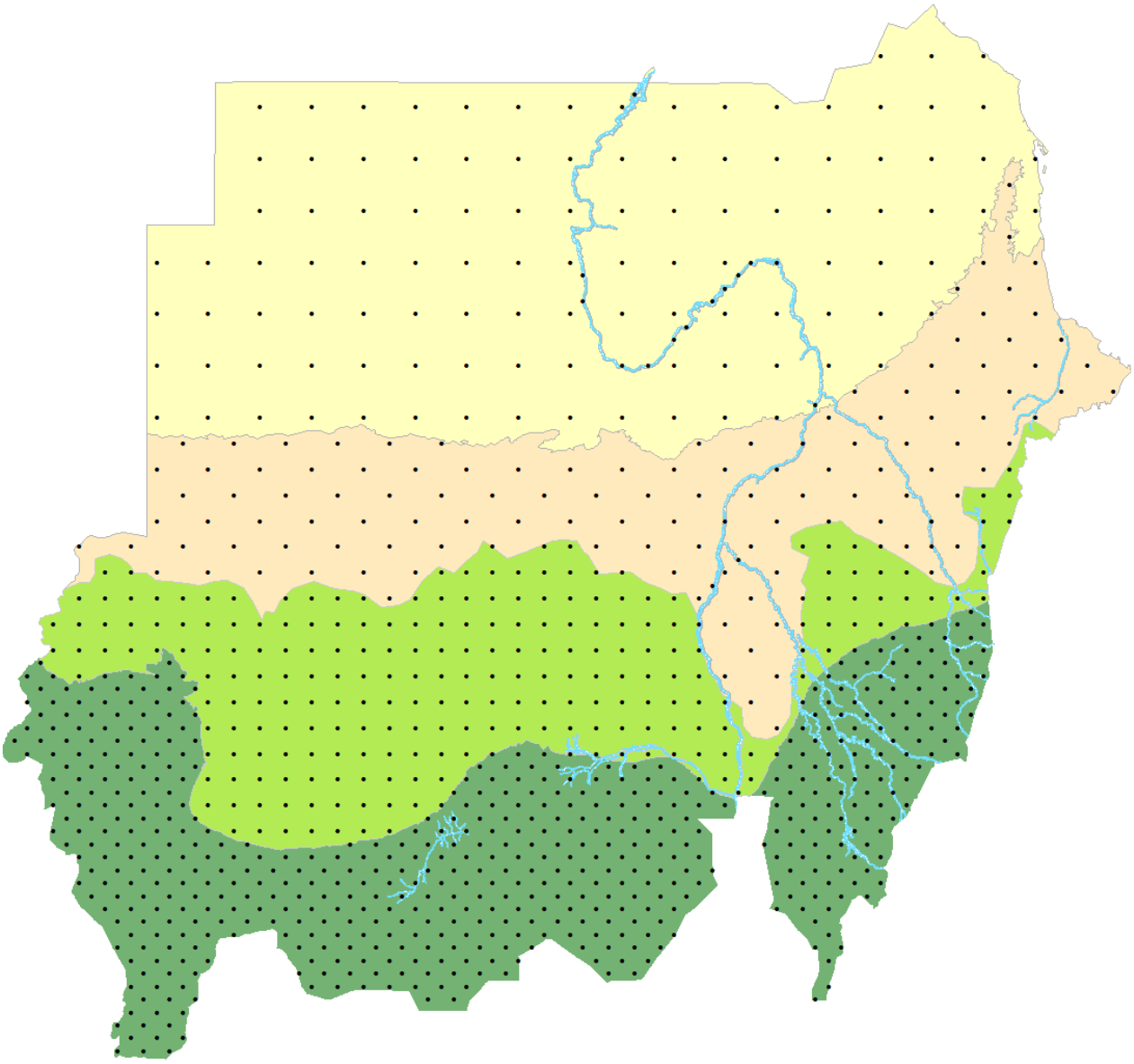
3.2.1. Sampling Design

After a number of consultation meetings with stakeholders, a systematic cluster sampling design was adopted, and Sampling Units (SU) were selected at the grid intersection of the latitude longitude degrees. The number of SU to be surveyed was determined by the available financial and human resources. Stratification of the area was adopted based on aridity zonation and ecological zones to improve the design (Annex 1). The project area was stratified into five strata and SU were allocated to each stratum according to vegetation density as shown in Figure 3.1. Initially 1333 SU were determined and then 422 SU were added to improve the estimates of the variables to be measured. The 1755 SU were then reduced to 968, and finally 784 SU were visited as the rest were inaccessible due to security or physical reason (Table 3.2).

Table 3.2 Sampling Design

Stratum No	Initial No. of S U	No. Of SU for measurement	No of SU done	Area km²	Interval
1	107	000	000	676 741.6	Baseline 80,000 m. Survey line 80,000 m
2	123	023	20	389 852.6	Baseline 80,000 m. Survey line 40,000
3a 3b	224 207	13 048	159	35 9723.1	Baseline 40,000 m. Survey line 20,000
4a 4b	540 215	540 215	577	431 610.4	Baseline 20,000 m. Survey line 20,000 m.
5	029	029	28	24403.3	Random
Total	1755	968	784	1 882 331	

Figure 3.1 Sampling Design



3.2.2 Sampling Unit, Sample Plots and Sub-plots description

Data was collected in the field through observations, measurements and interviews at levels within the limits of the SU and in smaller subunits, the plots, subplots, Land Use/Cover Sections (LUCS) and Land Use/Cover Classes (LUCC) (See fig.3 of Field Manual pages 13 and 14). The SU or tract was a square surface area of 1 km x 1 km. The coordinates of the south-west corner of the SUs corresponded to those of the points selected in the systematic sampling frame. Each Tract has 4 Plots with the dimension 20m x250m (area 0.5 ha), and it was within the Plots that the actual field measurements were carried out.

The plots were rectangles, with surface areas measuring 20 m wide and 250 m long within the SU. They started at each corner of an inner 500 m square (same center as SU's) and were numbered clockwise from1 to 4 as shown in the Figure 3.1 and Table 3.3 shows the location and orientation of the 4 plots.

Table 3.3 Plot location and orientation

Plot	Location of the starting point of the plot, within the 500 m inner square	Orientation	Bearing
Plot 1	South-West corner	South-North	0 / 360 degrees
Plot 2	North-West corner	West-East	90 degrees
Plot 3	North-East corner	North-South	180 degrees
Plot 4	South-East corner	East-West	270 degrees

Three sets of subplots corresponding to different data collection levels are delimited within each plot:

1. 3 rectangular subplots (RSP), 20 mx 10 m (200 m2). corresponding to level1;
2. 3 Circular Subplots (CSP), with a radius of 3.99 m (50 m2), corresponding to level 2 located in the left–hand half of the rectangular subplots; and
3. 3 litter Subplots (LSP), also circular but smaller with a radius of 18 cm (about 0.1 m2) corresponding to level 3, located in the center of the Circular Sub-plots.

All these subplots categories are numbered from 1 to 3, from the starting point of the plot to the end of the plot. The orientation or the approach or direction for collecting data from the plots are:

- Plot # 1 North-ward
- Plot # 2 East-ward
- Plot # 3 South-ward
- Plot # 4 West-ward

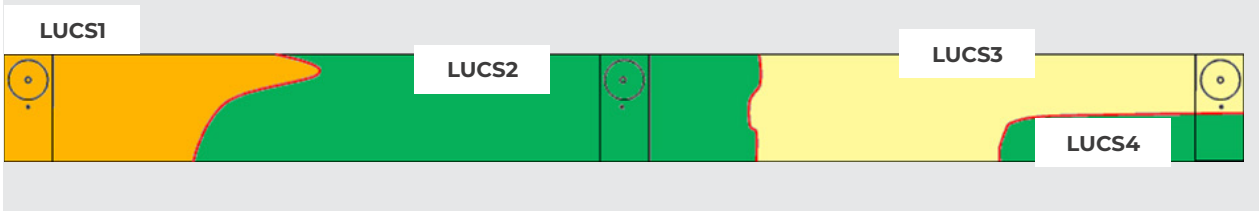
3.2.3 Land Use/Cover Sections (LUCS) and Land Use /Cover Classes Classification System

Each plot is divided into Land Use/Cover Sections (LUCS) were identified in the field as shown in the example below. The classification system adopted to identify the different land use/cover classes is described in chapter 1 of the manual. Data related to grazing, cropping and forest characteristics, management and resources use and users are collected within the LUCS.

All Land Use/Cover Class (LUCC) found in all 4 plots in the SU were also used to collect data on products and services If a land use/ cover class was identified in the SU but was not represented inside the plots, it was not considered. Example of Land Use/Cover Classes (LUCC) distribution within a Sampling Unit (Figure 3.3).

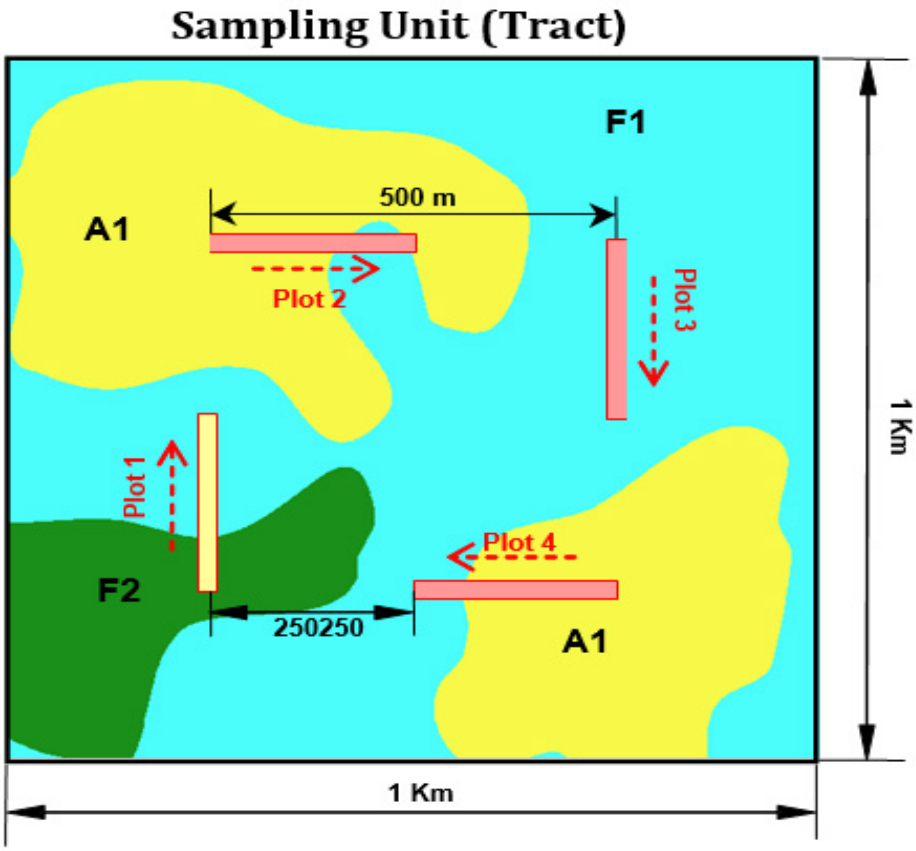
A land use/cover classification system was adopted before the decision on stratification and the sampling system. The land use/cover classes (LUCC) were defined on a dichotomous approach that included the following levels:

Figure 3.2 Land use Land Cover Section



Note: There are four land use/cover (LUCS) sections in this plot. The wavy lines indicate the limits between them. LUCS2 and LUCS4 belong to the same Land Use/Cover Class (LUCC).

Figure 3.3 Land Use land Cover Classes



Note: In this example there are three different land use/ cover classes in the sampling unit (coded A1, F1 and F2).

1. The first level was composed of the global classes designed for the assessment of resources at global level, and on the classification system developed by the FAO global Forest Resources Assessment (FRA). The global classes include Forests, Other wooded land, Other land and Inland water;
2. The other levels were country specific and included additional classes designed to meet specific national and subnational information needs. They were applied to differentiate between land use/cover categories according to criteria such as species composition, phenology, vegetation canopy cover (closed/ open/ sparse), naturalness (primary/ secondary forest)

A code characters was assigned to each class in order to facilitate data collection and input.

Refer to annex A2 for more information about Land use/cover classification in the NFA of SUDAN.

3.3. NFI Quality Assurance / Quality Control

3.3.1 Introduction

The whole NFI data production process undergoes a formal Quality control / Quality Assurance (QC/ QA) procedure that entail:

1. Mandatory training and accreditation of all of those responsible for conducting the NFI.
2. Ground control of 10% of sampling units by an independent contractor.
3. Product approval procedure (max. of 10% error index between FNC field crew and QC/QA university field crew data).

The goal of the NFI QA/QC study is to provide a framework to assure the production of complete, accurate, and unbiased forest information of known quality. During the data collection, it was important to ensure that the: data were complete,

the standards were kept consistent, and that the working equipment and measuring instruments were in good working order. The field supervision, the instruction (field manual) and training of the field crews, and periodically visiting the survey teams in the field all helped to meet this goal. Before the data will be analyzed they had to be checked to see if they were complete and plausible.

Following the NFI Sudan implementation in 2017, the Faculties of Forestry of the University of Khartoum and the University of Kordofan were solicited to assess the QA/QC study. The objectives for this NFI QA/QC are to: assess the data quality of the initial 784 SU measurements and identify inconsistencies. Prior to this study QA/QC, the FNC and FAO had:

1. Conducted training for 33 participants from the two Faculties of Forestry of the UKA and the UKO during the period 28th January to 1st of February 2018.
2. Set up a Letter of Agreement (LoA) with each university to re-measure 65 SU (49 SU for Kordofan and 16 SU for Khartoum) or about 8% of the total of 784 SU.

From March 2018, each Faculty had mobilized two QA/QC teams to conduct control measurements in the field in accordance with the IPCC Good Practice Guidance and Uncertainty Management (GPG2000, IPCC, 2000 Chapter 8, Quality Assurance and Quality Control, Section 8.10.1, Internal 3). The QA/QC teams completed the control measurements independently of the FNC field teams. The composition of the QA/QC teams is similar to the FNC regular team except that the field forms F1, F4, F5 and F6 will not be done.

3.3.2. Method of assessment

Evaluation of the quality of data being collected for the NFI Sudan will be accomplished by calculating the differences between FNC field crew and QA university field crew data. Sixty five SU are selected systematically in all the four stratums, are measured by operational NFI field and then re-measured by universities control team that made careful and unhurried measurements. The paired data will be evaluated, including diameter at breast height (DBH), total height, bole height, tree count, land use cover section, and coordinates, and then the two sets of data are compared, analyzed, and scored to the given measurement quality objectives (MQO) standards.

Each data measured in the field has an associated MQO for precision. This is an assigned tolerance or acceptable level of measurement error, and measure the ability of field staff to make repeatable measurements or observations within the assigned tolerances. In the analysis of QA/QC data, an observation is within tolerance when the difference between the collected data by FNC field staff and the university quality team do not exceed the assigned tolerance or MQO for that data element. For some data elements, the tolerance is no error, thus only observations such as name of species, code of the land use cover section (LUCS), the coordinates of plot. For example, the tolerance for measurement of diameter is+/- 3 cm for each tree or stump with the MQO for diameter set at 95%. The objective for DBH measurement would be that 95 percent or more of the DBH measurements are within +/– 3cm for each tree or stump of diameter for all trees measured by both FNC and Universities QA/QC crews. Results can be displayed as a simple percent of difference calculations that fell within the program tolerances. This percent will be referred to as the observed compliance rate.

3.3.3. Data entry and cleansing

Each SU field form had a table for tracking the work done. Each person handling the field data had to indicate their name, date of work and sign to certify that the work was completely and correctly performed. The work processes captured on the field form were data registration in the field, checking of field forms in the field, data entry in the office and data cleansing in the office. A field data delivery form had been introduced to track the delivery of field forms from the NFI field teams to the project management team and onwards to the FNC office. The delivery of completed SU field forms had been recorded for all SU numbers along with the date of submission to the next level. The hand over will be confirmed by signature of deliverer and receiver. Keeping a good

track of the delivery of the field forms is essential as they represent a large investment in time and money. Any loss of field forms would have seriously affected the project progress. To avoid loss, filled out NFI field forms are transported to FNC HQ in Khartoum respectively using project vehicles.

Data entry and cleansing: At the FNC Office, the field forms were registered, archived, and submitted to the data management team for entry and cleansing using the Open Foris Collect (OF-Collect) database application.

Initially, data entry was planned to be done in the field. However, due to various constraints (poor working conditions, logistical challenges and low quality outputs due to staff working in isolation and under little daily supervision), only a few NFI teams use the tablet on the field, this activity was centralized. Due to underestimation of data entry task, inadequate motivation of FNC staff involved and system down time there was a backlog.

Before starting data entry, NFI project team controlled all SU field forms and completed if necessary missing information or even ask for field controlling.

During data entry, OF-Collect is used to enter the data contained in the field form into a database exactly as it was written in the field form. In order to minimize possible data entry errors, the entered field forms will be further cleansed in the OF-Collect application. In doing so, the system stored a copy of the original data, which makes it possible to retrieve the original data. Also, all the original NFI field forms should be stored in an orderly fashion at the FNC office.

OF-Collect contains a number of logical rules to highlight values that cannot be accepted by the database application (errors) and values that seem improbable and need double checking (warnings) before accepting. All errors detected by OF-Collect had to be cleared before a cluster form is submitted for analysis.

3.3.4. Results and validation

Table 3.4 presents the summary of some irregularities captured by the QA teams during the NFI field work.

The general impression of the NFI project team was that the continuous field supervision and the presence of the QA teams and the feedback to the field teams had a positive effect on the quality of the work delivered by the field teams.

3.4. Data analysis

3.4.1. Database design

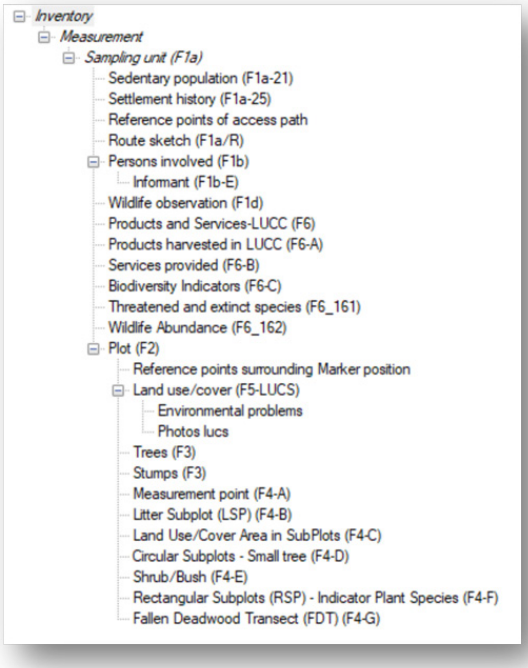
In order to perform the data analysis, a database was created in MS Access format (relational database system) to allow to implement queries (SQL-Structured Query Language instructions) for the generation of specific data sets for analysis. To develop the database in Access, the data structure

Table 3.4 Irregularities captured by the QA teams during the NFI field work

Irregularities detected by QA	Share (%)
Wrong tree identification	<5%
Wrong tree numbering or counting	10%
DBH measurement	5%
Total height	5%
Bole height	5%
Inadequate plot center description/referencing	10%

that the NFI originally had in Open Foris Collect was used. In the database of Access, the same variable coding and type was maintained.

Within the database several SQL procedures were created to calculate intermediate variables such as basal area, volume, biomass, carbon, etc. To consult the details of the calculation of the variables mentioned above and allometric equations used, a document on calculation procedures was prepared and is available for consultation[4].



Once the field information was cleaned in Open Foris, the process of export of the data was carried out in the format CSV (comma-separated values) of Excel. From Excel, the information was imported into the Access database for its respective analysis. The following figure (tree) shows the structure of the database, each one of the items represents a table and its dependents are derived from each one of them; for example, the table that contains the Trees information depends on the Plot and is in turn of sampling unit. The table at the top of the structure is the one for the inventory project.

3.4.2. Estimation methodology

In this NFI the Stratified Random Sampling estimators were applied, but only four of the five strata were used for calculation, the stratum I (deserts) was not included in the calculations because it has no SUs. Stratified Random Sampling applies when the strata are defined and a random (or systematic) sample is selected within each stratum. Table 3.5. Shows the areas and SUs in each stratum used for the calculations.

The process of calculation of estimators are explained in detail in the document Estimation Using Ratio-to-Size Estimator across Strata and Subpopulations (Scott, C. 2020). A brief summary of the estimations from this document is presented below.

For security reasons, negative of the owners or difficult topography, in some forest inventories a few of the plot could not be measured in their entirety and some of proportions of then are measured. In this case the Ratio-to-Size estimation is used to adjust for the missing parts. The method of Ratio-To-Size assumes that subplots are missing randomly within the stratum.

Table 3.5 Area and sampling units by stratum

Plot	Location of the starting point of the plot, within the 500 m inner square	Orientation	Bearing
1	Stratum II (semi-desert ecosystems)	38,985,260	20
2	Stratum III (Low rainfall woodland Savannah)	35,972,310	159
3	Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	43,161,040	577
4	Stratum V (this stratum includes rivers and streams)	2,440,330	28
	Total	120,558,940	784

4 NFC-FAO, 2020. Calculation Procedures, Sudan National Forest Inventory.

For Ratio-To-Size method the following text describes the estimators used. The letter y denotes the attribute of interest (example volume/ha or carbon/ha). The letter "a" denotes the area measured on each plot. The letter h denotes the stratum (1 to 4 in the case of Sudan). The letter d denotes the domain of interest. The domain can refer to an area characteristic of the plot or subplot or can refer to the observational aspect, such as tree species, health condition or diameter class for example.

The mean of the attribute of interest in domain d within stratum h is computed with a numerator as the total of the attribute measured that is in the domain of interest and the denominator as the total area measured:

$$\bar{Y}_{hd} = \frac{\sum_i^{n_h} y_{hid}}{\sum_i^{n_h} a_{hi}} = \frac{\sum_i^{n_h} \sum_k y_{hikd}}{\sum_i^{n_h} a_{hi}} \quad \text{(Eq. 1)}$$

Where:

yhid = sum of the attribute of interest in domain of interest d on plot i in stratum h,

yhikd = the attribute of interest in domain d in plot i on subplot k,

nh = the sample size in stratum h,

ahi = area measured on plot i in stratum h (this excludes inaccessible areas).

For example, when estimating values for trees sampled using different subplot sizes (in some forest inventories trees with DBH<20 cm are measured in a small nested plot and the trees with DBH>=20cm are measured in other plot with different size), in this case the largest subplot size is used in the denominator of the equation. For trees observed with smaller subplot sizes, then the attribute is expanded to the larger subplot size by multiplying it by the larger subplot area divided by the smaller subplot area. The plot attribute can be calculated as following:

$$y_{hid} = \sum_j^J y_{hijd} \frac{\sum_i^{n_h} a_{hiJ}}{\sum_i^{n_h} a_{hij}} \quad \text{(Eq. 2)}$$

Where:

yhijd = sum of the attribute of interest in domain of interest d on plot i on plot size j across all subplots

ahij = total area across all subplots of size j measured on plot i in stratum h

J = the value of j indicating the largest subplot size.

This same approach is used for computing totals across different components, such as standing tree carbon (above and belowground, live and dead) or carbon in down woody material. For the down woody material, the compilation steps described earlier result in per hectare estimates, thus a hectare is the largest total subplot area, thus correspond to J. The ratio of areas term expands trees to the hectare while compensating for any differences in the proportion of subplot sizes that were not measured.

The stratum variance is computed with the following equation:

$$v(\bar{Y}_{hd}) = \frac{s_h^2}{n_h} = \frac{n_h}{n_h - 1} \frac{\sum_i^{n_h} y_{hid}^2 - 2Y_{hd} \sum_i^{n_h} y_{hid} a_{hi} + Y_{hd}^2 \sum_i^{n_h} a_{hi}^2}{\left(\sum_i^{n_h} a_{hi}\right)^2}$$

(Eq. 3)

The strata means can then be combined using the known stratum weights (proportion) like a factor of ponderation, Wh are the stratum areas divided by the total area of all strata. The mean across all strata is computed with the following equation:

$$\bar{Y}_d = \sum_h^H W_h \bar{Y}_{hd} = \sum_h^H W_h \frac{\sum_i^{n_h} y_{hid}}{\sum_i^{n_h} a_{hi}} \quad \text{(Eq. 4)}$$

and its variance as:

$$v(\bar{Y}_d) = \sum_h^H W_h^2 \, v(\bar{Y}_{hd}) = \sum_h^H \frac{W_h^2 s_h^2}{n_h} \quad \text{(Eq. 5)}$$

For example if the calculation is related to carbon in forest, the means above must be adjusted for the proportion of the plot that is not in forest. Then the carbon in forest area means above must be divided by the proportion of the plots that were forest, domain d'. The proportion is estimated for each stratum as following:

$$\bar{X}_{hd'} = \frac{\sum_i^{n_h} x_{hid'}}{\sum_i^{n_h} a_{hi}} \quad \text{(Eq. 6)}$$

Where:

xhid' = sum of the total area of the largest subplot size J in domain of interest d' on plot i in stratum h.

The stratum variance is estimated using (Eq. 3) by substituting x for y. The overall mean and variance are evaluated substituting x for y in (Eq. 4) and (Eq. 5), respectively.

The mean of the attribute of interest (for example Carbon in forest area) is estimated as the ratio:

$$\hat{R}_{dd'} = \frac{\hat{Y}_d}{\hat{X}_{d'}} = \frac{\bar{Y}_d}{\bar{X}_{d'}} \quad \text{(Eq. 7)}$$

The variance for the ratio uses the covariance and is approximated via the following equation:

$$v(\hat{R}_{dd'}) = \frac{1}{\bar{X}_{d'}^2}\left[v(\bar{Y}_d) + \hat{R}_{dd'}^2\, v(\bar{X}_{d'}) - 2\,\hat{R}_{dd'}\, cov(\bar{Y}_d\,,\ \bar{X}_{d'})\right] \quad \text{(Eq. 8)}$$

The covariance of the equation 8 is estimated as:

$$cov(\bar{Y}_d\,, \bar{X}_{d'}) = \sum_h^H \frac{W_h^2\, cov(Y_{hd}\,,\ X_{hd'})}{n_h} \quad \text{(Eq. 9)}$$

Where the stratum covariance is:

$$cov(Y_{hd}\,,\ X_{hd'}) = \frac{n_h^2}{(n_h - 1)} \frac{\sum_i^{n_h}(y_{hid} - a_{hi}\bar{y}_{hd})(x_{hid'} - a_{hi}\bar{x}_{hd'})}{\left(\sum_i^{n_h} a_{hi}\right)^2} \quad \text{(Eq. 10)}$$

$$= \frac{n_h^2}{(n_h - 1)} \frac{\sum_i^{n_h} y_{hid}\, x_{hid'} - \bar{y}_{hd}\sum_i^{n_h} a_{hi} x_{hid'} - \bar{x}_{hd}\sum_i^{n_h} a_{hi} y_{hid'} + \left(\sum_i^{n_h} a_{hi}^2\right)\bar{y}_{hd}\bar{x}_{hd'}}{\left(\sum_i^{n_h} a_{hi}\right)^2}$$

These estimators were applied to each of the estimations of different variables in the Sudan NFI.

3.4.3. Silva Metricus

In the case of the estimations of the NFI of Sudan, the Silva Metricus software (http://www.silvahn.com) was used and the database described in section 3.4.2 was used to manage the data collected in the field.

Silva Metricus is a software developed for the calculation and management of forest inventory data; this system has been developed since 1995 (previously called SIBP2). Over the years, and for its development, it has had the support of organizations such as: United States Forest Service, SilvaCarbon, UNDP, FAO, among others. Silva Metricus is a mature software that has been used for the processing and management of data in forest inventories in countries such as Panama, Peru, Honduras, Guatemala, Costa Rica, Gabon, Angola, Vietnam, Equatorial Guinea, etc.

Silva Metricus is software that has no cost to the end user and can be freely downloaded and installed on computers with Windows. It has a desktop version for data analysis and a mobile version (Android) that is used to collect data in the field; the system handles different types of databases such as: Access, SQL Server, MySQL and SQLite.

Silva Metricus implements the calculation of different estimators according to the type of sampling design that has been implemented in a specific forest inventory, in addition, silva Metricus allows calculations of stand tables, double entry tables and biodiversity indicators. The statistical base implemented in Silva Metricus is described in document Estimation Using Ratio-to-Size Estimator across Strata and Subpopulations (Scott, C. 2020).

CHAPTER 4
RESULTS

4.1 Area results

The Sudan total area, 188,233,100 ha, is classified into four major Land Use Classes according to the FAO Forest Resources Assessment (FRA) scheme (Annex 2). National LUCs were also taken into consideration and included in the classification system (Table A1.1). The areas that were not covered in the field in the inventory due to security or inaccessibility were designated as inaccessible.

4.1.1. Area of Sudan by Major Land Use Classes

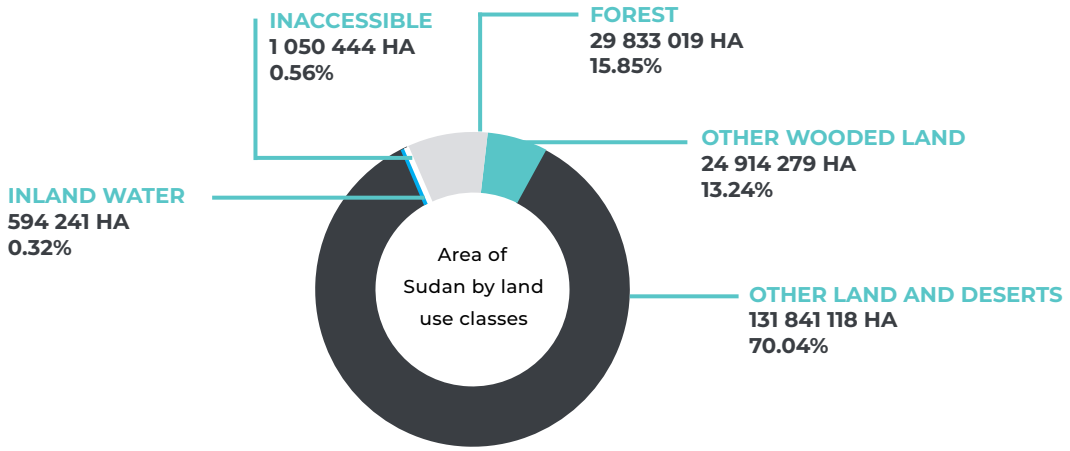
The Sudan total area of has been classified into major classes with the following proportions: 15.85% forest, 13.24% other wooded land, 0.32% inland water and 70.04% other land and desert (Table 4.1 and Figure 4.1). A further subdivision of land classes and their respective areas are presented in Table 4.2 and figure 4.2.

Table 4.1 Total area of Sudan by Land Use Classes

Major Land Use classes	Orientation		Sampling error (%)
	Percentage	Hectares	
Forest	15.85	29 833 019	8.64
Other Wooded Land	13.24	24,914,279	28.26
Other Land and Deserts*	70.04	131,841,118	11.23
Inland Water	0.32	594,241	60.26
Inaccessible	0.56	1,050,444	51.35
Total	100.00	188,233,100	0.00

**The sampling error applies for other Land area, the area of desert (stratum I) was calculated with GIS*

Figure 4.1 Proportions of Sudan's major land uses



4.1.2 Areas of Major land use classes and NFI sub-classes

The land use subclasses (described in A1.1) presented in Table 4.2 and figure 4.2 revealed that:

1. The forest tree cover is mostly naturally regenerated with limited areas of plantations. Also, the natural forest are mostly deciduous (7.76%) and semi-deciduous (7.74%).
2. The other woodland are mostly wooded grassland (11.74%) and woodland (1.42%).
3. The wooded wetland is very limited and lies entirely along the River Nile and its tributaries.

The desert constitutes the vast majority of Other Land (35.95%, add stratum 1 area) while all other categories contribute to smaller fractions of area.

Figure 4.2 Relative proportions of Sudan forests and woodlands subclasses (% of the total area)

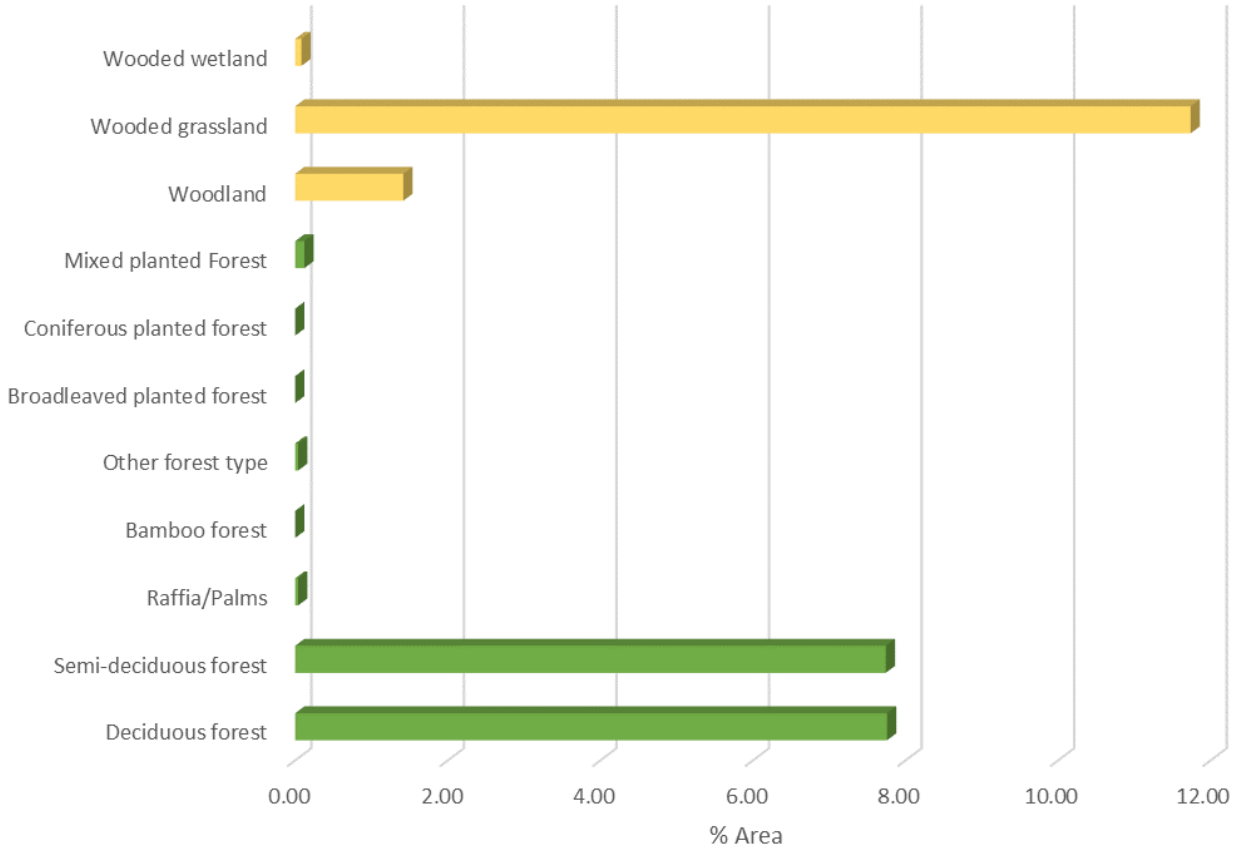


Table 4.2 Total area of Sudan by National Land Use Classes

LUC level 0	FRA Classes (Level 1)	Orientation		%	Area(ha)
		LUC level 2	LUC level 3		
Forest	Forest	Natural regenerated forest	Evergreen forest	0.15	280,509
			Deciduous forest	7.76	14,604,191
			Semi-deciduous forest	7.74	14,572,473
			Raffia/Palms	0.04	74,802
			Bamboo forest	0.00	0
			Other forest type	0.04	74,802
		Plantation	Broadleaved planted forest	0.00	0
			Coniferous planted forest	0.00	0
			Mixed planted Forest	0.12	226,241
Non forest	Other Wooded Land	Woodland	Woodland	1.42	2,666,624
		Wooded grassland	Wooded grassland	11.74	22,093,812
		Wooded wetland	Wooded wetland	0.08	153,844
	Other Land	Natural	Other	0.10	194,751
			Natural Grassland	11.43	21,506,664
			Marsh	0.10	195,297
			Barren Land	8.95	16,840,549
		Cultivated	Annual Crop	11.63	21,886,966
			Mixed annual and perennial crop	0.06	112,204
			Perennial crop	0.28	527,518
			Fallow	0.23	433,444
			Improved pastures	0.22	414,622
			Wood lot of Bamboo	0.00	0
		Built up area	Built up area	1.01	1,892,986
		Quarry/Mining site	Quarry/Mining site	0.09	161,957
		Deserts (Stratum I)	Deserts (Stratum I)	35.95	67,674,160
	Inland Water	Dam	Dam	0.09	161,957
		Lake	Lake	0.01	18,701
		Pond	Pond	0.00	3,740
		Perennial river	Perennial River	0.16	302,190
		Intermittent river (seasonal)	Intermittent River (seasonal)	0.06	107,653
		Inland water	Inland water	0.00	0
Inaccessible	Inaccessible	Inaccessible	Inaccessible	0.56	1,050,444

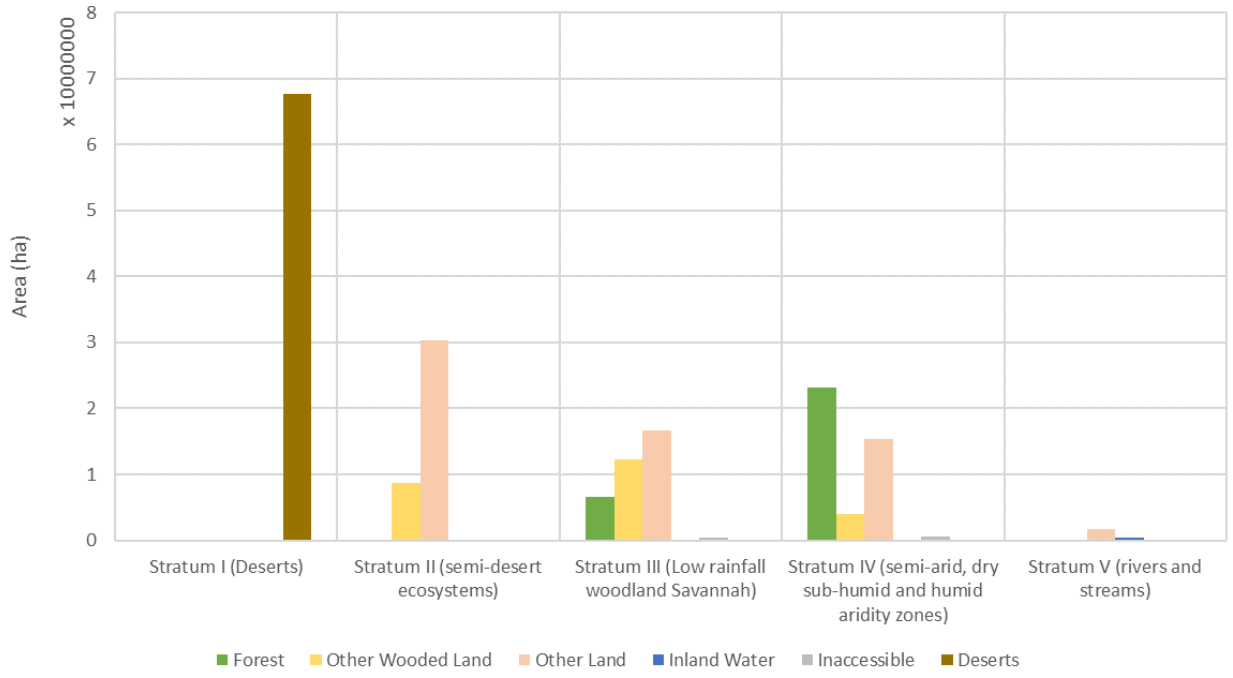
4.1.3. Area by FRA classes and per Stratum

The 4.3 shows proportion of each Major Land Use Class within the delineated strata. See section 3.2.1, which contains a map with the division of each of the strata into which the country was divided.

Table 4.3 Total area by FRA classes and per Stratum

No.	Stratum	FRA Classes Land use Level 1				Inacce-ssible	Deserts	Total	%
		Forest (ha)	Other Wooded Land (ha)	Other Land (ha)	Inland Water (ha)				
1	Stratum I (Deserts)	0	0	0	0	0	67,674,160	67,674,160	35.95
2	Stratum II (semi-desert ecosystems)	0	8,625,489	30,359,771	0	0	0	38,985,260	20.71
3	Stratum III (Low rainfall woodland Savannah)	6,563,250	12,226,966	16,729,613	56,560	395,922	0	35,972,310	19.11
4	Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	23,106,790	3,938,501	15,310,949	150,278	654,522	0	43,161,040	22.93
5	Stratum V (rivers and streams)	162,979	123,324	1,766,625	387,402	0	0	2,440,330	1.30
	Total	29,833,019	24,914,279	64,166,958	594,241	1,050,444	67,674,160	188,233,100	100.00
	%	15.85	13.24	34.09	0.32	0.56	35.95	100.00	

Figure 4.3 Total area by LUC and per Stratum



4.1.4. Areas of the major land use classes by States

Table 4.4 summarizes the distribution of FRA Classes by state, where Western Kordofan, Southern Darfur and Eastern Darfur are the most forested in Sudan (55% of the land is covered by forests). The Other Land LUCs occupied about 70% of the total area of the country, in which 35.74% is mainly desert.

4.1.5. Total area of Major land use classes by designation and protection status

Of the Major Land Use Classes (LUCs) other wooded land, other land and inland water have a low level of protection, while the forest has a high protection level according to the IUCN categories of management. Table 4.5 and Figure 4.5.

Table 4.4 Total area (hectares) of Sudan's States by major land use classes and by State[5]

State	FRA classes				Inaccessible (ha)	Deserts (ha)	TOTAL (ha)
	Forest (ha)	Other Wooded Land (ha)	Other Land (ha)	Inland Water (ha)			
Blue Nile	1,330,721	165,827	2,167,690	112,762	0		3,777,000
El Gadarif	464,154	232,988	5,236,035	21,922	0		5,955,100
Gezira[6]							2,378,200
Kassala	82,057	609,649	4,150,194	12,899	0		4,854,800
Khartoum	0	176,497	2,004,603	0	0		2,181,100
Northern	0	0	2,198,514	477,938	0	33,798,847	36,475,300
Northern Darfur	2,965,307	5,694,122	11,324,521	1,334	318,820	11,891,296	32,195,400
Northern Kordofan	1,559,715	4,437,285	12,182,491	69,669	139,339		18,388,500
Red Sea	0	3,585,091	3,768,942	0	0	14,213,067	21,567,100
River Nile	0	0	5,012,936	98,814	0	7,770,950	12,882,700
Sinnar	757,828	119,356	3,044,317	17,016	66,383		4,004,900
Southern Darfur	5,546,477	1,239,895	1,637,977	16,844	112,507		8,553,700
Southern Kordofan	4,486,348	517,500	3,317,652	0	0		8,321,500
Cantral Darfur	2,178,062	243,791	790,917	13,882	157,747		3,384,400
White Nile	52,213	373,470	3,487,510	170,407	0		4,083,600
Western Darfur	1,304,123	290,817	682,415	0	14,646		2,292,000
Eastern Darfur	2,687,929	654,382	2,011,826	12,496	99,967		5,466,600
Western Kordofan	5,023,525	3,473,175	2,944,125	0	30,375		11471200
TOTAL	**29,833,019**	**24,914,279**	**64,166,958**	**594,241**	**1,050,444**	**67,674,160**	**188,233,100**

5 - In the case of this table, the area calculated with the data of the NFI was adjusted to keep the official areas of the states. For example, the forest area has a difference of approximately 0.1% when using official data and those calculated with NFI areas.

6 - The State of Gezira has no Sampling Units in its area

Figure 4.4 Forest and other wooded land by State

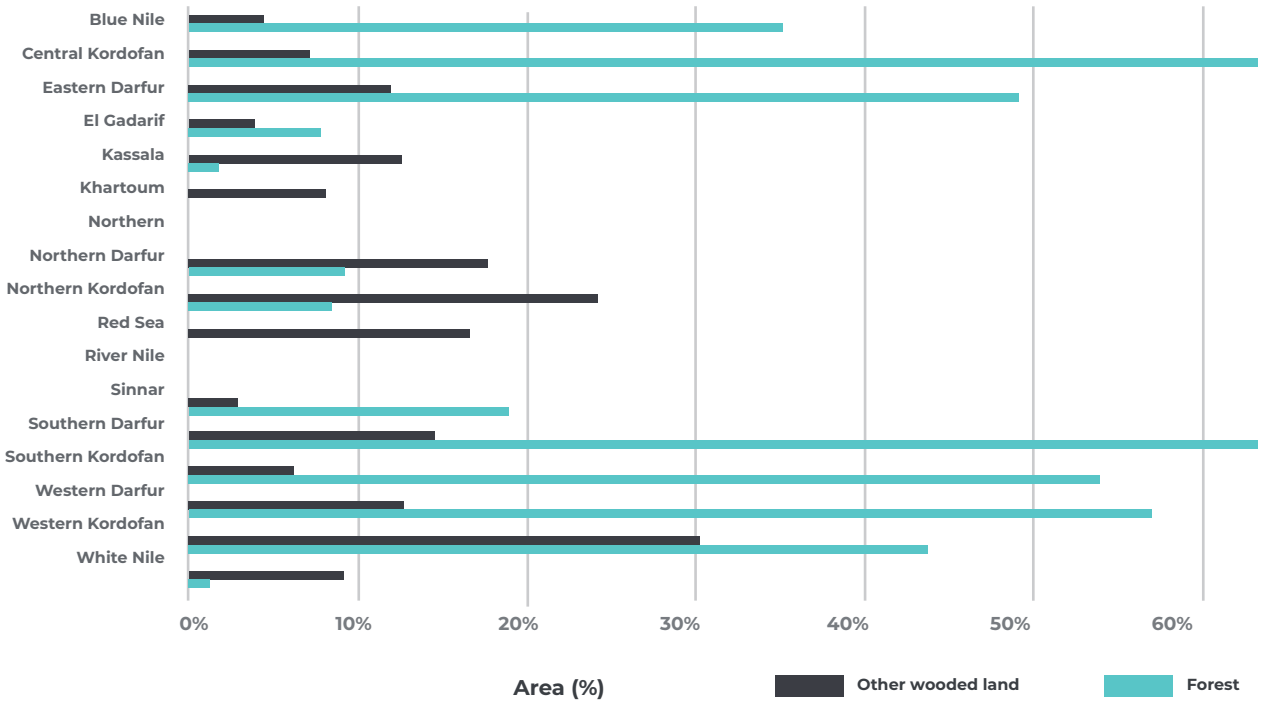
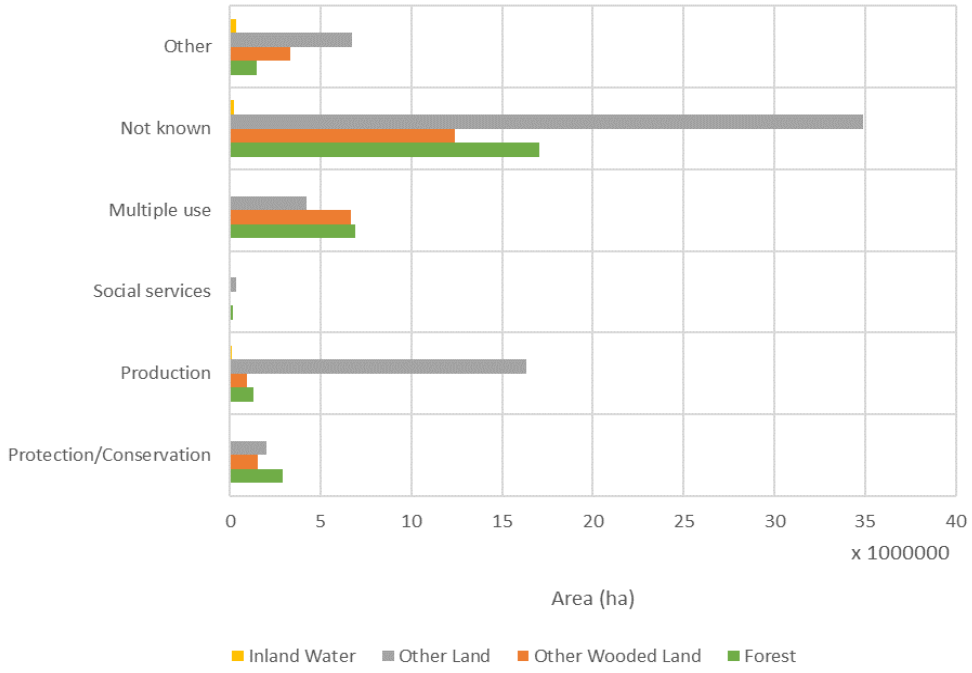


Table 4.5 Area of Major LUCCs by classes of designation and protection status

Designation or Protection status	FRA classes				Inaccessible (ha)	Deserts (ha)	TOTAL (ha)
	Forest (ha)	Other Wooded Land (ha)	Other Land (ha)	Inland Water (ha)			
Strict nature reserve/ Wilderness area	785,426	18,701	617,640	18,701	0		1,440,467
National Park	579,719	18,701	0	0	0		598,420
Natural monument	1,521,335	1,313,918	477,008	0	0		3,312,261
Habitat/ species management area	0	131,363	509,721	0	0		641,083
Protected landscape / seascape	37,401	56,560	374,427	5,229	0		473,617
Production	1,267,310	928,340	16,257,929	79,387	0		18,532,965
Social services	168,306	37,401	311,621	0	0		517,328
Multiple use	6,922,931	6,679,689	4,196,497	0	0		17,799,117
Not known	17,054,930	12,395,226	34,757,716	185,231	0		64,393,102
Other	1,495,661	3,334,381	6,664,400	305,693	1,050,444	67674160	80,524,739
Total	29,833,019	24,914,279	64,166,957	594,241	1,050,444	67,674,160	188,233,100

Figure 4.5 Area of Major LUCCs by classes of protection level



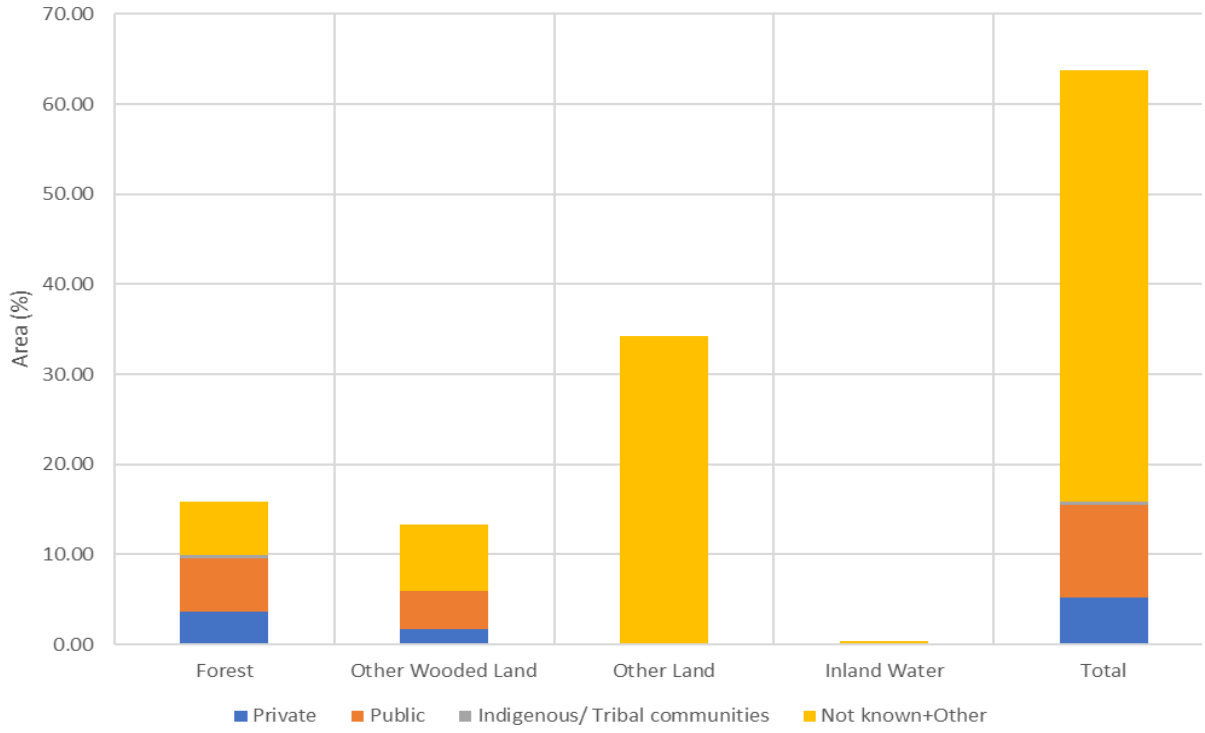
4.1.6. Total area of major land use classes by land ownership

More than 24% of the area of Sudan is owned by a mixture of owners (private, public and Indigenous/ Tribal communities). In forest areas almost the third of the area is state owned. Approximately 27% of the forest area is owned by individuals. Table 4.6 and Figure 4.6.

Table 4.6 Major LUCCs by type of ownership

Designation or Protection status	FRA classes				Inacce-ssible (ha)	Deserts (ha)	TOTAL (ha)
	Forest (ha)	Other Wooded Land (ha)	Other Land (ha)	Inland Water (ha)			
Private - Individual	2,759,804	1,904,915	0	0	0	0	4,664,719
Private - Industries	655,439	0	0	0	0	0	655,439
Private - Local communities	3,197,522	1,222,123	5,984	0	0	0	4,425,630
Private -Other private	112,204	0	0	0	0	0	112,204
Public - State	8,930,198	2,199,517	0	0	0	0	11,129,715
Public - Local government	2,386,761	5,724,144	0	0	0	0	8,110,905
Indigenous/Tribal communities	558,027	56,102	0	0	0	0	614,128
Not known	8,751,525	10,595,219	18,701	0	0	0	19,365,445
Other	2,481,539	3,212,258	64,142,273	594,241	1,050,444	67,674,160	139,154,914
Total	29,833,019	24,914,279	64,166,957	594,241	1,050,444	67,674,160	188,233,100

Figure 4.6 Major National LUCs by ownership class (%) [Deserts and inaccessible areas are excluded]



4.1.7. Total area of Global Ecological Zone (GEZ) classes

Table 4.7 and Figure 4.7 shows that almost all forests are located in the Subtropical dry forest and the Subtropical humid forest ecosystems.

Table 4.7 Total area of Sudan by GEZ classes

GEZ classes	Sub-classes	Area (ha)	%
Subtropical steppe		2,725,410	1.45
Deserts*	Subtropical desert	35,247,581	18.73
	Stratum 1 (desert)	67,674,160	35.95
Subtropical humid forest		7,035,101	3.74
Subtropical dry forest		73,885,507	39.25
Subtropical mountain		1,353,779	0.72
Other		311,562	0.17
Total area of Sudan		188,233,100	100.00

**Stratum 1 is the northern part of Sudan and is formed mainly by deserts, however, it is an area that was not sampled in the NFI and it is for that reason that it is located as a special category within the table. If the area of stratum 1 is added to the area of the Subtropical desert, the total area is 102,921,741 hectares, with an area percentage of 54.68%.*

Figure 4.7 Total area of Sudan by GEZ classes (%)

4.1.8. Total area of National Ecological Zone classes

The total area of ecological zones semi-desert and woodland savannah comprise approximately 56% of the total area, while the desert and stratum 1 comprise approximately 41% of the total area of the country. The remaining 2.39% of the country area goes to flood region. Table 4.8 and Figure 4.8.

4.1.9 Forest area by type of management agreement and by forest LUCs

Most of the country's total forest (94%) is not under a management agreement. In most of the areas in semi deciduous forest the Owner is the exclusive manager. Table 4.9 and Figure 4.9.

Table 4.8 Total area of Sudan by National Ecological Zone classes

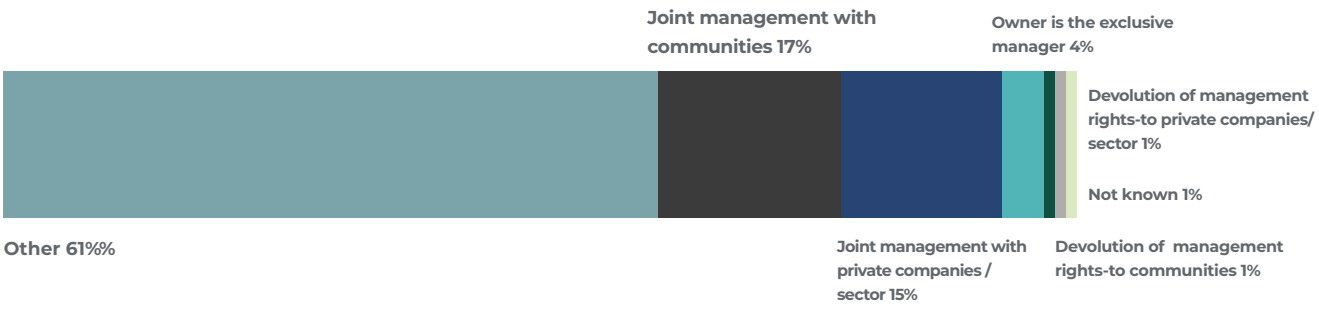
GEZ classes	Sub-classes	Area (ha)	%
Desert	Desert	8,917,461	4.74
	Stratum 1	67,674,160	35.95
Semi desert		60,272,999	32.02
Woodland savannah		44,964,045	23.89
Flood region		4,491,817	2.39
Montane vegetation		398,717	0.21
Other		1,513,902	0.80
Total area of Sudan		188,233,100	100.00

Figure 4.8 Total area of Sudan by National Ecological Zone classes (%)

Table 4.9 Distribution of forest area by type of management agreement and by forest LUCs

Land use/cover class	Owner is the exclusive manager	Joint management-with communities	Joint management-with private companies /private sector	Devolution of management rights-to communities	Devolution of management rights-to private companies/ private sector	Not known	Other	Total
Deciduous forest	376,521	1,748,267	1,575,193	18,701	56,102	87,220	10,667,386	14,529,389
Evergreen forest	0	0	0	0	0	0	280,509	280,509
Mixed planted Forest	0	226,241	0	0	0	0	0	226,241
Raffia/Palms	0	0	0	0	0	0	74,802	74,802
Semi-deciduous forest	817,639	3,007,397	2,833,940	355,312	187,006	149,605	7,146,771	14,497,670
Total	1,194,160	4,981,904	4,409,134	374,013	243,108	236,825	18,169,469	29,608,612
Indigenous / Tribal communities	558,027	56,102	0	0	0	0	614,128	614,128
Not known	8,751,525	10,595,219	18,701	0	0	0	19,365,445	19,365,445
Other	2,481,539	3,212,258	64,142,273	594,241	1,050,444	67,674,160	139,154,914	139,154,914
Total	29,833,019	24,914,279	64,166,957	594,241	1,050,444	67,674,160	188,233,100	188,233,100

Figure 4.9 Forest area by type of management agreement and by forest LUCs (%)



4.1.10 Area of forest and other wooded land subclasses according to silvicultural practices

Table 4.10 shows that 99.6% of the total forest hasn't been subjected to silviculture practices. Analyses also show that few silviculture practices have been applied in deciduous forest and semi-deciduous forest.

Table 4.10 Area of forest with silviculture practices by LUCs

Land use/cover class	No silvicultural practice	Pruning	Thinning	Coppicing	Total
Deciduous forest	14,510,688	18,701	0	74,802	14,604,191
Evergreen forest	280,509	0	0	0	280,509
Mixed planted Forest	226,241	0	0	0	226,241
Raffia/Palms	74,802	0	0	0	74,802
Semi-deciduous forest	14,535,071	18,701	18,701	0	14,572,473
Total	29,627,312	37,401	18,701	74,802	29,758,216
%	99.56	0.13	0.06	0.25	100.00

4.2. Canopy and fire

4.2.1. Canopy Cover in Forest land

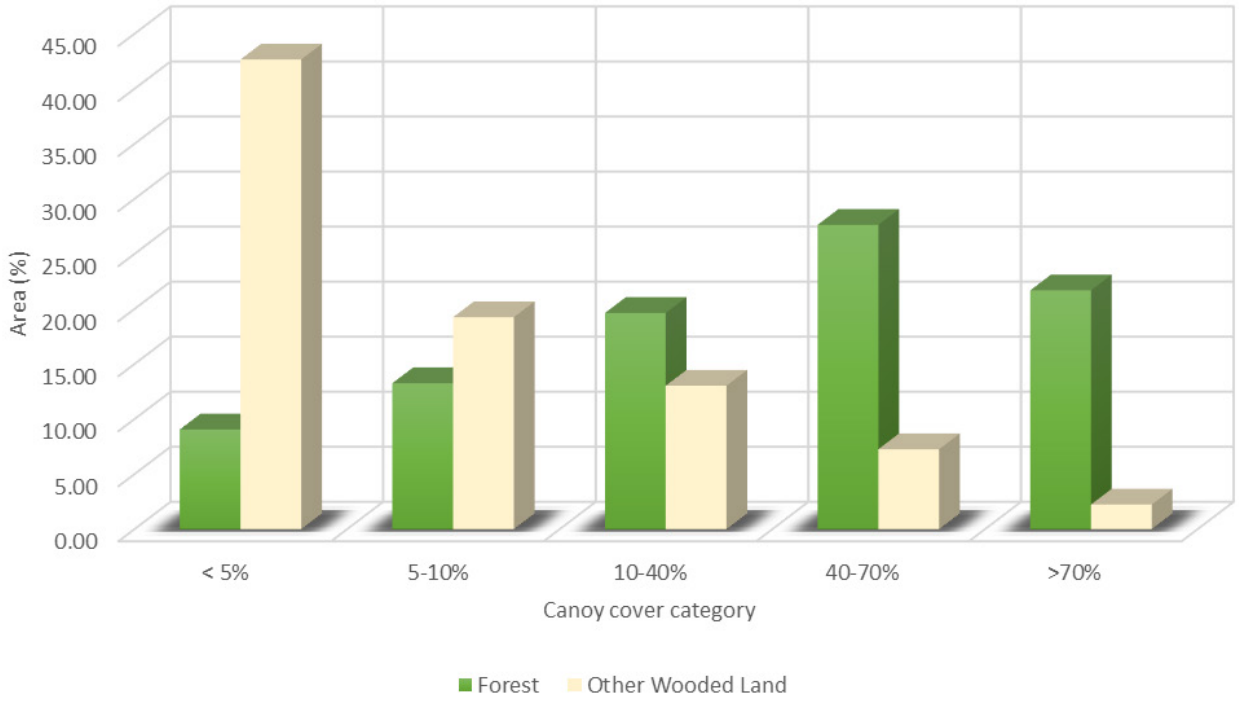
Almost 9.08% of the forest area has a tree cover of <5%. 13.28% of the forest area has a tree cover of 5-10%. 19.66% of the forest area has a tree cover of 10-40%. 27.67% of the forest area has a tree cover of 40-70%. Almost 21.71% of the forest area has a very high tree cover of > 70%.

Generally, very high tree cover (> 70%) is equivalent to 21.71% of the forest area, while low tree cover is equivalent to 9.08% of the forest area. Table 4.11 and Figure 4.10.

Table 4.11 Area of Canopy Cover in Forest and other wooded land classes

Tree canopy cover category	Forest		Other Wooded Land	
	Hectares	%	Hectares	%
No data	1,513,904	5.07	1,501,916	6.03
No trees	1,051,876	3.53	2,345,607	9.41
< 5%	2,707,679	9.08	10,635,465	42.69
5-10%	3,962,544	13.28	4,802,799	19.28
10-40%	5,865,892	19.66	3,251,588	13.05
40-70%	8,253,544	27.67	1,814,327	7.28
>70%	6,477,581	21.71	562,577	2.26
Total	29,833,019	100.00	24,914,279	100.00

Figure 4.10 Area of Canopy Cover in Forest and other wooded land classes (%)



4.2.2. National Land Use Classes by classes of fire evidence

Table 4.12 and Figure 4.11 indicate that in most of the forest area in Sudan there is no evidence of fire, only 3.63% of the total forest area has experienced burning (1.35 million of hectares). In the total area of the country the burned area represents only 0.72% of the total. The figure 4.12 show the fire type that occur in the country, the most common type is the surface fire (92.1% of area).

Table 4.12 National Land Use Classes by classes of fire evidence

Evidence of fire	FRA classes (ha)					TOTAL (ha)
	Forest	Other Wooded Land	Other Land	Inland Water	Inaccessible	
Recent fire	671,152	59,194	176,498	0	0	906,844
Old fire	413,155	14,949	19,651	0	0	447,756
Total	1,084,307	74,144	196,149	0	0	1,354,600

Figure 4.11 National Land Use Classes by classes of fire evidence

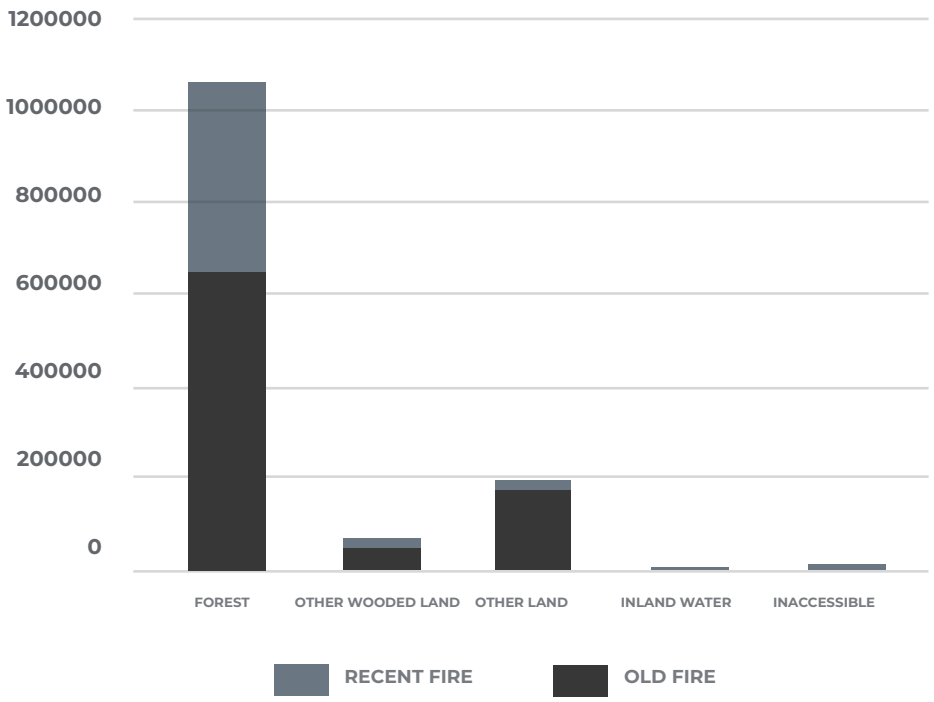
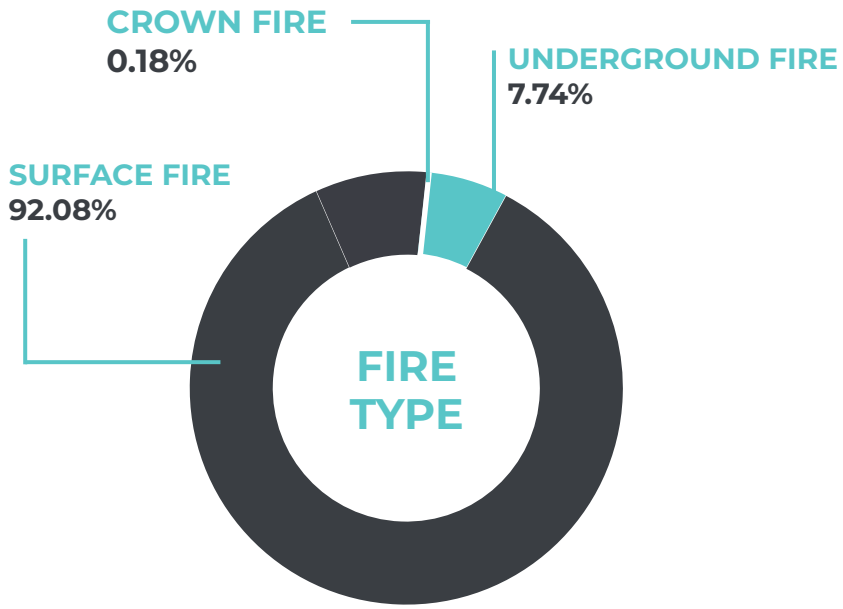


Figure 4.12 Distribution of fire type



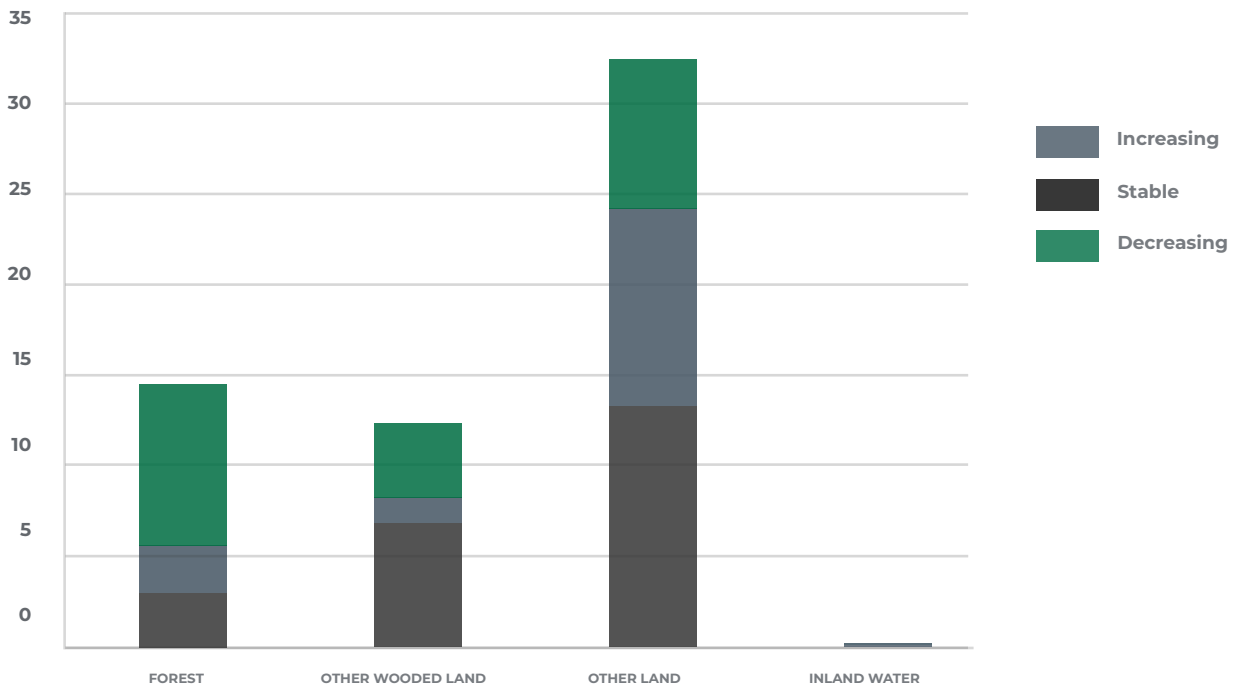
4.2.3. Expected change in tree cover by major national LUC

The forest LUC is expected to increase its current tree cover. The decrease in tree cover is expected to occur in the LUCS of other land and other wooded land (Table 4.13 and Figure 4.13).

Table 4.13 Expected change in tree cover by major national LUC

Trees expected	Major National LUC (ha)					Desert (ha)	TOTAL (ha)
	Forest	Other Wooded Land	Other Land	Inland Water	Inaccessible		
No data	2,398,333	1,595,877	3,125,208	312,201	1,050,444		8,482,063
Decreasing	5,706,334	12,964,846	25,154,821	66,224	0		43,892,225
Stable	4,786,577	2,660,396	20,373,257	172,238	0		27,992,469
Increasing	16,941,774	7,693,160	15,513,672	43,577	0		40,192,183
Stratum 1						67674160	67,674,160
Total	29,833,019	24,914,279	64,166,958	594,241	1,050,444	67,674,160	188,233,100

Figure 4.13 Expected change in tree cover by major national



4.3. Tree density

This section includes the results for the number of trees per hectare in the FRA classes, LUCS and stratums. The mean numbers of trees per hectare in forests and outside of forest is 81.26 and 5.94 respectively.

4.3.1. Tree density by forest and non-forest and by stratum

On average, forests have a tree density of 81.75 trees/ha, while non-forests have a tree density of 5.96 trees/ha. When tree densities are examined by stratum (Table 4.14), the highest densities are located in Stratum IV (semi-arid, dry sub-humid and humid aridity zones) with 58.49 trees/ha and Rivers and streams (riverine vegetation 4.833 trees/ha).

Table 4.14 Number of trees per hectare in Forest and Non-forest lands by strata

Land use level 0	Strata (trees/ha)				Mean (trees/ha)
	Stratum II (semi-desert ecosystems)	Stratum III (Low rainfall woodland Savannah)	Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	Stratum V (rivers and streams)	
Forest	0.00	23.37	100.04	34.00	81.75
Non forest	5.49	9.58	13.92	10.61	5.96
Mean (trees/ha)	3.84	9.89	58.49	4.83	24.87

4.3.2. Tree density by stratum and FRA classes

Table 4.15 shows the averages of trees by hectare for the FRA classes and strata of the NFI. The highest mean density by stratum is 99.67 trees/ha for forest LUC in stratum Forest and Stratum IV (semi-arid, dry sub-humid and humid aridity zones).

Table 4.15 Tree (DBH>=10 cm) density per ha, by stratum and FRA classes

FRA Classes	Strata (trees/ha)				Mean (trees/ha)
	Stratum II (semi-desert ecosystems)	Stratum III (Low rainfall woodland Savannah)	Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	Stratum V (rivers and streams)	
Forest	0.00	23.37	100.04	34.00	81.75
Other Wooded Land	12.84	13.19	22.17	15.19	12.86
Other Land	2.31	6.60	10.94	12.41	3.27
Inland Water	0.00	36.00	49.30	0.00	6.73
Mean (trees/ha)	3.91	10.03	58.86	5.12	24.87
Mean (trees/ha)	3.84	9.89	58.49	4.83	24.87

4.3.3. Tree density per hectare by stratum and by diameter classes

Tree densities by DBH classes typically follow a reversed J-shape curve in natural forests. Therefore, the highest number of trees is found in the smaller DBH classes. Big trees (DBH ≥ 40cm) constitute the lowest tree density in the forest land (Table 4.16 and Figure 4.14).

4.3.4. Tree density by height classes and stratum

The results by of tree density by height classes and stratum show that the highest proportion of trees taller than 15m in Forest are found in the Forest and woodland vegetation stratum (IV) table 4.17.

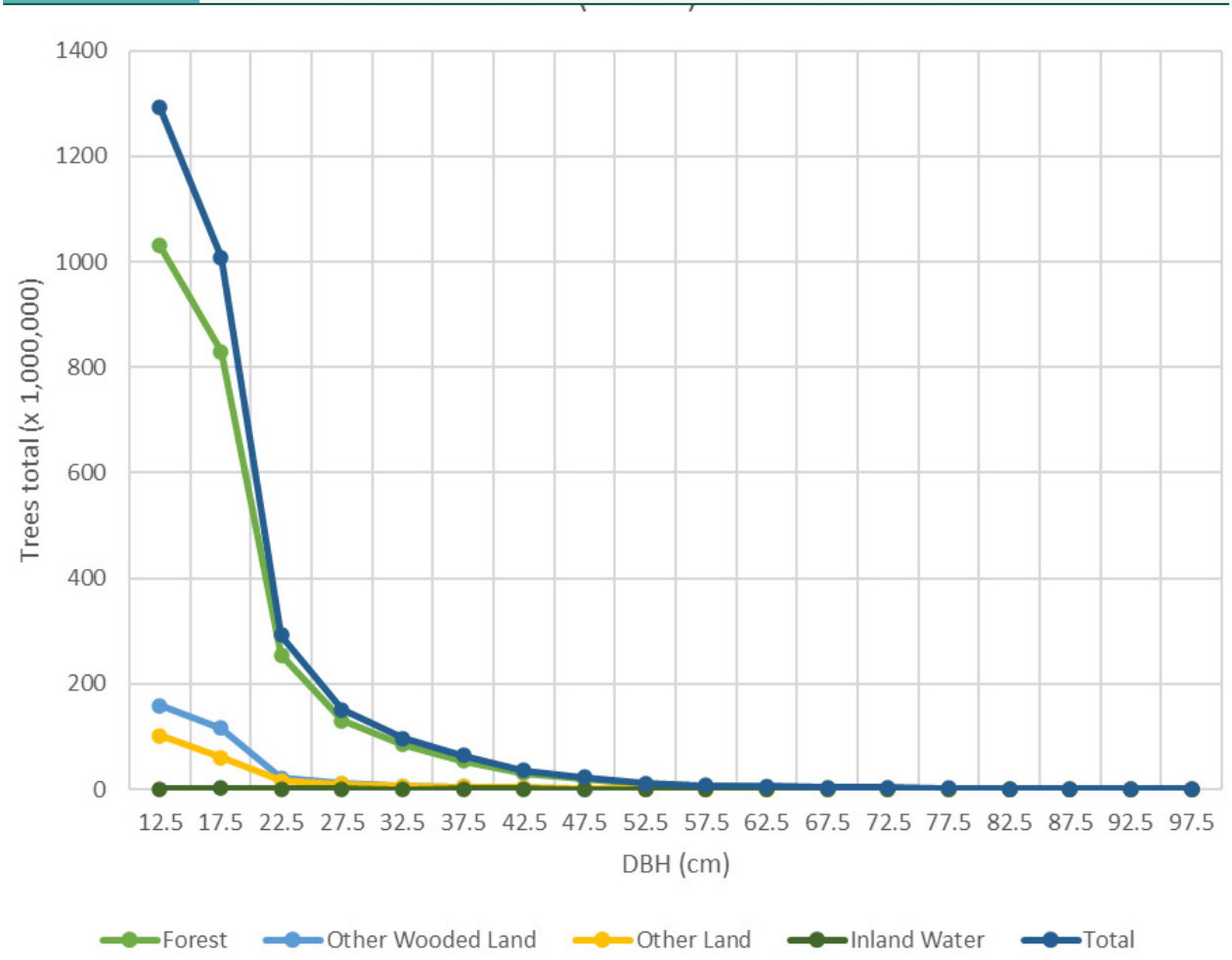
Table 4.16 Number of trees in Sudan by stratum and diameter classes

DBH classes (cm)	DBH mark class (cm)	FRA Classes (trees x 1,000,000)				Total (trees)
		Forest	Other Wooded Land	Other Land	Inland Water	
10 - 14.99	12.5	1,030.32	158.46	102.11	1.18	1,292.07
15 - 19.99	17.5	830.03	116.22	60.77	1.51	1,008.52
20 - 24.99	22.5	254.24	21.18	16.32	0.30	292.04
25 - 29.99	27.5	130.95	10.57	9.32	0.19	151.03
30 - 34.99	32.5	84.40	5.87	6.55	0.08	96.89
35 - 39.99	37.5	54.52	4.11	5.26	0.23	64.12
40 - 44.99	42.5	30.32	1.90	3.30	0.23	35.76
45 - 49.99	47.5	18.54	1.18	2.38	0.08	22.18
50 - 54.99	52.5	9.19	0.99	1.35	0.00	11.53
55 - 59.99	57.5	6.04	0.42	0.76	0.00	7.22
60 - 64.99	62.5	3.84	0.38	1.07	0.04	5.32
65 - 69.99	67.5	2.16	0.27	0.42	0.00	2.85
70 - 74.99	72.5	2.20	0.15	0.46	0.00	2.81
75 - 79.99	77.5	1.29	0.11	0.11	0.04	1.56
80 - 84.99	82.5	1.06	0.08	0.23	0.04	1.41
85 - 89.99	87.5	0.61	0.11	0.04	0.00	0.76
90 - 94.99	92.5	0.27	0.04	0.08	0.00	0.38
95+	97.5	0.72	0.15	0.42	0.11	1.41
Total		**2,460.70**	**322.19**	**210.94**	**4.02**	**2,997.85**

Table 4.17 Number of trees (total), by stratum and tree height classes

Height classes (m)	Height mark class (m)	Strata Classes (trees x 1,000,000)				Total (trees)
		Stratum II (semi-desert ecosystems)	Stratum III (Low rainfall woodland Savannah)	Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	Stratum V (rivers and streams)	
0 - 4.99	2.5	92.27	76.02	112.44	2.35	283.08
5 - 9.99	7.5	57.50	240.96	1,493.22	7.54	1,799.22
10 - 14.99	12.5	0.00	26.57	777.07	1.37	805.01
15 - 19.99	17.5	0.00	3.77	92.70	0.17	96.65
20 - 24.99	22.5	0.00	0.34	10.71	0.00	11.05
25 - 29.99	27.5	0.00	0.00	2.10	0.36	2.46
30 - 34.99	32.5	0.00	0.00	0.30	0.00	0.30
35 - 39.99	37.5	0.00	0.00	0.04	0.00	0.04
40-44.99	42.5	0.00	0.00	0.00	0.00	0.00
45+	47.5	0.00	0.00	0.04	0.00	0.04
Total		**149.77**	**347.68**	**2,488.61**	**11.79**	**2,997.85**

Figure 4.14 Number of trees (total) by diameter classes for major LUC classes



4.3.5 Number of trees per hectare by FRA and height classes

The highest density for FRA classes' forest and other wooded land were found in the low height mid-classes 7.5 m and 12.5 m, reduced in the mid-class 17.5 and 22.5, and very reduced in the top height classes. The density per FRA class Other Land is also high in mark class 7.5 m. and decreases towards increased mark-classes (Table 4.18 and Figure 4.15).

4.4. Regeneration count

4.4.1. Regeneration count by FRA classes and National LUCCS types

Small tree and tree regeneration data contains observations where tree height is more or equal to 1.3 meters and DBH less than 10 cm. In naturally regenerated forest the highest mean density of saplings is located in Raffia/Palms national LUCC, followed by Evergreen forest types, where the mean densities are 2,283.34 and 835.56, respectively (see table 4.19 and figure 4.16).

Figure 4.15 Tree density per ha and FRA height classes

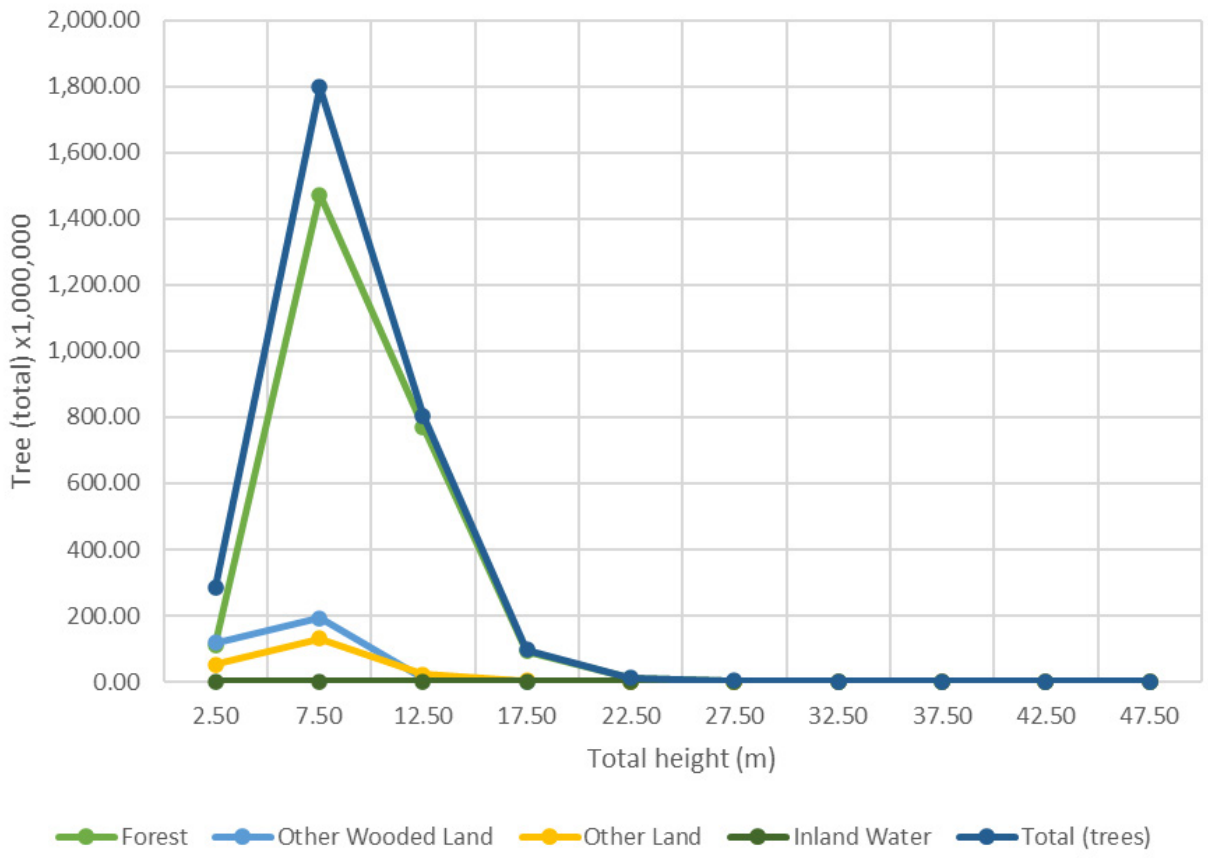


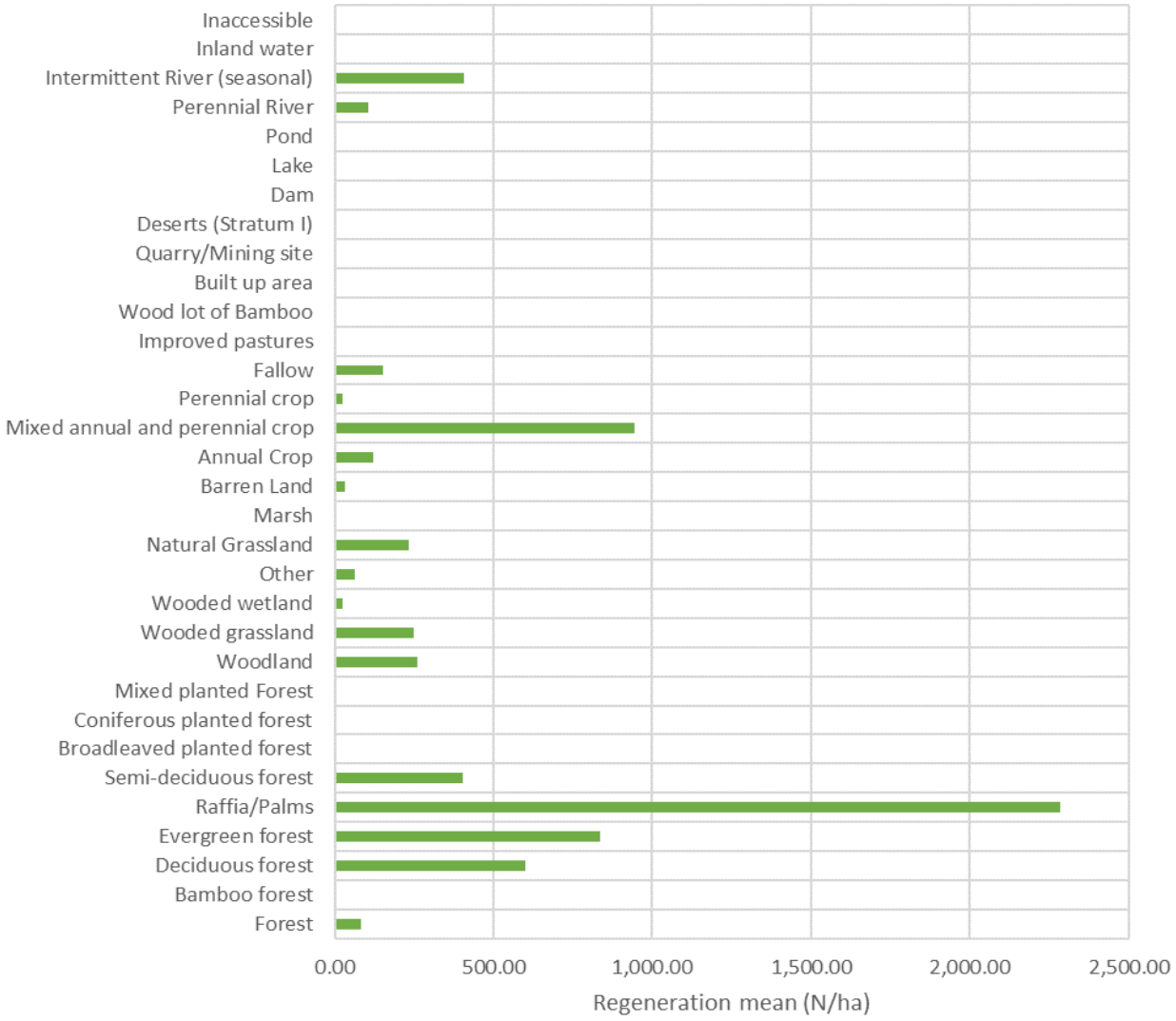
Table 4.18 Number of trees (total) by FRA and height classes

Height classes (m)	Height mark class (m)	FRA Classes (trees x 1,000,000)				Total (trees)
		Forest	Other Wooded Land	Other Land	Inland Water	
0 - 4.99	2.50	111.99	117.25	52.35	1.49	283.08
5 - 9.99	7.50	1,473.85	192.37	131.10	1.89	1,799.22
10 - 14.99	12.50	771.48	10.13	23.09	0.30	805.01
15 - 19.99	17.50	91.41	1.79	3.30	0.15	96.65
20 - 24.99	22.50	10.22	0.49	0.19	0.15	11.05
25 - 29.99	27.50	1.48	0.15	0.79	0.04	2.46
30 - 34.99	32.50	0.19	0.00	0.11	0.00	0.30
35 - 39.99	37.50	0.04	0.00	0.00	0.00	0.04
40-44.99	42.50	0.00	0.00	0.00	0.00	0.00
45+	47.50	0.04	0.00	0.00	0.00	0.04
Total		**2,460.70**	**322.19**	**210.94**	**4.02**	**2,997.85**

Table 4.19 Regeneration count by FRA classes and National LUCC types

LUC level 0	FRA Classes (Level 1)	National Land Use Classes		Regeneration mean (N/ha)
		LUC level 2	LUC level 3	
Forest	Forest	Natural regenerated forest	Other forest type	83.33
			Bamboo forest	0.00
			Deciduous forest	599.54
			Evergreen forest	835.56
			Raffia/Palms	2,283.34
			Semi-deciduous forest	403.27
		Plantation	Broadleaved planted forest	0.00
			Coniferous planted forest	0.00
			Mixed planted Forest	0.00
Non forest	Other Wooded Land	Woodland	Woodland	261.36
		Wooded grassland	Wooded grassland	247.58
		Wooded wetland	Wooded wetland	24.51
	Other Land	Natural	Other	64.28
			Natural Grassland	231.89
			Marsh	0.00
			Barren Land	31.87
		Cultivated	Annual Crop	122.31
			Mixed annual and perennial crop	944.45
			Perennial crop	24.85
			Fallow	152.78
			Improved pastures	0.00
			Wood lot of Bamboo	0.00
		Built up area	Built up area	5.99
		Quarry/Mining site	Quarry/Mining site	0.00
		Deserts (Stratum I)	Deserts (Stratum I)	0.00
	Inland Water	Dam	Dam	0.00
		Lake	Lake	0.00
		Pond	Pond	0.00
		Perennial river	Perennial River	104.68
		Intermittent river (seasonal)	Intermittent River (seasonal)	407.06
		Inland water	Inland water	0.00
Inaccessible	Inaccessible	Inaccessible	Inaccessible	0.00
Total				248.68

Figure 4.16 Regeneration count by National LUCC types



4.4.2. Regeneration count by main species

The highest regeneration count was recorded mainly within the species Suaeda monoica, Acacia tortilis subsp. spirocarpa and Boscia salicifolia species (see Table 4.20).

4.5. Basal area

4.5.1. Basal area by FRA classes and stratum

The basal area by FRA classes shows a similar pattern to tree density and volume. The mean of basal area in inland water is 0.5341 m²/ha and 0.1155 m²/ha in other land. Table 4.21.

Table 4.20 Regeneration count by species

Specie	FRA classes				Regeneration mean (N/ha)
	Forest	Other Wooded Land	Other Land	Inland Water	
Suaeda monoica	1,983.34				1,983.34
Acacia tortilis subsp. Spirocarpa	133.33	1,762.96	1,674.18		1,644.36
Boscia salicifolia	1,616.67	200.00			908.34
Lannea humilis	616.67				616.67
Acacia drepanolobium	904.76	124.38	186.67		566.10
Guiera senegalensis	641.41	502.32	495.46		551.41
Cassia siamea	466.67				466.67
Dichrostachys cinérea	366.71	1,294.20	135.27	11,666.69	358.79
Boswellia papyrifera	333.33				333.33
Combretum glutinosum	300.00				300.00
Hymenocardia acida	300.00				300.00
Maerua crassifolia	50.00	400.00	33.33		286.72
Combretum ghasalense	325.97	44.44	139.56		284.43
Combretum paniculatum	214.34		777.78		279.32
Grewia villosa	357.54	253.88	33.33		278.06
Combretum lamprocarpum	55.91		1,083.34		266.67
Ziziphus spina-christi var. spina-christi	241.02	472.73	166.67	4,444.45	266.67
Acacia mellifera	275.29	295.27	138.60	133.33	261.95
Piliostigma thonningii	219.76	358.33	312.12		261.53
Cassia sp.	250.00				250.00
Acacia nilotica subsp. tomentosa	240.39				240.39
Lannea fruticosa	229.17				229.17
Prosopis africana	259.26		33.33		218.18
Ziziphus spina-christi var. microphylla	256.65	300.00	102.22		216.62
Acacia nilotica subsp. nilotica	282.62	160.78	129.87	410.26	215.87
Acacia oerfota	249.65	83.19	232.24		215.77
Acacia sieberiana	233.33		33.33		213.33
Boscia senegalensis	164.37	205.55	222.18		201.43
Lannea schweinfurthii	197.51				197.51
Acacia seyal var. Seyal	221.45	99.08	78.78		187.92
Combretum adenogonium	177.78				177.78
Acacia seyal	177.78	133.33			176.00
Bauhinia rubescens	191.67	169.11	83.33		169.70
Stereospermum kunthianum	166.67				166.67
Terminalia brownii	168.52	66.67			165.77
Acacia ehrenbergiana	16.67		169.22		163.60

Specie	FRA classes				Regeneration mean (N/ha)
	Forest	Other Wooded Land	Other Land	Inland Water	
Calotropis procera	323.81	116.67	149.30		161.48
Leptadenia pyrotechnica	116.67	71.87	225.80		157.64
Combretum hartmannianum	172.97	16.67	83.33		154.84
Commiphora quadricincta	117.89	57.85	566.67		149.25
Acacia tortilis subsp. tortilis		69.08	158.35		148.27
Detarium macrocarpum	158.33	16.67			145.45
Polycarpaea corymbosa	50.00	233.33			141.67
Dalbergia boehmii	130.33		133.33		130.46
Dalbergia melanoxylon	130.28				130.28
Albizia amara	106.56	198.65	153.87		126.05
Ziziphus sp.	125.00				125.00
Tamarindus indica	122.22				122.22
Prosopis chilensis		62.00	238.10		119.76
Hyphaene thebaica	158.33		33.33		116.67
Acacia tortilis f. raddiana	184.89	93.07	75.05	333.33	113.15
Acacia Senegal	133.79	86.44	74.50	833.34	111.77
Acacia polyacantha subsp. campylacantha	110.94		66.67		104.04
Acacia nilotica var. adstringens	105.28	74.21	125.80		102.47
Leptadenia arbórea		100.00			100.00
Balanites aegyptiaca	85.36	88.38	119.49	555.56	92.46
Grewia tenax		87.78			87.78
Cordia abyssinica	122.95	16.67	41.67		86.26
Butyrospermum paradoxum	83.33				83.33
Dobera glabra	83.33				83.33
Lannea barteri	86.96	55.56	133.33		83.33
Lannea schimperi	83.27				83.27
Ziziphus mauritiana	110.63	119.07	47.34		82.75
Combretum aculeatum	69.33		100.00		76.79
Maerua pseudopetalosa	75.02	66.67	77.72		76.31
Maerua aethiopica	22.22		116.67		76.19
Acacia gerrardii var. Gerrardii	71.10	29.63	88.89		70.54
Anogeissus leiocarpus	68.26				68.26
Boscia angustifolia	66.67				66.67
Lannea sp.	66.67				66.67
Strychnos spinosa	66.67				66.67
Terminalia glaucescens	66.67				66.67
Terminalia macroptera	60.72				60.72
Albizia anthelmintica	83.33		25.15		60.14

Specie	FRA classes				Regeneration mean (N/ha)
	Forest	Other Wooded Land	Other Land	Inland Water	
Pseudocedrela kotschyi	58.33				58.33
Sclerocarya birrea	49.88		58.33		51.46
Cadaba rotundifolia		50.00			50.00
Combretum gallabatense	50.00				50.00
Ricinus communis	50.00				50.00
Sterculia africana	50.00				50.00
Tamarix nilotica			50.00		50.00
Maerua oblongifolia		49.99			49.99
Acacia laeta	33.33	72.46	33.33		49.35
Bauhinia tomentosa	50.00		44.44		48.78
Ziziphus spina-christi	50.00		26.67		37.04
Bauhinia sp.	36.67				36.67
Commiphora africana	33.33		33.33		33.33
Grewia sp.	33.33				33.33
Terminalia laxiflora	33.33				33.33
Cadaba farinosa	93.37	66.72	22.22		31.79
Diospyros mespiliformis	33.33	29.63			31.37
Ficus sycomorus	29.63				29.63
Capparis spinosa	28.53	16.67			23.05
Cordia sinensis	16.67				16.67
Gardenia lutea	16.67				16.67
Phoenix reclinata	16.67				16.67
Piliostigma reticulatum	16.67		16.67		16.67
Terminalia arjuna	16.67				16.67
Xeromphis nilotica	16.67				16.67
Ximenia americana	16.67				16.67
Total	477.57	232.56	128.94	118.31	248.13

Table 4.21 Average Tree basal area by stratum and FRA classes

Strata	FRA Classes				Mean of total (m2/ha)
	Forest	Other Wooded Land	Other Land	Inland Water	
Stratum II (semi-desert ecosystems)		0.2300	0.0437		0.0710
Stratum III (Low rainfall woodland Savannah)	0.7114	0.3300	0.1799	0.6297	0.2770
Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	3.1104	0.7248	0.5118	7.1097	1.8726
Stratum V (rivers and streams)	0.9876	0.2895	0.7969		0.2357
Mean of total (m2/ha)	2.5385	0.3147	0.1155	0.5341	0.7635

4.5.2. Basal area by National LUCC and DBH classes

As usual the basal area increases with the DBH increase. Descending from the highest perennial crop through annual crop, deciduous forest, barren land, built-up area, to the lowest semi-deciduous, respectively. Table 4.22.

Table 4.22 Average Tree basal area (m^2/ha) by national LUCC and DBH classes

Land Use Class	DBH Classes (cm)					Mean of total (m2/ha)
	10 - 19.99	20 - 29.99	30 - 39.99	40 - 49.99	+50	
Deciduous forest	1.2934	0.7027	0.5360	0.3457	0.5619	2.4813
Evergreen forest	1.4789	1.1537	0.6056	0.5573	0.4899	2.2783
Raffia/Palms	0.3663	0.8964	0.5272	1.1215	1.9961	4.9075
Semi-deciduous forest	0.9088	0.5197	0.4633	0.3387	0.4986	1.9019
Mixed planted Forest	0.0077	0.0727	0.0000	0.0000	0.0000	0.0803
Woodland	0.5131	0.0377	0.1468	0.2966	0.5689	0.4047
Wooded grassland	0.1829	0.1030	0.1299	0.1697	0.3597	0.2483
Wooded wetland	0.5565	0.4972	0.7190	0.2037	0.0000	1.3440
Other	0.1319	0.0000	0.1885	0.0000	11.4616	0.8859
Natural Grassland	0.0575	0.0437	0.1137	0.0903	0.4253	0.0562
Barren Land	0.0586	0.0280	0.1344	0.4604	1.5888	0.0344
Annual Crop	0.1318	0.1006	0.1185	0.1486	0.4958	0.2008
Mixed annual and perennial crop	0.1348	0.1293	0.2531	0.1919	0.4727	0.6371
Perennial crop	0.1695	0.1148	0.3897	0.4657	0.5695	0.4653
Fallow	0.0219	0.0424	0.0000	0.0000	0.0000	0.0191
Improved pastures	0.2097	0.0327	0.0000	0.0000	0.0000	0.1278
Built up area	0.1021	0.3181	0.7617	1.1824	0.0000	0.0219
Perennial River	2.9788	0.2094	0.0000	0.0000	15.5959	0.3411
Intermittent River (seasonal)	0.5715	0.2658	1.3994	1.5797	5.5596	0.9750
Mean of total (m2/ha)	**0.4819**	**0.3385**	**0.3660**	**0.2913**	**0.5279**	**0.7635**

4.6. Volume

4.6.1. Gross volume

4.6.1.1. Gross volume by FRA classes, National LUCC and stratum

In Sudan the average gross volume per hectare is 4.6055 m^3/ha. "Forest" is the LUC with the highest gross volume per hectare, followed by "inland water". Tables 4.23, 4.24 and Figure 4.17 show the distribution of average gross volume by FRA classes, national LUC and stratum.

Forests cover is 29.8 million hectares, which account for 85.7% of the volume stock. Other wooded lands cover 24.9 million ha and contain 6.1% of the volume stock. The remaining 133.5 million ha are TOF (other land and inland water), which constitute 8.2% of the volume stock.

To estimate the volume of each of the trees in the NFI, the cylinder volume equation multiplied by a form factor of 0.6 was used.

Table 4.23 Average gross volume/ha for FRA classes and strata

Strata	FRA Classes				Volume mean (m3/ha)
	Forest	Other Wooded Land	Other Land	Inland Water	
Stratum II (semi-desert ecosystems)	0.0000	0.6292	0.1189	0.0000	0.1941
Stratum III (Low rainfall woodland Savannah)	3.7528	1.4498	0.8950	1.7392	1.3562
Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	19.5575	3.9496	3.4089	66.3402	11.7827
Stratum V (rivers and streams)	5.0514	1.0133	3.8071	0.0000	1.1220
Volume mean (m3/ha)	15.8129	1.3611	0.6587	4.5879	4.6055

Figure 4.17 Average gross volume/ha for FRA classes and stratum

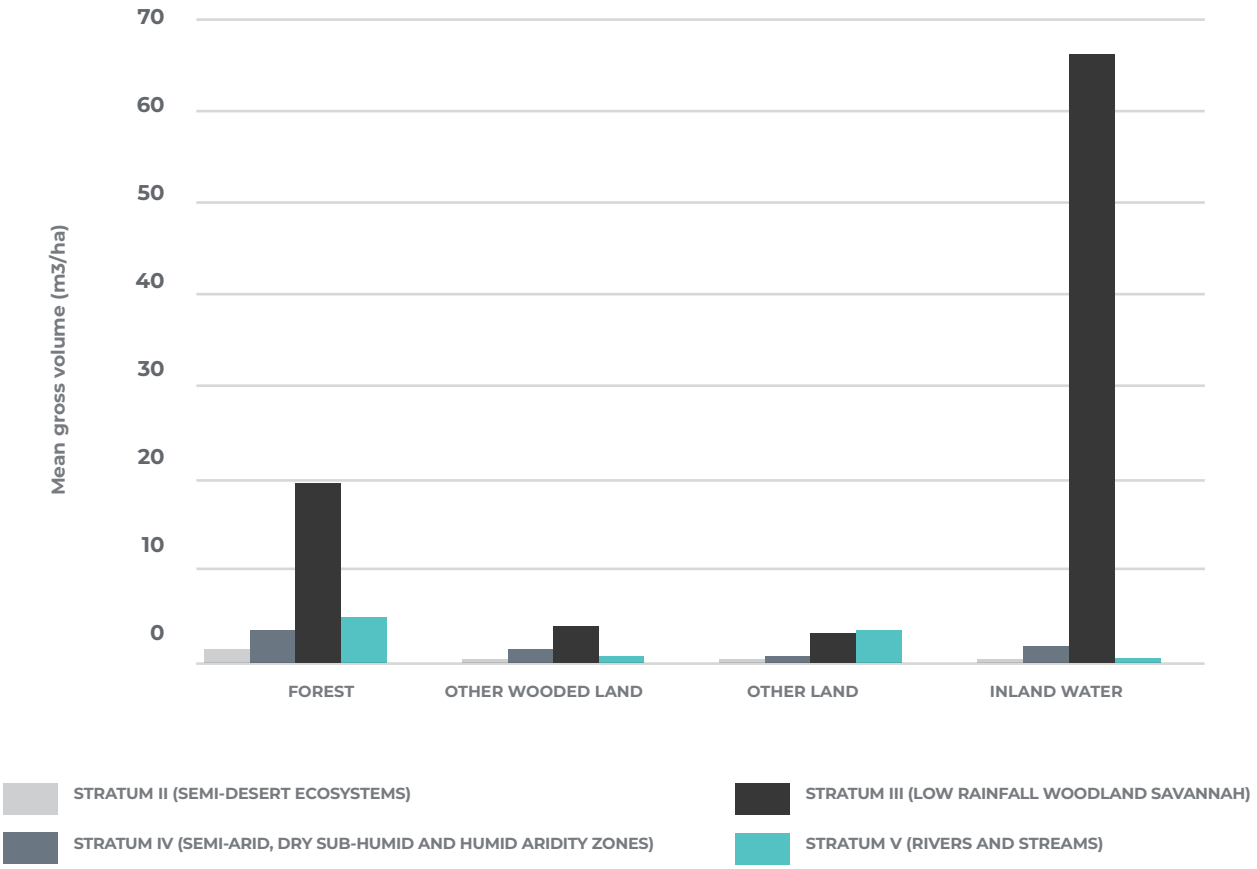


Table 4.24	Total gross volume (m3) per major National LUCs		
FRA class	**National LUC**	**Total Gross volume (m3)**	**Gross Volume (%)**
Forest	Other forest type	1,876,674	0.3380
	Deciduous forest	267,394,498	48.1587
	Evergreen forest	6,425,001	1.1572
	Raffia/Palms	2,869,391	0.5168
	Semi-deciduous forest	197,329,064	35.5396
	Mixed planted forest	76,932	0.0139
	Forest Total	475,971,561	85.7241
Other wooded land	Woodland	4,576,430	0.8242
	Wooded grassland	28,181,007	5.0755
	Wooded wetland	1,340,088	0.2414
	Total Other wooded land	34,097,525	6.1411
Other land	Annual crop	31,042,756	5.5909
	Barren land	2,424,060	0.4366
	Buit up area	248,291	0.0447
	Fallow	29,892	0.0054
	Improved pastures	169,313	0.0305
	Marsh	0	0.0000
	Mixed annual and perennial crop	589,237	0.1061
	Natural grassland	4,801,206	0.8647
	Perennial crop	1,532,625	0.2760
	Quarry Mining site	0	0.0000
	Desert	0	0.0000
	Other	1,590,289	0.2864
	Total Other land	42,427,669	7.6414
Water	Dam	0	0.0000
	Intermittent river (seasonal)	1,557,705	0.2805
	Lake	0	0.0000
	Perennial river	1,182,102	0.2129
	Pond	0	0.0000
	Total Inland water	2,739,807	0.4934
	Total country	**555,236,562**	**100.0000**

4.6.1.2. Gross tree volumes for the most common species

The most common species, according to the highest average gross volume, are Acacia seyal var. seyal and Anogeissus leiocarpus. Table 4.25.

Table 4.25 Total Gross volume by main tree species and FRA classes (m³)

No.	Specie	FRA classes				Total (m3)
		Forest	Other Wooded Land	Other Land	Inland Water	
1	Acacia seyal var. seyal	82,593,514	526,672	663,662	3,258	83,787,106
2	Anogeissus leiocarpus	66,143,927	1,175,465	1,205,666	209,611	68,734,669
3	Balanites aegyptiaca	47,498,286	5,228,805	8,656,560	61,348	61,444,999
4	Albizia amara	46,105,174	2,349,537	2,161,273	0	50,615,985
5	Combretum ghasalense	26,019,051	411,362	2,156,410	0	28,586,823
6	Sclerocarya birrea	21,435,297	1,426,457	2,562,696	0	25,424,449
7	Tamarindus indica	12,544,511	620,638	331,048	53,603	13,549,801
8	Acacia senegal	7,804,131	2,584,187	2,292,172	0	12,680,491
9	Acacia gerrardii var. gerrardii	12,186,441	34,803	96,642	8,521	12,326,407
10	Acacia tortilis f. raddiana	3,632,148	6,130,651	2,151,961	86,049	12,000,809
11	Boswellia papyrifera	10,104,359	0	18,337	0	10,122,695
12	Acacia mellifera	5,922,109	2,425,733	650,999	0	8,998,841
13	Acacia seyal	8,981,151	0	0	0	8,981,151
14	Terminalia macroptera	7,780,173	66,374	405,399	0	8,251,946
15	Sterculia setigera	7,746,416	0	501,776	0	8,248,193
16	Acacia nilotica var. adstringens	6,790,398	714,494	445,264	0	7,950,156
17	Adansonia digitata	4,667,962	1,512,903	1,697,854	0	7,878,718
18	Terminalia brownii	7,610,219	143,384	21,268	0	7,774,871
19	Dalbergia melanoxylon	7,153,693	134,093	326,606	0	7,614,392
20	Others	83,252,601	8,611,966	16,082,076	2,317,417	110,264,060
	Total (m3)	475,971,561	34,097,525	42,427,669	2,739,807	555,236,562

4.6.1.3. Average gross volume by FRA and DBH classes

In general, the average gross volume decreases with the decrease in a DBH class in the forest and other wooded land FRA classes. The maximum volume will be found in the DBH class of 10-19.99 cm. Table 4.26.

Table 4.26 Average gross volume by FRA and DBH classes (m³)

DBH classes (cm)	FRA Classes (volume m3)				Total (m3)
	Forest	Other Wooded Land	Other Land	Inland Water	
10 - 19.99	157,406,838	13,525,229	9,181,172	143,651	180,256,890
20 - 29.99	98,924,630	5,766,612	5,262,610	109,475	110,063,326
30 - 39.99	85,270,857	5,209,513	6,093,393	190,940	96,764,702
40 - 49.99	54,887,463	3,153,077	4,971,401	324,922	63,336,864
50 - 1000	79,481,773	6,443,094	16,919,093	1,970,818	104,814,779
Total (m3)	475,971,561	34,097,525	42,427,669	2,739,807	555,236,562

4.6.1.4. Gross volume by state

As evidentiated by this NFI, the forest cover in the 4 Darfur states (excluding Northern Darfur) is good. We also know that Southern and Western Kordofan areas have a good forest cover. The Blue Nile area is also known to have a good cover, but it is likely that the inventory result may be underestimated as a good cover plots south of the state were not reached due to safety consideration.

Western Kordofan, Northern Darfur, Southern Darfur, Eastern Darfur, Central Darfur, and Northern Kordofan states contain more than 83% of the growing stock. Table 4.27 presents the total gross volume by state.

Table 4.27 Total gross volume by States

DBH classes (cm)	FRA Classes (volume m3)				Total (m3)
	Forest	Other Wooded Land	Other Land	Inland Water	
Blue Nile	16,797,295	246,649	1,251,991	209,611	18,505,547
Central Darfur	49,254,660	1,060,030	7,618,557	1,595,708	59,528,954
Gezira					
Eastern Darfur	79,892,781	2,440,017	6,339,720	0	88,672,517
El Gadarif	1,260,347	578,725	1,620,475	172,603	3,632,150
Kassala	0	110,074	10,963	0	121,037
Khartoum	0	1,223,038	319,342	0	1,542,380
Northern	0	0	1,333,759	0	1,333,759
Northern Darfur	9,510,300	4,188,573	3,474,012	0	17,172,886
Northern Kordofan	5,209,884	5,287,181	3,847,296	99,462	14,443,823
Red Sea	0	3,405,850	91,263	0	3,497,112
River Nile	0	0	301,725	0	301,725
Sennar	9,079,202	42,234	23,520	0	9,144,956
Southern Darfur	137,593,181	4,436,865	7,417,619	662,423	150,110,089
Southern Kordofan	38,812,884	741,876	2,130,510	0	41,685,269
Western Kordofan	119,585,146	9,330,911	5,334,360	0	134,250,418
Western Darfur	8,975,879	974,889	1,241,570	0	11,192,338
White Nile	0	30,614	70,989	0	101,603
Total (m3)	**475,971,561**	**34,097,525**	**42,427,669**	**2,739,807**	**555,236,562**

4.6.2. Bole volume

Bole volume refers to the merchantable part of stem, up to trees first big branch. Because bole volume representas a rather technical measure of the stem, it cannot give exact information on the commercial value of the forest. However, bole volume can serve as an indicator for timber harvesting potential. Some Sudanese tree species produce industrial timber from the bole and fire wood from the branches. Other tree species are not suitable for timber production, but utilized for fuel-wood. Some species can be used for fuel-wood but will not be used as such given their value non-wood timber products. Some species have multiple uses, but will be kept for protection purposes.

4.6.2.1. Bole volume by FRA classes, National LUCC and stratum

Table 4.28 and Table 4.29 present respectively the average and total bole volume by FRA classes. The biggest (85.7%) commercial volume occurs in forest land areas.

Table 4.28 Average bole volume per hectare for FRA classes and by stratum (m^3/ha)

Strata	FRA Classes				Volume mean (m3/ha)
	Forest	Other Wooded Land	Other Land	Inland Water	
Stratum II (semi-desert ecosystems)	0.0000	0.2071	0.0449	0.0000	0.0666
Stratum III (Low rainfall woodland Savannah)	0.9504	0.3262	0.2448	0.5299	0.3370
Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	4.9919	0.9091	0.7867	13.6907	2.9795
Stratum V (rivers and streams)	1.0690	0.2836	2.3171	0.0000	0.5702
Volume mean (m3/ha)	4.0338	0.3313	0.1744	0.9632	1.1739

Table 4.29 Total bole volume per major National LUCs

FRA class	National LUC	Total Gross volume (m3)	Gross Volume (%)
Forest	Other forest	423960	0.2996
	Deciduous forest	69019900	48.7674
	Evergreen forest	1428826	1.0096
	Raffia/Palms	1343615	0.9494
	Semi-deciduous forest	49182753	34.7510
	Mixed planted forest	19295	0.0136
	Forest Total	121,418,347	85.7905
Other wooded land	Woodland	1189827	0.8407
	Wooded grassland	6812150	4.8133
	Wooded wetland	297010	0.2099
	Total Other wooded land	8,298,986	5.8638
Other land	Annual crop	7581941	5.3572
	Barren land	924114	0.6530
	Built up area	91162	0.0644
	Fallow	7924	0.0056
	Improved pastures	81165	0.0573
	Marsh	0	0.0000
	Mixed annual and perennial crop	231486	0.1636
	Natural grassland	1467410	1.0368
	Perennial crop	713483	0.5041
	Quarry/Mining site	0	0.0000
	Desert	0	0.0000
	Other	137625	0.0972
	Total Other land	11,236,310	7.9392
Water	Dam	0	0.0000
	Intermittent river (seasonal)	344924	0.2437
	Lake	0	0.0000

FRA class	National LUC	Total Gross volume (m3)	Gross Volume (%)
Water	Perennial river	230269	0.1627
	Pond	0	0.0000
	Total Inland water	575,192	0.4064
	Total country	**141,528,836**	**100.0000**

4.6.2.2. Tree bole volumes of the most common species

The species Hyphaene thebaica, Sterculia setigera, Sclerocarya birrea, Anogeissus leiocarpus, Balanites aegyptiaca, Acacia tortilis, and Albizia amara had the highest value within Forest FRA classes (Table 4.30).

Table 4.30 Average Bole volume by main tree species and FRA classes (m^3)

No.	Specie	FRA classes				Total (m3)
		Forest	Other Wooded Land	Other Land	Inland Water	
1	Acacia seyal var. seyal	20,368,176	135,592	142,890	819	20,647,477
2	Balanites aegyptiaca	13,384,344	1,230,926	2,429,602	14,902	17,059,774
3	Anogeissus leiocarpus	15,937,015	197,412	192,410	62,638	16,389,475
4	Albizia amara	9,264,696	461,725	565,371	0	10,291,792
5	Combretum ghasalense	7,561,132	106,799	468,971	0	8,136,902
6	Sclerocarya birrea	5,591,204	243,021	567,945	0	6,402,170
7	Acacia tortilis f. raddiana	1,046,792	1,625,893	677,446	27,664	3,377,795
8	Acacia gerrardii var. gerrardii	3,260,751	10,225	31,101	1,972	3,304,050
9	Acacia senegal	2,060,204	626,281	613,691	0	3,300,177
10	Tamarindus indica	2,925,251	155,523	61,737	13,744	3,156,256
11	Boswellia papyrifera	2,911,716	0	6,088	0	2,917,804
12	Terminalia macroptera	2,047,759	14,813	106,256	0	2,168,828
13	Terminalia brownii	2,119,516	39,944	5,302	0	2,164,762
14	Adansonia digitata	1,315,544	343,612	505,314	0	2,164,469
15	Acacia mellifera	1,384,371	598,848	140,099	0	2,123,318
16	Ficus sycomorus	1,829,854	0	32,458	247,945	2,110,257
17	Acacia nilotica var. adstringens	1,689,656	172,857	120,074	0	1,982,587
18	Dalbergia melanoxylon	1,556,950	42,551	141,654	0	1,741,154
19	Sterculia setigera	1,596,118	0	78,590	0	1,674,708
20	Others	23,567,297	2,292,965	4,349,312	205,508	30,415,082
	Total (m3)	**121,418,347**	**8,298,986**	**11,236,310**	**575,192**	**141,528,836**

4.6.2.3. Average bole volume by FRA and DBH classes

The results of bole volume and DBH classes can be seen in the table 4.31; generally, when DBH class increases the average bole volume of the FRA class decreases.

Table 4.31 Bole volume by FRA and DBH classes (m^3)

DBH classes (cm)	FRA Classes (volume m3)				Total (m3)
	Forest	Other Wooded Land	Other Land	Inland Water	
10 - 19.99	44,194,586	3,916,446	2,795,938	43,325	50,950,295
20 - 29.99	25,687,816	1,373,100	1,409,254	33,714	28,503,883
30 - 39.99	20,836,296	1,043,240	1,791,441	49,532	23,720,509
40 - 49.99	13,207,787	649,562	1,518,983	88,038	15,464,370
50 +	17,491,863	1,316,638	3,720,695	360,583	22,889,779
Total (m3)	121,418,347	8,298,986	11,236,310	575,192	141,528,836

4.6.2.4. Bole volume by FRA Classes and state

Total bole volume by state (5 states) is ranked from highest in Southern Darfur(1), Eastern Darfur(2), Western Kordofan (3), Central Darfur (4) and Southern Kordofan(55); and to the lowest total bole volume in White Nile state (see table 4.32).

Table 4.32 Total Bole Volume (m3) by FRA Classes and State

State	FRA Classes (volume m3)				Total Bole volume (m3)
	Forest	Other Wooded Land	Other Land	Inland Water	
Blue Nile	3,486,403	62,224	304,959	62,638	3,916,223
Central Darfur	14,750,542	206,371	1,412,683	283,224	16,652,820
Gezira					
Eastern Darfur	23,251,403	681,121	1,861,260	0	25,793,784
El Gadarif	243,636	106,882	429,651	35,959	816,127
Kassala	0	32,445	3,074	0	35,519
Khartoum	0	501,746	181,090	0	682,837
Northern	0	0	912,265	0	912,265
Northern Darfur	2,480,761	1,167,588	1,078,810	0	4,727,159
Northern Kordofan	1,135,316	1,088,293	1,056,657	30,302	3,310,568
Red Sea	0	1,038,068	35,282	0	1,073,350
River Nile	0	0	186,192	0	186,192
Sennar	1,800,041	11,326	4,190	0	1,815,557
Southern Darfur	43,677,627	1,060,072	1,927,422	163,069	46,828,189
Southern Kordofan	8,380,976	207,343	440,430	0	9,028,750
Western Kordofan	20,069,281	1,887,690	1,018,792	0	22,975,764
Western Darfur	2,142,361	241,054	366,755	0	2,750,170
White Nile	0	6,764	16,797	0	23,562
Total bole volume (m3)	**121,418,347**	**8,298,986**	**11,236,310**	**575,192**	**141,528,836**

4.7. Biomass and carbon stocks

4.7.1. Biomass estimation

Forest biomass can be estimated through field measurement, remote sensing and GIS methods (Ravindranath and Ostwald, 2008). For field measurement based methods, the following methods can be used:

1. Destructive sampling
2. Non-destructive sampling
3. Allometric equations
4. Conversion from volume to biomass

Due to the lack of reliable data, the conversion from volume to biomass method is used. The inventoried volume is measured from stump to top of bole and excludes branches (FRA 2000). In the absence of applicable biomass models for every stratum in Sudan, consistent with international requirements, the choice between the models has been restricted to the pantropical model of Chave et al. (2014). The value for the wood density for each specie is based in the list of the global database of DRYAD and IPCC.

Tables 4.33 and 4.34 respectively present the average AGB and BGB by stratum and National LUCC. Forest and woodland vegetation stratum contain the highest mean above-ground biomass in Sudan. Equally, Forest FRA classes contains the highest mean above ground biomass (12.69 t/ha).

Table 4.33 Total of Above Ground Biomass (AGB) and Below Ground Biomass (BGB) by stratum and FRA classes

Stratum	Biomass type	FRA classes				Total	Grand total (tons)
		Forest	Other Wooded Land	Other Land	Inland Water		
Stratum II (semi-desert ecosystems)	AGB (t)	0	4,080,497	1,917,085	0	5,997,582	8,922,096
	BGB (t)	0	1,967,270	957,244	0	2,924,514	
Stratum III (Low rainfall woodland Savannah)	AGB (t)	18,828,879	12,307,190	6,897,977	94,714	38,128,759	54,442,427
	BGB (t)	7,835,120	5,445,815	2,982,925	49,809	16,313,668	
Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	AGB (t)	365,112,103	11,198,605	21,864,338	1,604,326	399,779,372	565,102,953
	BGB (t)	151,785,886	4,606,981	8,385,146	545,567	165,323,581	
Stratum V (rivers and streams)	AGB (t)	463,542	119,290	1,361,012	0	1,943,844	2,753,125
	BGB (t)	194,416	54,463	560,401	0	809,280	
Total	AGB (t)	384,404,524	27,705,583	32,040,411	1,699,040	445,849,557	631,220,601
	BGB (t)	159,815,422	12,074,529	12,885,716	595,376	185,371,044	
Grand total (tons)		**544,219,946**	**39,780,112**	**44,926,127**	**2,294,416**	**631,220,601**	

Figure 4.18 Total of AGB and BGB by stratum and FRA classes

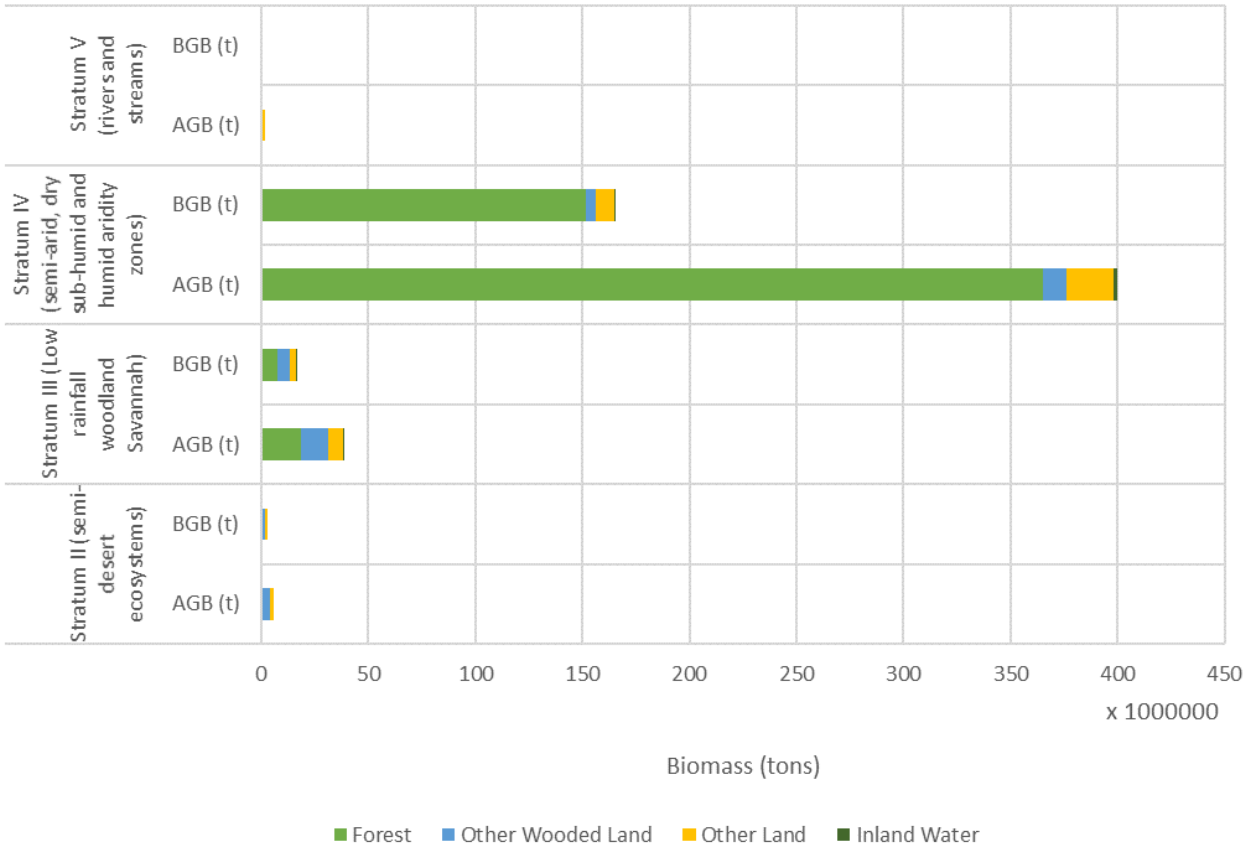


Table 4.34 Total of Above Ground Biomass (AGB) and Below Ground Biomass (BGB) by National LUCC types

LUC level 0	FRA Classes (Level 1)	LUC level 2	LUC level 3	AGB (tons)	BGB (tons)	Total (tons)
Forest	Forest	Natural regenerated forest	F) Forest	909,384	336,270	1,245,654
			FB) Bamboo forest	0	0	0
			FD) Deciduous forest	215,487,338	89,960,223	305,447,562
			FE) Evergreen forest	5,505,750	2,350,386	7,856,136
			FRP) Raffia/Palms	2,333,686	865,492	3,199,178
			FSD) Semi-deciduous forest	160,093,766	66,268,982	226,362,748
		Plantation	FPB) Broadleaved planted forest	0	0	0
			FPC) Coniferous planted forest	0	0	0
			FPM) Mixed planted Forest	74,600	34,067	108,667

LUC level 0	FRA Classes (Level 1)	LUC level 2	LUC level 3	AGB (tons)	BGB (tons)	Total (tons)
Non forest	Other Wooded Land	Woodland	W) Woodland	2,977,065	1,352,431	4,329,496
		Wooded grassland	WG) Wooded grassland	23,583,842	10,202,499	33,786,341
		Wooded wetland	WW) Wooded wetland	1,144,676	519,599	1,664,275
	Other Land	Natural	O) Other	917,158	280,254	1,197,412
			OG) Natural Grassland	3,926,601	1,756,200	5,682,800
			OM) Marsh	0	0	0
			OX) Barren Land	1,873,243	861,584	2,734,827
		Cultivated	OCA) Annual Crop	23,370,080	9,175,337	32,545,417
			OCM) Mixed annual and perennial crop	511,417	204,976	716,393
			OCP) Perennial crop	1,059,107	442,083	1,501,190
			OF) Fallow	27,720	13,955	41,675
			OP) Improved pastures	165,461	72,353	237,814
			OW) Wood lot	0	0	0
		Built up area	OWB) Wood lot of Bamboo	0	0	0
		Quarry/Mining site	OB) Built up area	189,624	78,975	268,599
		Deserts (Stratum I)	OQ) Quarry/Mining site	0	0	0
	Inland Water	Dam	ID) Dam	0	0	0
		Lake	IL) Lake	0	0	0
		Pond	IP) Pond	0	0	0
		Perennial river	IRP) Perennial River	554,718	172,666	727,384
		Intermittent river (seasonal)	IRS) Intermittent River (seasonal)	1,144,321	422,710	1,567,032
		Inland water	IW) Inland water	0	0	0
Total (tons)				**445,849,557**	**185,371,044**	**631,220,601**

4.7.2. Total Carbon stocks by national LUCC, FRA classes and stratum

The result on total carbon was derived from the conversion of the biomass to carbon. The factor used for the conversion is 0.47 (recommended by IPCC). Table 4.35 shows that:

1. The “Forest” FRA class has the highest total Carbon (80.30%) and “Inland Water” had the lowest (0.32%).
2. The “Annual crop”, “Deciduos” and “Semi-deciduous” National LUCC had the highest total Carbon.
3. The stratums “Forest and woodland vegetation and Low rainfall woodland Savannah” contain the highest total Carbon in Sudan.

Table 4.35 **Total Carbon by National LUCC, FRA classes and stratum**

LUC level 0	FRA Classes	LUC level 2	LUC level 3	Stratum II (semi-desert ecosystems)	Stratum III (Low rainfall woodland Savannah)	Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	Stratum V (rivers and streams)	Total (tons)
Forest	Forest (293,323,006 tons-80.30%)	Natural regenerated forest	F) Other Forest	0	0	685,965	0	685,965
			FB) Bamboo forest	0	0	0	0	0
			FD) Deciduous forest	0	5,352,424	157,690,737	365,261	163,408,422
			FE) Evergreen forest	0	0	4,052,662	0	4,052,662
			FRP) Raffia/Palms	0	0	1,699,045	0	1,699,045
			FSD) Semi-deciduous forest	0	11,360,925	111,865,360	69,965	123,296,250
		Plantation	FPB) Broadleaved planted forest	0	0	0	0	0
			FPC) Coniferous planted forest	0	0	0	0	0
			FPM) Mixed planted Forest	0	193,048	0	0	193,048
	Other Wooded Land (34,347,115 tons - 9.92%)	Woodland	W) Woodland	4,013,677	134,158	1,252,508	133,510	5,533,853
		Wooded grassland	WG) Wooded grassland	5,180,535	13,817,862	8,996,784	30,886	28,026,068
		Wooded wetland	WW) Wooded wetland	0	787,194	0	0	787,194
Non forest	Other Land (36,234,842 Tons – 9.92%)	Natural	O) Other	0	38,240	619,723	0	657,963
			OG) Natural Grassland	7,576,450	1,607,836	1,645,411	6,140	10,835,837
			OM) Marsh	0	0	0	0	0
			OX) Barren Land	1,585,998	770,411	401,659	279,726	3,037,795
		Cultivated	OCA) Annual Crop	0	4,441,009	15,475,529	228,564	20,145,101
			OCM) Mixed annual and perennial crop	0	0	446,098	0	446,098
			OCP) Perennial crop	0	290,898	4,839	432,660	728,397
			OF) Fallow	0	0	116,709	0	116,709
			OP) Improved pastures	0	113,834	0	0	113,834
			OWB) Wood lot of Bamboo	0	0	0	0	0
		Built up area	OB) Built up area	10,795	0	91,139	51,174	153,107
		Quarry/ Mining site	OQ) Quarry/Mining site	0	0	0	0	0
		Dam	ID) Dam	0	0	0	0	0
Non forest	Inland Water (1,182,987 tons (0.32%)	Lake	IL) Lake	0	0	0	0	0
		Pond	IP) Pond	0	0	0	0	0
		Perennial river	IRP) Perennial River	0	0	377,695	0	377,695
		Intermittent river (seasonal)	IRS) Intermittent River (seasonal)	0	88,899	716,394	0	805,292
Total (tons)				**18,367,455**	**38,996,739**	**306,138,257**	**1,597,886**	**365,100,337**

Carbon is 89.75% high in the forest and wood land vegetation equivalent to FRA classes forest, other wooded land and other land. Carbon is 10.68% in the low rainfall wood land savannah. It is 5.03% in the semi-desert ecosysteem, and it is 0.44% low in the riverine vegetation.

Table 4.36 **Total Carbon by National LUCC, FRA classes and by source**

LUC Levels				Source of carbon									
LUC level 0	FRA Classes	LUC level 2	LUC level 3	Above Ground Carbon Live trees (tons)	Below Ground Carbon Live trees (tons)	Above Ground Carbon dead trees (tons)	Below Ground Carbon dead trees (tons)	Fallen dead wood carbon (tons)	Shrubs Above Ground Carbon (tons)	Shrubs Below Ground Carbon (tons)	Stumps Carbon (tons)	Small trees carbon (tons)	Total (tons)
Forest	Forest	Natural regenerated forest	F) Other Forest	427,410	158,047	6,322	3,064	75,758	3,976	2,066	645	8,677	685,965
			FB) Bamboo forest	0	0	0	0	0	0	0	0	0	0
			FD) Deciduous forest	101,279,053	42,281,295	771,153	333,090	4,373,026	2,357,257	1,019,342	162,379	10,831,827	163,408,422
			FE) Evergreen forest	2,587,702	1,104,681	15,933	7,528	0	7,177	3,715	1,925	324,001	4,052,662
			FRP) Raffia/Palms	1,096,833	406,782	12,638	4,947	0	7,909	4,190	0	165,747	1,699,045
			FSD) Semi-deciduous forest	75,244,069	31,146,408	2,200,262	937,937	3,481,345	2,050,561	943,402	68,145	7,224,121	123,296,250
		Plantation	FPB) Broadleaved planted forest	0	0	0	0	0	0	0	0	0	0
			FPC) Coniferous planted forest	0	0	0	0	0	0	0	0	0	0
			FPM) Mixed planted Forest	35,062	16,012	0	0	0	95,704	46,270	0	0	193,048
Non forest	Other Wooded Land	Woodland	W) Woodland	1,399,226	635,645	0	0	1,438,302	865,656	401,515	7,112	786,398	5,533,853
		Wooded grassland	WG) Wooded grassland	11,084,400	4,795,168	87,076	38,407	1,324,475	2,800,505	1,249,606	39,178	6,607,253	28,026,068
		Wooded wetland	WW) Wooded wetland	537,998	244,211	0	0	0	0	0	0	4,985	787,194
	Other Land	Natural	O) Other	431,064	131,719	0	0	0	59,860	23,686	0	11,634	657,963
			OG) Natural Grassland	1,845,501	825,412	2,917	1,540	250,362	1,085,892	522,362	7,766	6,294,085	10,835,837
			OM) Marsh	0	0	0	0	0	0	0	0	0	0
			OX) Barren Land	880,426	404,947	149,267	78,370	4,735	711,196	294,890	0	513,965	3,037,795
		Cultivated	OCA) Annual Crop	10,983,937	4,312,409	97,658	41,648	353,821	951,335	414,183	50,984	2,939,127	20,145,101
			OCM) Mixed annual and perennial crop	240,366	96,339	0	0	0	5,578	2,983	0	100,833	446,098
			OCP) Perennial crop	497,781	207,779	0	0	0	6,071	3,000	1,165	12,601	728,397
			OF) Fallow	13,028	6,559	0	0	0	10,656	5,057	433	80,975	116,709
			OP) Improved pastures	77,767	34,006	0	0	0	1,244	818	0	0	113,834
			OWB) Wood lot of Bamboo	0	0	0	0	0	0	0	0	0	0
		Built up area	OB) Built up area	89,123	37,118	0	0	443	6,684	4,111	0	15,628	153,107
		Quarry/Mining site	OQ) Quarry/Mining site	0	0	0	0	0	0	0	0	0	0
	Inland Water	Dam	ID) Dam	0	0	0	0	0	0	0	0	0	0
		Lake	IL) Lake	0	0	0	0	0	0	0	0	0	0
		Pond	IP) Pond	0	0	0	0	0	0	0	0	0	0
		Perennial river	IRP) Perennial River	260,718	81,153	0	0	0	38	29	0	35,757	377,695
		Intermittent river (seasonal)	IRS) Intermittent River (seasonal)	537,831	198,674	0	0	0	6,406	3,086	550	58,746	805,292
Total (tons)				**209,549,293**	**87,124,362**	**3,343,225**	**1,446,531**	**11,302,267**	**11,033,706**	**4,944,310**	**340,281**	**36,016,361**	**365,100,337**

Figure 4.19 Total Carbon by national land use classes and source

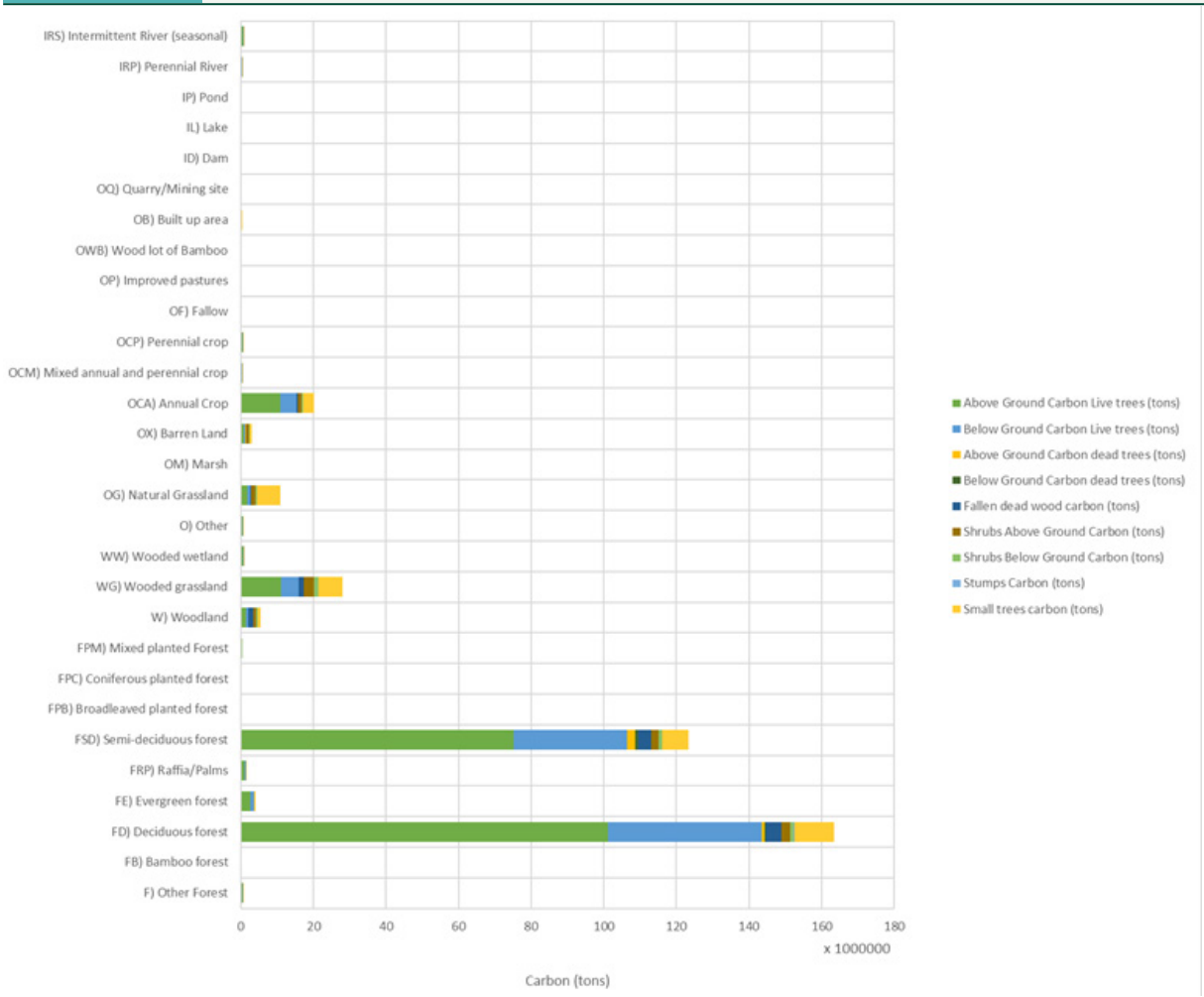


Figure 4.20 Total Carbon by Source

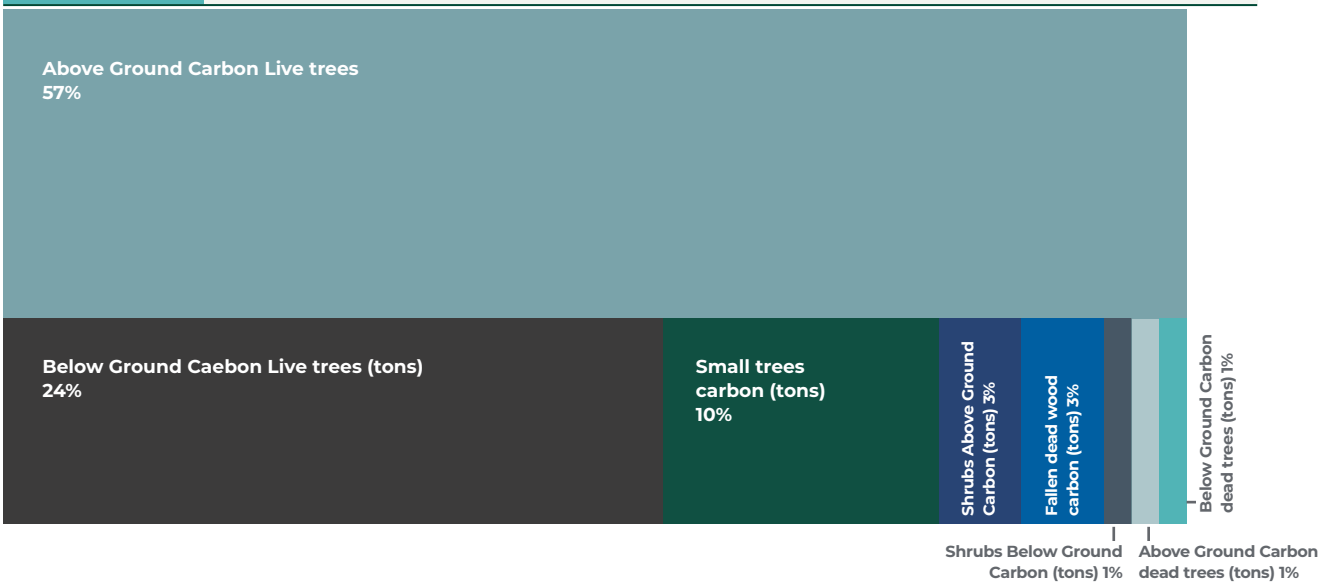


Table 4.37 Total Carbon by state

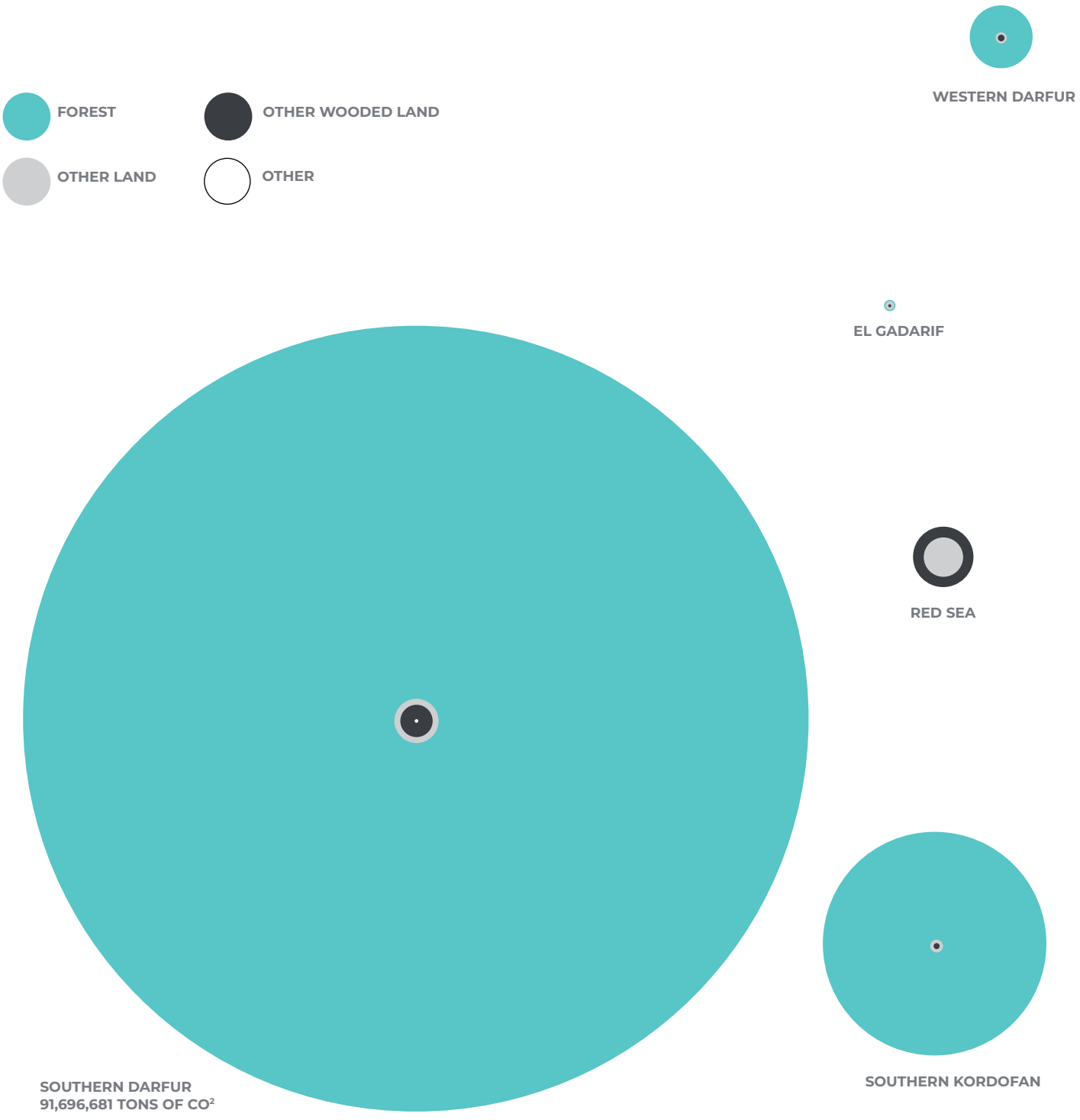
State	FRA Classes (volume m3)					Total (tons)	%
	Forest	Other Wooded Land	Other Land	Inland Water	Other		
Blue Nile	9,779,009	321,195	873,036	113,505	0	11,086,745	3.04
Central Darfur	27,277,532	1,010,501	4,314,928	547,211	111	33,150,283	9.08
Eastern Darfur	51,239,834	2,013,293	4,212,236	0	0	57,465,364	15.74
El Gadarif	1,193,972	327,819	927,274	50,941	100	2,500,105	0.68
Kassala	47,077	390,239	30,721	0	0	468,036	0.13
Khartoum	0	1,098,295	2,044,088	0	0	3,142,382	0.86
Northern	0	0	643,620	0	0	643,620	0.18
Northern Darfur	7,803,347	6,854,909	4,165,834	0	0	18,824,089	5.16
Northern Kordofan	3,847,247	3,741,667	3,203,925	88,899	0	10,881,737	2.98
Red Sea	0	6,506,876	4,241,885	0	0	10,748,761	2.94
River Nile	0	0	193,896	0	0	193,896	0.05
Sennar	6,108,055	108,449	179,795	0	11,587	6,407,887	1.76
Southern Darfur	83,237,630	3,410,319	4,666,299	382,432	0	91,696,681	25.11
Southern Kordofan	24,185,215	639,684	1,359,000	0	5,961	26,189,860	7.17
Western Kordofan	71,569,916	6,787,353	3,030,489	0	249	81,388,008	22.29
Western Darfur	6,887,171	728,939	1,226,463	0	0	8,842,573	2.42
White Nile	159,388	407,577	921,354	0	0	1,488,318	0.41
Total (tons)	**293,335,393**	**34,347,115**	**36,234,842**	**1,182,987**	**18,007**	**365,118,345**	**100.00**

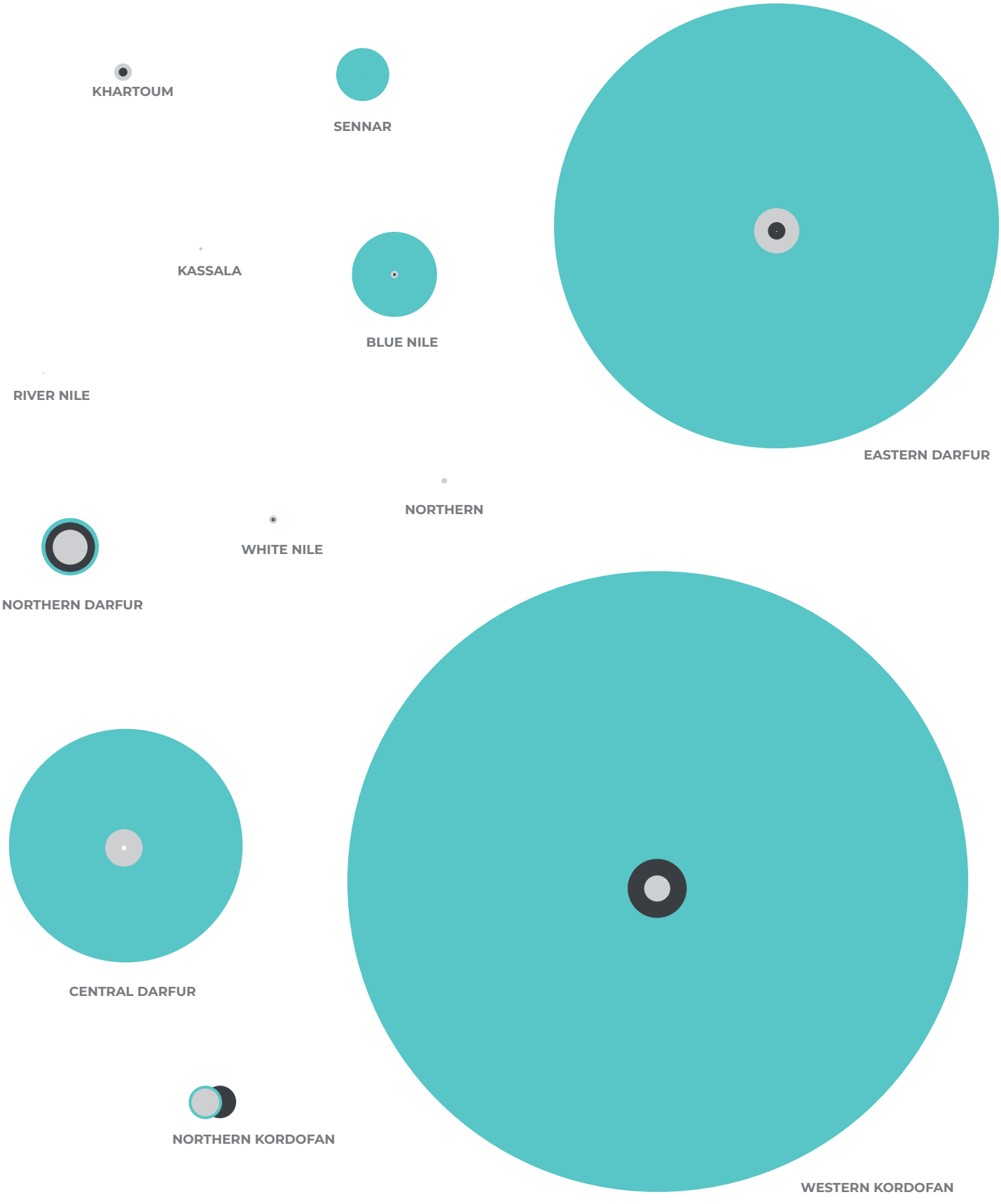
The states Southern Darfur, Western Kordofan and Eastern Darfur contain more than 63% of the total carbon. Table 4.37 shows the distribution of the total carbon by state and FRA classes. 9.41% of the carbon is produced in other wooded land; 80.3% in the forest; 9.96% in the other land and 0.32% in the inland water.

Darfur region is composed of 5 states and it contributes to 57.51% carbon sink in the country. The secondnext is Kordofan region,contributing to 32.44% carbon sink.

Figure 4.21 Distribution of the total carbon by FRA classes

Figure 4.21b Total Carbon by state

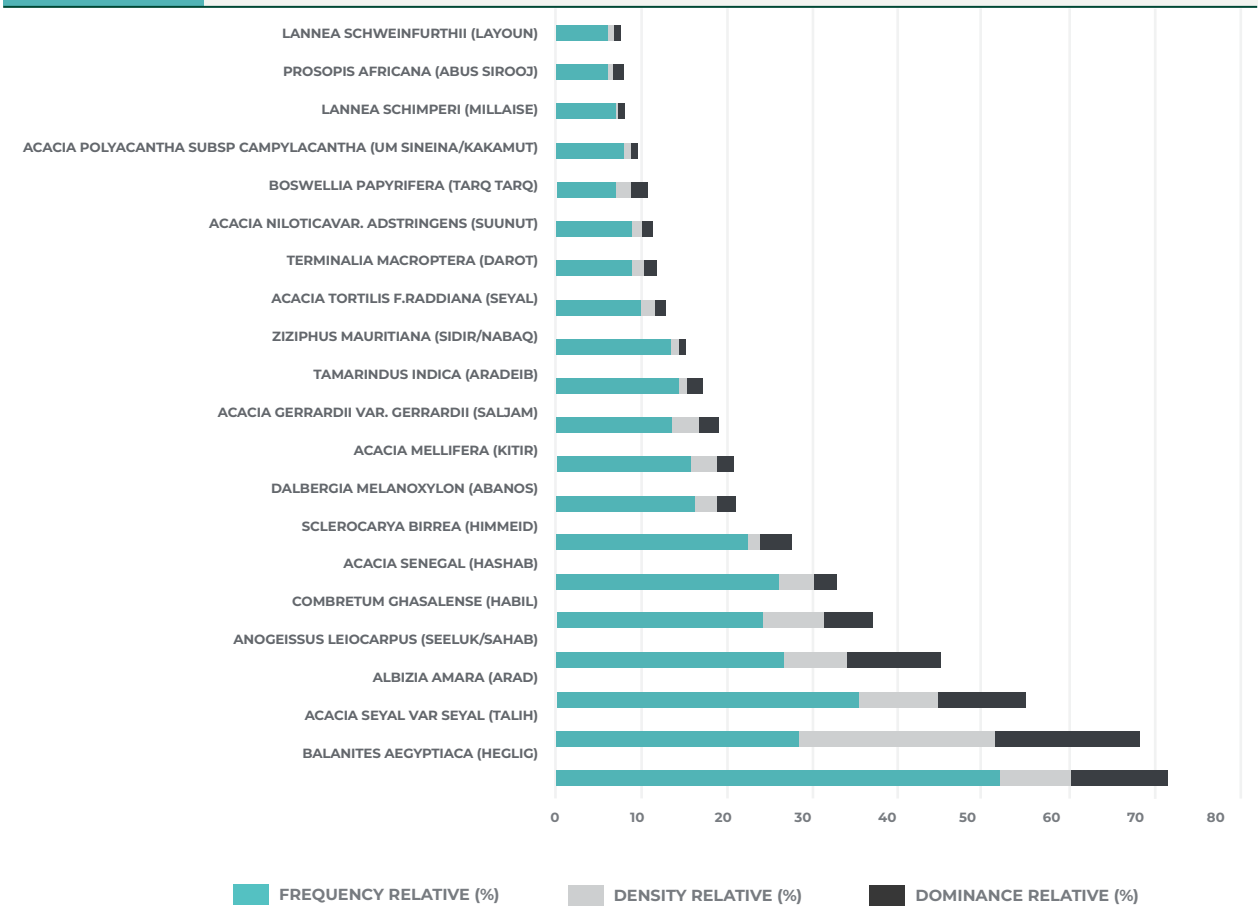



KHARTOUM
SENNAR
KASSALA
BLUE NILE
RIVER NILE
EASTERN DARFUR
NORTHERN
WHITE NILE
NORTHERN DARFUR
CENTRAL DARFUR
NORTHERN KORDOFAN
WESTERN KORDOFAN

4.8. Tree species and biodiversity

The total number of tree species that were measured and identified in Sudan is 319. Of these, 142 species are in Forest, 81 species in Other wooded land, 83 species in Other land and 13 species in Inland water. The species representing the highest mean volume in general are Acacia seyal var. seyal, Anogeissus leiocarpus, Balanites aegyptiaca (as shown previously in Table 4.30).These three species are also the most common in the Forest FRA classes. Figures 4.22 shows the 20 most important tree species using the Important Value Index (IVI).

Figure 4.22 The 20 most important tree species in Sudan



To characterize the species diversity in the major land use classes, the Shannon's Diversity Index, which accounts for both abundance and evenness of the species present, ranges from 0.0 to approximately 4.6. A value near 0.0 means that every tree in the sample is of the same species and a value near 4.6 would indicate that the numbers of individuals are evenly distributed among the different species.

The Shannon index was computed per plot notably for forest and other wooded land FRA classes and then averaged by Major national LUCC type. Results show a generally higher tree species diversity, as expected, in the natural regenerated forest and lower in the forest plantations. Forest and Other woodland had a high level of tree species biodiversity in the country

Table 4.38 Shannon index by Major national LUCC types

Land use/cover class	FRA Classes				Mean of Total
	Forest	Other Wooded Land	Other Land	Inland Water	
FD) Deciduous forest	1.0627				1.0627
FE) Evergreen forest	1.3702				1.3702
FPM) Mixed planted Forest	0.8357				0.8357
FRP) Raffia/Palms	2.4924				2.4924
FSD) Semi-deciduous forest	1.1621				1.1621
ID) Dam				0.8305	0.8305
IL) Lake				1.2701	1.2701
IN) Inaccessible					1.0044
IP) Pond				0.0000	0.0000
IRP) Perennial River				1.0148	1.0148
IRS) Intermittent River (seasonal)				1.0000	1.0000
O) Other			1.2025		1.2025
OB) Built up area			0.5955		0.5955
OCA) Annual Crop			0.7537		0.7537
OCM) Mixed annual and perennial crop			1.0480		1.0480
OCP) Perennial crop			1.3332		1.3332
OF) Fallow			0.4707		0.4707
OG) Natural Grassland			0.3253		0.3253
OM) Marsh			1.4366		1.4366
OP) Improved pastures			0.7930		0.7930
OQ) Quarry/Mining site			1.0839		1.0839
OX) Barren Land			0.3494		0.3494
W) Woodland		0.5923			0.5923
WG) Wooded grassland		0.7310			0.7310
WW) Wooded wetland		1.8047			1.8047
Mean of Total	**1.1684**	**0.7303**	**0.6362**	**0.9661**	**1.0039**

4.9. Products and Services

4.9.1. Major Products obtained from forest

A variety of products are obtained from the forest, and the most harvested products are: Plant food (38.20%), Fodder (16.00%), fire-wood (12.22%) and Wood charcoal (10.87%). Results are shown below and are expressed in terms of percentage of weight (see Figure 4.23).

4.9.2. Major services provided by the forest and trees

Similarly to the products mentioned above, the forest also provides a number of services to the Sudan people. The most important include: Shade, Soil protection, Soil fertility and Climate regulation. These results yet again show the importance of forests to the livelihood of local communities (See Figure 4.24).

Figure 4.23 Major Forest Products (%)

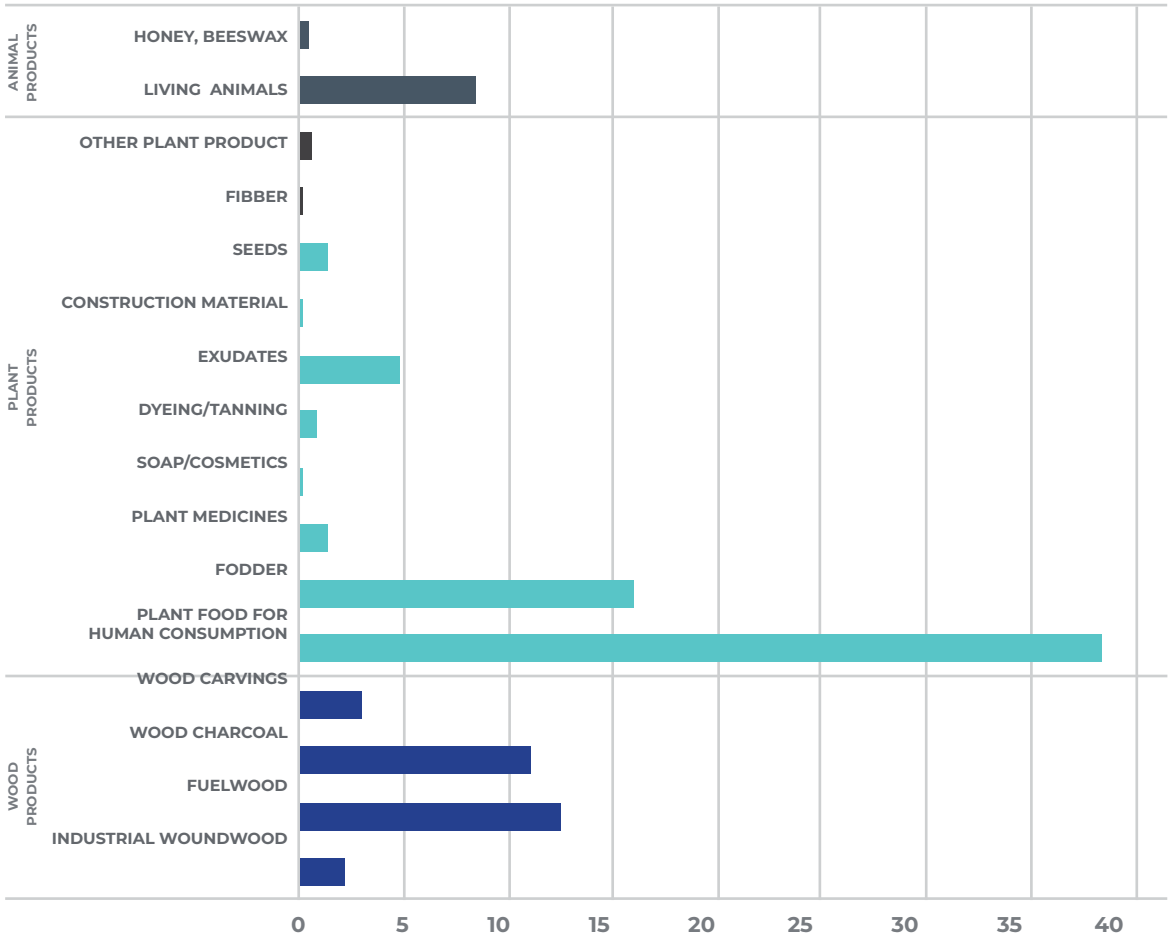
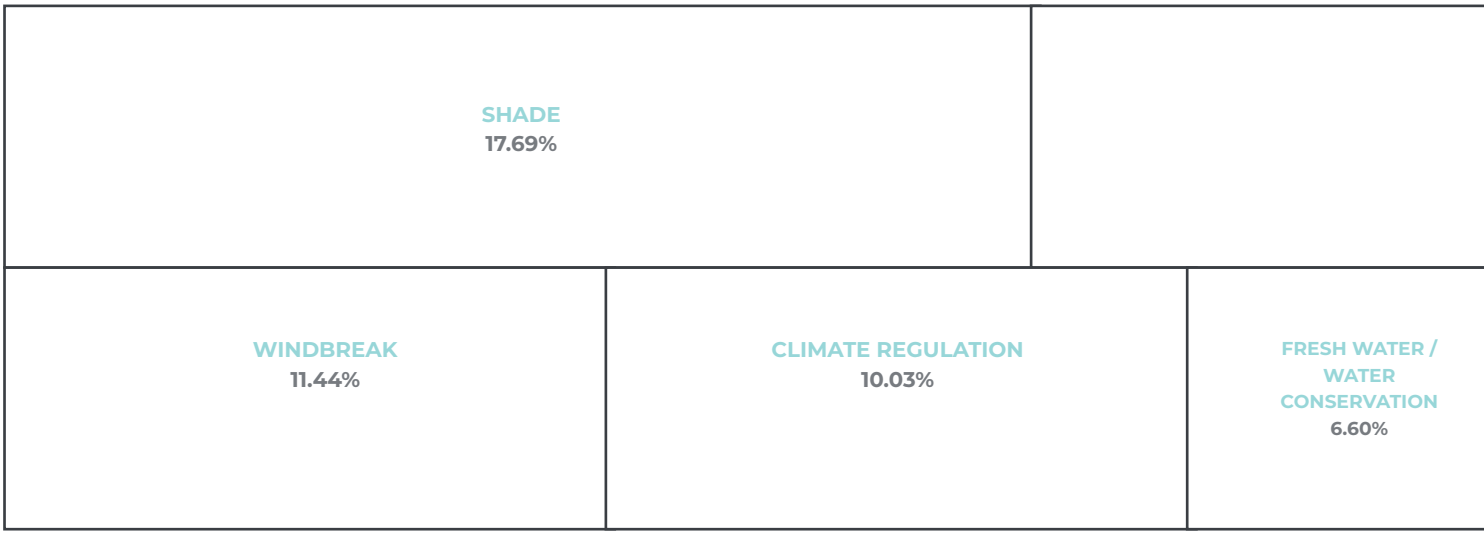
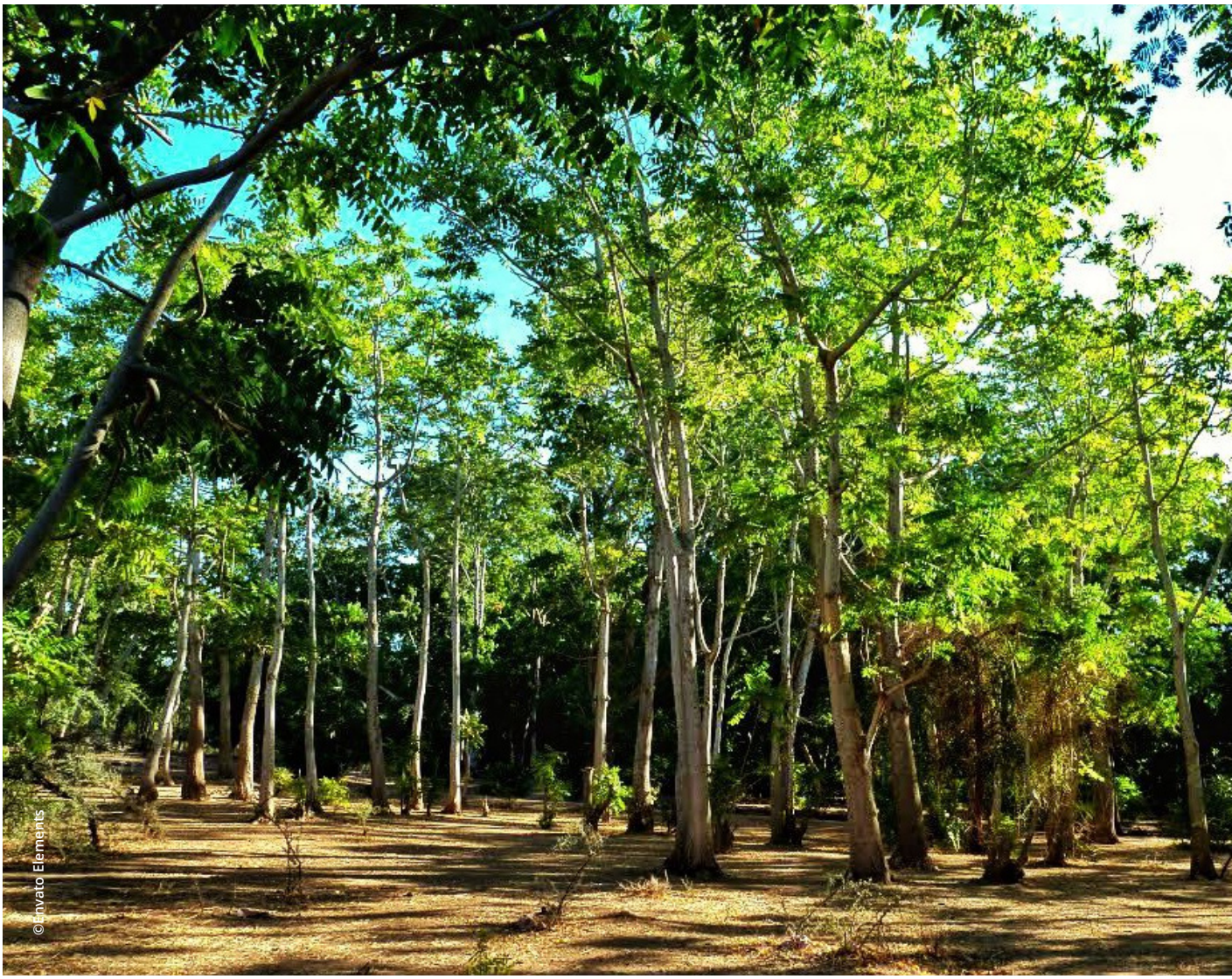


Figure 4.24 Major Services from Forest





SOIL PROTECTION 16.76%			SOIL FERTILITY 15.02%						
	DETOXIFICATION / WATER PURIFICATION 4.61%	RELIGIOUS / SPIRITUAL 4.46%	NONE IDENTIFIED 4.04%	EMPLOYMENT 3.34%	RECREATION / TOURISM 2.52%	AESTHETIC (1.62%)	CULTURAL HERITAGE (1.07%)	OTHER (0.13%)	DISEASE CONTROL (0.27%)	EDUCATION/ SCIENTIFIC STUDIES (0.40%)

CHAPTER 5
COMPARISONS OF THE NFIS RESULTS

We shall compare FRA categories of area of Forests, Other wooded land, Other Land and Inland water with the various surveys currently reported. The reporting of the area and the categories was a result of various studies of Forest Resources Assessment FRA, FRA-RS 2019 in Tanzania, NFI 2017/19 RS results and the ground National Inventory 2017-2019 results all conducted and analyzed by FAO (Table 5.1).

It was observed from the table below that: ground results are not much different from FRA-RS results of Tanzania workshop, a forest area of 10% and 16% respectively had been detected. However, the NFI-RS results are lower in forest area = 6%. But when the forest is summed up to other-wooded land, the result differ in 7%. In total the interpretation and error into it, from assessing forest to other wooded land and vice versa, may be one of the reasons of the variance.

The inland water detected/measured in the ground survey is lower than the statistics of water from the remote sensing data (FRA). In general, the water issue is linked to the UN statistics of global water and it may be in international debate.

Volume comparison between the NFI 1995 and the recent inventory 2017/19, is the total gross volume of the former inventory (16 million m^3) had been calculated from the inventoried area only, which is 25% of the area of the country, and it did not include branch volume. While the gross total volume (555 million m^3) in the latter inventory included branch volume. It may also be due to the wide coverage of the recent inventory. It is good to have different sources of information that assist all types of international reporting and provide information to the country about its forest cover and state. Future FRA reports will encounter new data sources that may change the area of forests and other wooded land.

Table 5.1 The different comparative forest area of Sudan (000 ha)

FRA Classes	Forest Area (000 ha)			
	FRA 2015	FRA-RS 2019	NFI-RS/2017	NFI 2017/19
Forest	19,209.0	27,163.000	18,941.502	29,850.897
Other Wooded Land	20,677.0	15,269.000	22,418.680	24,932.553
Other Land	147,022.0	145,311.800	145,568.764	131,709.208
Inland Water	1,290.0	0.455	1,269.854	655.927
Total	188,198.800*	188,198.800*	188,198.800*	188,198.800*

**Total area of Sudan in this report is 188,233,100*

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1. The report presented thorough accounts on the history of National Forest Inventory in Sudan since 1868up to the latest one conducted in 1997.
2. The NFI of 2021 signifies a good step forward of the national experience based on sound field sampling and methodology.
3. The NFI plots are permanent sample plots which are geo-referenced and will be re-visited for future inventories.
4. The current NFI provides baseline information of the state of the forest resources in Sudan based on genuine ground measurements.
5. With replications and updating of this inventory it will be possible to capture information related to the change in the extent, state and uses of the forest resources and it will be possible to monitor the changes.
6. Further parameters can be incorporated for future measurements.
7. The NFI paved the way for conducting systematic inventories and using the congregated information on the forest resources in the development of applicable national policies and plans and their subsequent implementation.
8. Systematic updates are essential to address new emerging demands and to take advantage of new technologies.
9. The FNC staff's capacities were built on diverse skills of forest inventory.
10. Forest inventory is very important tool for sustainable forest management; the information released by the inventory enables forest management decision.
11. The NFI of 2021 built on the accumulated experience of FNC in systematic sampling using GPS receiver and GIS technology.
12. The 2020 NFI incorporated variables which made possible calculations of biomass and carbon stock complying with the international practices.
13. The current FNI followed a LU/LC classification system which is in agreement with both the national and international levels

6.2 Recommendations

1. Multiple objectives in forestry, such as conservation of biodiversity, mitigation of climate change and ecosystem products and services further than wood, have generated additional tasks to forest management in this era. Hence, it is necessary to develop and sustain national capacities related to sampling design, field data collection, data processing and analysis, remote sensing, reporting to improve the field and map data processing and analytical capacity of the FNC inventory staff.
2. The forest resources inventory division need to be capacitated and boosted in order to take the systematic comprehensive inventory update. Capacity building includes both short-term training and longer-term academic and technical education, and can be implemented through national expertise or by international cooperation.
3. Landsat-based image maps, vegetation maps and surveys, and socio-ethno-economic studies are vital tasks of the inventory department of FNC, this entails that, socio economic crew should complement the inventory team, so that, they can be able to update the field surveys and model management proposals.
4. Institutional collaboration between FNC, Pasture and Range Administration and wildlife Administration to gather data of sufficient level for detailed management purposes to ensure sustainable utilization of the resources. Collaboration concerning the fieldwork and the sharing of data between relevant institutional stakeholders should therefore be encouraged.
5. Establishment of a sound data management system for managing the forestry information. This information is essential to drive statistically reliable information on woody vegetation. It will assist monitoring of changes in forest resources over time
6. For efficient future NFIs, there is a need to improve the species identification to reduce the number of unknowns would greatly enhance the estimates for biomass and carbon for example and also provide more precise estimates of species diversity. It will also improve the assessment and quantification of NWFPs.
7. Efforts should be put forth at collecting additional comprehensive information on pests and diseases and other disturbances would boost the capacity to update the state of forest health by being able to quantify potential loss of trees volume.
8. Permanent sample plots should be established in the forest reserves to serve as the baseline information on biomass and carbon, regeneration, annual increment and species diversity of our forest resources. It will enable monitoring of changes in forest resources over time and enable improved management of our resources through periodic inventory and assessment.
9. Country specific factors for volume, conversion factors and ratios for carbon calculation for different tree species should be worked out and be made readily available.
10. The future inventories should include soil carbon, litter and dead wood estimations.

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ANNEXES

ANNEX 1
STRATIFICATION FOR SUDAN FOREST INVENTORY

Sampling Design for Sudan Forest and Inventory

Selection and implementation of appropriate sampling design to collect forest data determines the output of forest information for various kinds of used and decision-making processes. The sample design that will be in place during the forest inventory together with data collection procedures have crucial role to control the accuracy and the quality of information from the field

After series of consultations with FNC and other stakeholders, it was agreed to employ stratified systematic sampling with reasonable sampling intensities. Thus, stratification process and the determination of the sampling intensity in the strata.

Stratification

Sudan maps and datasets were used to create not-overlapping strata in the GIS environment.. The aridity zones map elaborated by CGIAR-CSI[1] (in the context of land suitability analysis to delineate CDM-AR suitable areas[2]) was used to capture the main country landscapes, characterized by a climate that ranges from hyper-arid in the north to tropical wet-and dry in the far southwest. Methodology is well documented in Zomer et al., 2006, 2007 and 2008. The authors have used the formula proposed by UNEP (1997) to calculate the Aridity Index (AI), as the ratio between the mean annual precipitations (PET)[3] over the mean annual evapotranspiration (MAE), using monthly values for precipitation and temperature from WORLDClim[4] (Hijmans et al.,2004) and MAE from estimates based on modeling (Trabucco et al., 2008). The original classification present five aridity classes[5] which have been reduced to three by grouping in a unique class Humid, Dry sub-humid and Semi-Arid[6]. This decision is justified by the extremely limited extent of the Humid and Dry sub-Humid zones in the country.

To better investigate on the stratification, taking into consideration other aspects beside the biophysical criteria (i.e. precipitation,

1 See at: http://www.cgiar-csi.org/data/global-aridity-and-pet-database

2 The CDM allows for a small percentage of emission reduction credits to come from reforestation and afforestation (CDM-AR).

3 PET is the amount of moisture that, if it were available, would be removed from a given land area by evaporation and transpiration (UNEP 1997).

4 WorldClim is a database of high spatial resolution global weather and climate data

5 Indeed, this classification corresponds closely to the widely adopted classification scheme based on LGP, whereby AI = 0.03 = 10 growing days; AI = 0.2 = 65 growing days; AI = 0.5 = 150 growing days; and AI = 0.65 = 185 growing days (De Haan, 2016).

6 The Aridity Index values reported in the geodataset have been multiplied by a factor of 10000 to derive and distribute the data as integers (with 4 decimal accuracy). Therefore, values needs to be multiplied for 0.0001 to retrieve the values in the correct units.

evapotranspiration), other layers have been used for comparison: the Agro Ecological Zones, the main Land Cover Pattern (GAEZ3), WWF ecoregions (WWF-US 2004), the World Database on Protected Areas (WDPA)[7], the Tropical Dry Forest map (Miles, 2006). From the overlaying data, it is possible to note that predominant biomes are Desert and xeric Shrub-lands, which cover almost all the first strata of the hyper-arid region, and the Tropical, Subtropical Grassland, Savanna and Shrub-land, in the other two strata. Furthermore, two spots are located in the second strata: one under Tropical and the second one on subtropical moist broadleaf forests biome. In terms of ecoregions, Deserts, South Saharian Steppe, and woodlands characterize the first stratum. The second and third strata instead, mostly by the extensive Sahelian Acacia Savanna and in the southern part, by the sub-humid aridity zone, the East Sudanian Savanna. In terms of protected area, the most important protected area fall fully in the third strata, and it is a National Park (Dinder) while other features of this layer represent Marine National Parks, On top of the protected area, the map of Tropical Dry Forest (Miles, 2006).

Rivers layer

Another stratum has been assigned to the River Nile (Nile, Blue Nile and White Nile) and seasonal streams considered important for the presence of Riverine vegetation, Acacia nilotica Forests and Plantations (e.g. Eucalyptus). In particular: Atbara, Dinder, Rahad, Atbar, Bhar Barka, Gash, Khawr Abuhabile (near Khor). These streams have been indicated during the discussion occurred with the FNC. Indeed, to the shapefile of the rivers provided by the country a buffer of 1.5 km each side has been applied. Another reason for considering the buffer as a separate stratum is that it cross all the country with presence of agricultural fields and vegetation: this helps to maintain homogeneity in the strata reducing as much as possible variability in the others.

Harrison and Jackson (1985) and Africover 2000:

The ecological classification from Harrison and Jackson and Africover have been suggested during the mission in order to separate Low rainfall savanna (mostly characterized by trees of maximum 10 m height and not more than 10% cover) from Semi-desert (covered by scattered shrubs with almost not tree cover) in the second strata. Details of the Harrison and Jackson map are found in Annex 1. Africover 2000 layer was used since intended as an updated version of the ecological map, to better delineate the two zones (using the class of Trees and Shrub Savanna). In general, it is important to bear in mind that these boundaries are somehow subjective since in nature there are rarely clear-cuts classes but rather gradients (transitional zones) or mixed classes. Boundaries are always a compromise between generality and specificity. Despite Africover 2010 is more updated, the classification adopted is more detailed and the level of precision is not suitable for the purposes.

GIS analysis

The layer of the stratification has been developed starting from the Aridity index map using a GIS software. The map has been obtained by multiplying by a factor of 10000 the downloaded data to work on data as integers (with 4 decimal accuracy), as indicated in the bibliography. The original data in raster format has been converted in vector and sliver polygons removed. To make a sharp division between semi-arid zone and savanna Harrison and Jackson (1958) and Africover (2000) have been overplayed and a manual editing (splitting) of the original strata carried out. Another refinement of the third stratum regards the Xeric Woodland ecoregion (according to WWF) on the west, analyzed and drafted using VHRI. As regard the river layer, a separate shapefile has been used and database with rivers names completed with the knowledge of the colleagues in the field. A buffer of 1.5 (ha) has been created. The river (polyline) shapefile has been rasterized and polygonised to be erased from the buffer layer, in order to mask out water. The result has been integrated in the original layer and dissolve has been applied, after removing sliver polygons in the fifth stratum. The resulting map used for stratification is shown in the below figure.

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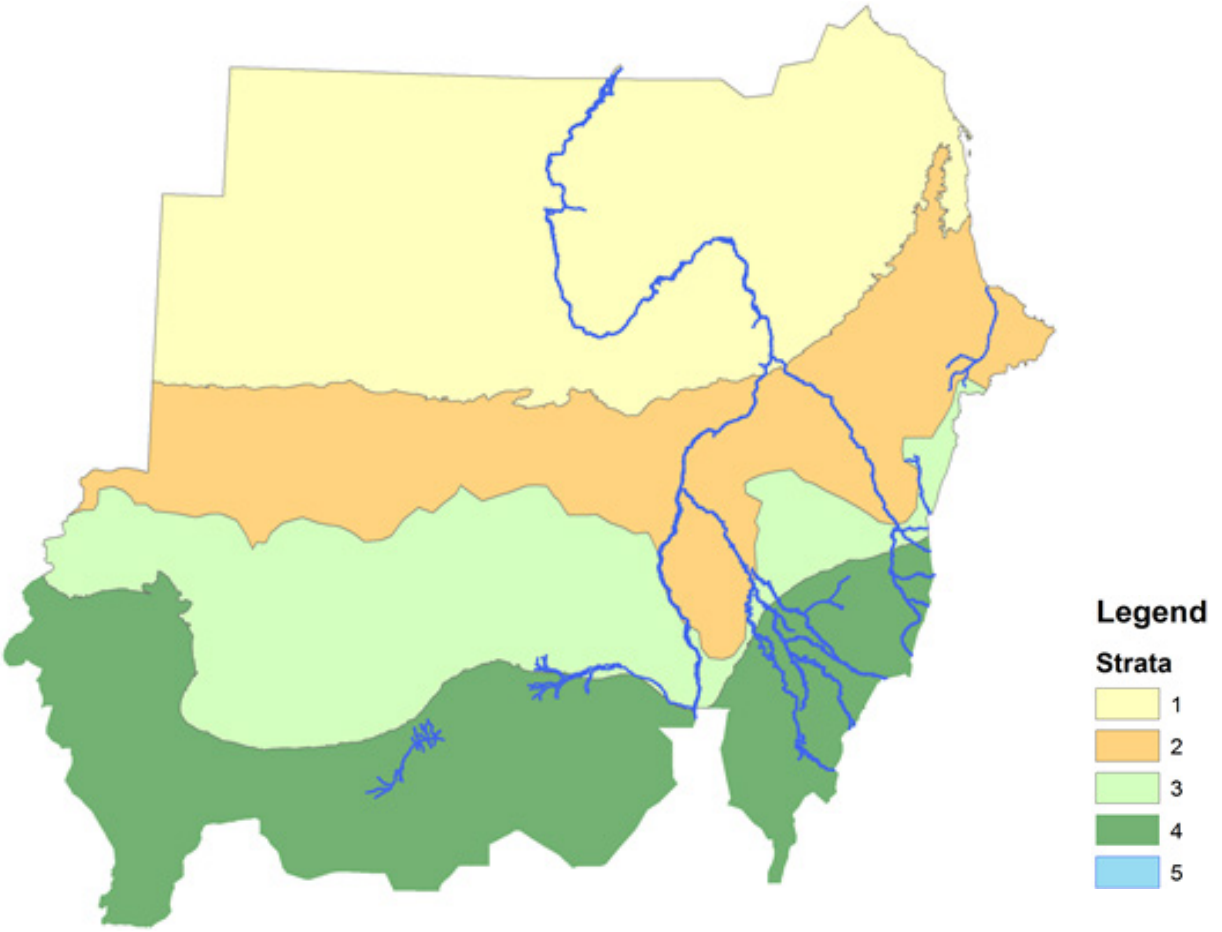


ANNEX 2
LAND USE LAND COVER

Level 1	Level 2	Level 3	Brief description	Code
Forest	**FNC Definition: "Forest means an area of land spanning at least a minimum area of 0.4 ha with trees that have attained, or have the potential to attain at least 2 m. in height and a minimum tree canopy cover of 10%. It includes wind-breaks and/or shelter-belts with a minimum of 20 m. in width".**			
		Forest predominantly composed of trees established through natural regeneration.		
		Evergreen forest	Naturally regenerated forest composed of more than 75% of evergreen trees species. Includes : Moist forest Dry forest	FE
		Deciduous forest	Naturally regenerated forest composed of more than 75% of deciduous trees species. Includes : Moist forest Dry forest Secondary young	FD
		Semi-deciduous forest	Naturally regenerated forest where trees are at least 25% each of evergreen and deciduous species. Includes : Moist forest Dry forest Secondary young	FSD
		Bamboo forest	Naturally regenerated forest predominantly composed of bamboo vegetation.	FB
		Raffia/Palms	Naturally regenerated forest predominantly composed of palm or raffia vegetation.	FRP
		Forest predominantly composed of trees established through planting and/or deliberate seeding. Includes coppice from trees that were originally planted or seeded.		
		Broadleaved planted forest	Planted forest composed of more than 75% of broadleaved species. Includes: Eucalyptus sp. Acacia sp. Gravillia	FPB
		Coniferous planted forest	Planted forest composed of more than 75% of coniferous species. Includes : Cupressus lusita. Juniperus Pinus patula	FPC
		Mixed planted Forest	Planted forest of at least 25% each of coniferous and broadleaved species.	FPM

Level 1	Level 2	Level 3	Brief description	Code
Forest	**FNC Definition: "Forest means an area of land spanning at least a minimum area of 0.4 ha with trees that have attained, or have the potential to attain at least 2 m. in height and a minimum tree canopy cover of 10%. It includes wind-breaks and/or shelter-belts with a minimum of 20 m. in width".**			
		Forest predominantly composed of trees established through natural regeneration.		
		Evergreen forest	Naturally regenerated forest composed of more than 75% of evergreen trees species. Includes : Moist forest Dry forest	FE
		Deciduous forest	Naturally regenerated forest composed of more than 75% of deciduous trees species. Includes : Moist forest Dry forest Secondary young	FD
		Semi-deciduous forest	Naturally regenerated forest where trees are at least 25% each of evergreen and deciduous species. Includes : Moist forest Dry forest Secondary young	FSD
		Bamboo forest	Naturally regenerated forest predominantly composed of bamboo vegetation.	FB
		Raffia/Palms	Naturally regenerated forest predominantly composed of palm or raffia vegetation.	FRP
		Forest predominantly composed of trees established through planting and/or deliberate seeding. Includes coppice from trees that were originally planted or seeded.		
		Broadleaved planted forest	Planted forest composed of more than 75% of broadleaved species. Includes: Eucalyptus sp. Acacia sp. Gravillia	FPB
		Coniferous planted forest	Planted forest composed of more than 75% of coniferous species. Includes : Cupressus lusita. Juniperus Pinus patula	FPC
		Mixed planted Forest	Planted forest of at least 25% each of coniferous and broadleaved species.	FPM
Other wooded lands	**Area ≥ 0.5 ha, tree crown cover 5- 10% or shrubs/bushes canopy cover ≥10%**			
	Woodland	Includes : Acacia comiphora Combretum terminalia Others (bushes)		W
	Wooded grassland	Land covered by natural growth of graminea and herbaceous vegetation, with some scattered trees (tree canopy cover between 5-10%); Land not covered seasonally or permanently by water. Includes: Acacia sp. Others (Combretum sp...)		WG
	Wooded wetland	Land seasonally or permanently covered by water with natural growth of graminea and herbaceous vegetation and some scattered trees (canopy cover between 5-10%).		WW

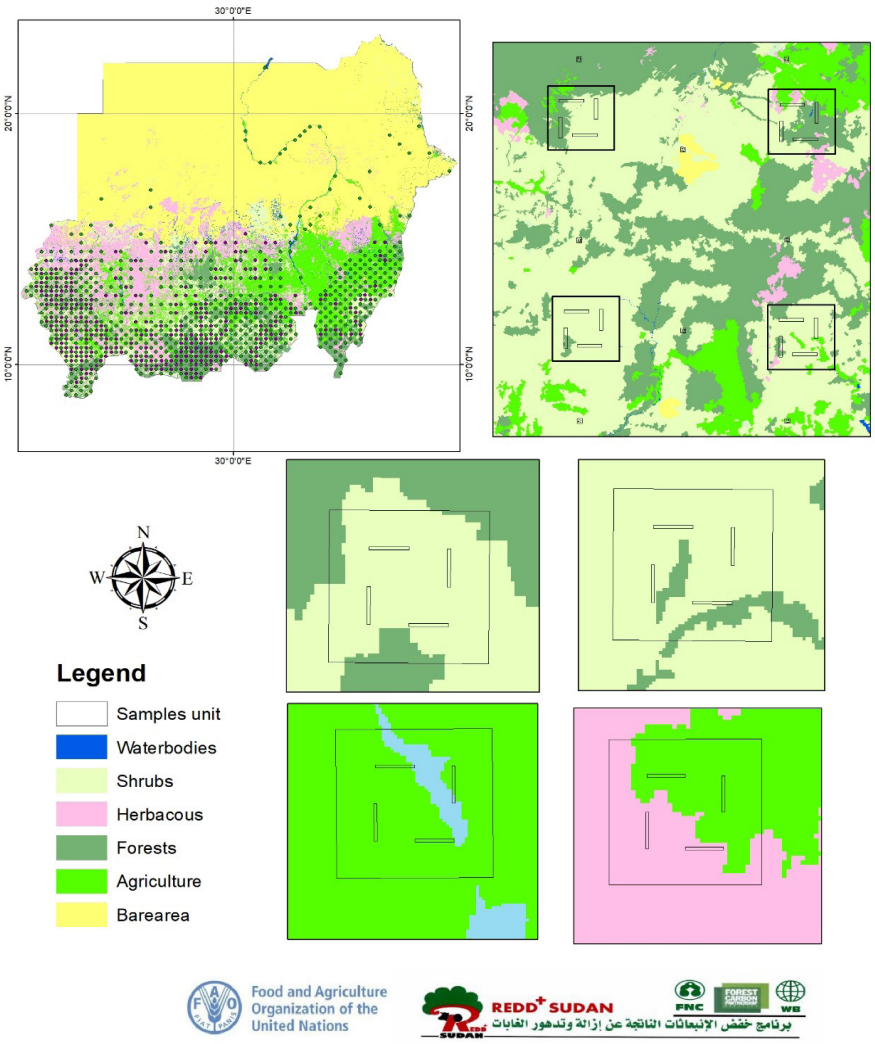
Level 1	Level 2	Level 3	Brief description	Code
Other Land	**Land not classified as forest or other wooded land, as described above (Includes land with tree canopy cover <5% or with shrubs/bushes <10% or with predominant agricultural/urban land use or with shrubs/ trees<0.5ha).**			
	Natural	Barren Land	Land where vegetation cover is less than 2%. Includes land covered of sand, soil and rocks.	OX
		Natural Grassland	Land covered with natural growth of graminea and herbaceous vegetation.	OG
		Marsh	Land seasonally or permanently covered by water and dominated by natural growth of graminea, reed and other herbaceous.	OM
	Cultivated	Improved pastures	Land sown with introduced grass and leguminous for the grazing of livestock.	OP
		Annual Crop	Area covered by crops that are sown and harvested during the same production season/ agricultural year.	OCA
		Perennial crop	Crops that are sown or planted once and need not to be replanted after each annual harvest. Includes trees (e.g. apples or other fruit trees), bushes and shrubs (e.g. berries, coffee...), palms (e.g. dates), vines (e.g., grapes), herbaceous stems (e.g. bananas) and stemless plants (e.g. pineapples).	OCP
		Mixed annual and perennial crop	Association of annual and perennial crops.	OCM
		Fallow	Previously cultivated land kept free from crops or weeds during at least one growing season, where woody vegetation is and will not reach 5m height.	OF
		Wood lot of Bamboo	Bamboo areas spanning between 0.2 and 0.5 ha , with trees >5m at maturity mainly used is for wood stock	OWB
		Wood lot	Other areas spanning between 0.2 and 0.5 ha , with trees >5m at maturity mainly used is for wood stock	OW
	Built up area	Populated areas with significant constructions. Includes homes scattered in the field. Notes: a road is considered as a distinct Land Use/Cover Section (built-up area) if wider than 15 meters (from bottom of ditch on one side to the bottom of ditch on the other side when ditches exists, otherwise the width of the road bank) and if not a forest road.		OB
	Quarry/Mining site	Areas used for extraction of minerals, rocks, sands, clay... Includes: quarry, mining, extraction areas, oil/gas wells.		OQ
Inland water	**Area occupied by major rivers (width ≥ 15m), lakes, ponds and reservoirs.**			
	Perennial River	Rivers (width ≥ 15m) that maintains water in its channel throughout the year.		IRP
	Intermittent River (seasonal)	Rivers (width≥ 15m) that flows only at certain times of the year.		IRS
	Lake	Large body of salt or fresh water surrounded by land.		IL
	Dam	Reservoir created by a barrier constructed to hold back the water and raise its level.		ID
	Pond	Small body of still water formed naturally or by hollowing or embankment.		IP

ANNEX 3
GUIDELINES FOR NATIONAL FOREST INVENTORY (NFI) DATA PROCESSING

Determination of Land Area

The NFI area results have been calculated by analyzing Land Use/ Land Cover (LULC) data observed and recorded in the field Sampling Units (SU). The area of each stratum was determined using the land use/cover classification developed in the NFI, the SU data field and the known area of Sudan. The proportional area estimate of a domain category (e.g. deciduous forest, tree Cover Classes, type of ownership, management agreement, and silvicultural practices) in each stratum was estimated using the ratio of the number of the plots on the stratum. Finally, the estimated land area of each category of land use with in strata was calculated using these proportions and total areas of the strata. Consequently, the mean estimates for domain categories strata were computed using the estimated stratum total and areas. Figure A2.1 shows, as an example, one stratum with a sample of 4 sampling units (SU), which will be used to explain the logic of how to generate national statistics.

Figure A2.1 Map of Sudan showing a sample example of six SU



The total area of the stratum is 4,500.000 hectares. Before NFI data can be analyzed and results can be generated, data in the NFI database must be processed in order to prepare consistent datasets. A dataset should contain the same number of records as the total number of SU in the country, meaning that every SU should generate one record in the dataset.

Employing the example of a NFI sample consisting of 4 SU we will see how data from these 4 SUs are processed to generate a dataset containing 4 records:

In this figure also, are presented the spatial composition of the 4 SUs in our sample. Each SU covers an area of 1 km2 and consists of a cluster of 4 Plots with the size 20m*250m (0,5ha). Within the Plots, Land Use classification and area measurements are carried out together with a variety of measurements and observations, such as tree measurements, fire occurrence, environmental problems, use and users of products and services provided by trees and forests, etc. The Plots are numbered from 1 to 4 clockwise in each SU, starting from the South-Western-most Plot. The inventory records follow the same clockwise direction. In Table A2 all Land Use Sections (LUS) with their corresponding Area value (calculated as [LUS Length] * [LUS Width]) and Land Use Class (global) are presented by SU and Plot number.

Table A2.1 **Primary data on Land Use Sections (LUS) showing the SU, Strata, Plot, LUCs, width, length of the LUS and area**

SU_no	Strata (*)	State name	Plot no	LUCs	LUC (FRA Classes)	Land Use Section's		
						Width (m)	Length (m)	Area (ha)
110	2	Red Sea	1	Wooded grassland	Other wooded land	20	250	0.5
	2	Red Sea	2	Woodland	Other wooded land	20	250	0.5
	2	Red Sea	3	Wooded grassland	Other wooded land	20	250	0.5
	2	Red Sea	4	Wooded grassland	Other wooded land	20	250	0.5
113	2	Red Sea	1	Barren Land	Other land	20	25	0.05
	2	Red Sea	1	Woodland	Other wooded land	20	225	0.45
	2	Red Sea	2	Barren Land	Other land	20	100	0.2
	2	Red Sea	2	Woodland	Other wooded land	20	150	0.3
	2	Red Sea	3	Barren Land	Other land	20	80	0.16
	2	Red Sea	3	Woodland	Other wooded land	20	170	0.34
	2	Red Sea	4	Woodland	Other wooded land	20	250	0.5
114	2	Red Sea	1	Natural Grassland	Other land	20	250	0.5
	2	Red Sea	2	Natural Grassland	Other land	20	250	0.5
	2	Red Sea	3	Natural Grassland	Other land	20	250	0.5
	2	Red Sea	4	Natural Grassland	Other land	20	250	0.5
136	2	Red Sea	1	Natural Grassland	Other land	20	250	0.5
	2	Red Sea	2	Natural Grassland	Other land	20	250	0.5
	2	Red Sea	3	Natural Grassland	Other land	20	250	0.5
		Red Sea	4	Natural Grassland	Other land	20	250	0.5

(*) Description of stratum:

N° Description

2 semi-desert ecosystems

3 Low rainfall woodland Savannah

4 Forest and woodland vegetation

5 Rivers and streams (riverine vegetation)

To prepare a dataset showing the area of each land use, the LUC Areas are summarized by Land Use for each SU and presented as one record per SU as in Table A.2.2.

Table A2.2 **Dataset for Land Use Areas showing the sum of Land Use Areas by SU and by Land Use for the whole sample**

SU	Area (ha)		
	Other land	Other wooded land	Total
110		2	2
113	0.41	1.59	2
114	2		2
136	2		2
Sum	4.41	3.59	8

To estimate the area proportions of the different Land Uses in the total sample of 4 SU (=proportion of the stratum area), ratio estimates (R) are calculated as the sum of the specific Land Use area divided by the sum of all Land Use areas (see Table A2.3s A2.3 and A2.4). For example the proportion of Other Wooded land Area in the sample is calculated as a ratio estimate by dividing the sum of all Other Wooded land Areas in the whole sample (3.59 ha) by the sum of all Land Use Areas in the whole sample (8.00ha), which gives us a ratio estimate of 0,448, meaning that 44.8% of the stratum area is Wooded land Area. In the following table the ratio estimates (R) are calculated for all of the global Land Uses.

Table A2.3 **Dataset for Land Use Areas presenting the ratio estimates for global Land Use Areas in the sample (=in the stratum)**

SU	Area (ha)		
	Other land	Other wooded land	Total
110		2	2
113	0.41	1.59	2
114	2		2
136	2		2
Sum	4.41	3.59	8
Ratio	0.55125	0.44875	

Table A2.4 **Area estimation of the stratum by National LUCC and SU (ha)**

National LUCC	Sampling Unit				Total
	110	113	114	136	
Barren Land		230.625			230.625
Natural Grassland			1,125.000	1,125.000	2,250.000
Wooded grassland	843.750				843.750
Woodland	281.250	894.375			1,175.625
TOTAL	1,125.000	1,125.000	1,125.000	1,125.000	4,500.000

To calculate the precision in the ratio estimates as shown in table 5 the statistical functions for ratio estimates are employed

Table A2.5 Dataset for Land Use Areas presenting the ratio estimates and various examples of statistical expressions for the precision of the estimations of Land Use Areas

SU	Area (ha)		Total
	Other Land	Other Wooded land	
110		2	2
113	0.41	1.59	2
114	2		2
136	2		2
Sum	4.41	3.59	8
Ratio	0.55125	0.44875	
Area= Ratio* Stratum area (ha)	2,480.625	2,019.375	4,500.000
V			
Sd			
V_R			
S_R			
SE_R			
SE_R%			

Table A2.6 Species total number of standing live trees per Stratum and global ecological zones in Sudan listed alphabetically (Number per global ecological ones and by geographical states is also available)

No	Species	Stratum				Total
		Stratum II (semi-desert ecosystems)	Stratum III (Low rainfall woodland Savannah)	Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	Stratum V (rivers and streams)	
1	Acacia drepanolobium	0	0	4,519,297	0	4,519,297
2	Acacia ehrenbergiana	0	0	2,303,953	0	2,303,953
3	Acacia gerrardii	0	0	3,531,883	0	3,531,883
4	Acacia gerrardii var. gerrardii	0	4,460,818	79,676,343	0	84,137,161
5	Acacia laeta	0	800,656	924,113	0	1,724,769
6	Acacia mellifera	1,949,263	60,583,203	78,663,690	0	141,196,156
7	Acacia nilotica	0	0	37,977	0	37,977
8	Acacia nilotica subsp. nilotica	0	1,525,066	12,937,595	2,338,664	16,801,325
9	Acacia nilotica subsp. tomentosa	0	0	455,726	0	455,726
10	Acacia nilotica var. adstringens	0	7,777,820	29,141,240	174,309	37,093,369
11	Acacia polyacantha	0	0	1,316,547	0	1,316,547

No	Species	Stratum				Total
		Stratum II (semi-desert ecosystems)	Stratum III (Low rainfall woodland Savannah)	Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	Stratum V (rivers and streams)	
12	Acacia polyacantha subsp. Campylacantha	0	0	25,140,970	43,577	25,184,547
13	Acacia senegal	0	75,185,628	86,866,748	87,155	162,139,531
14	Acacia seyal	0	0	51,952,927	0	51,952,927
15	Acacia seyal var. seyal	0	1,143,794	675,363,104	784,392	677,291,290
16	Acacia sieberiana	0	0	13,203,443	0	13,203,443
17	Acacia tortilis f. raddiana	59,452,716	71,220,416	13,076,849	1,655,947	145,405,928
18	Acacia tortilis subsp. spirocarpa	3,898,526	457,517	2,797,663	130,732	7,284,439
19	Acacia tortilis subsp. tortilis	9,746,315	343,138	0	0	10,089,453
20	Adansonia digitata	0	457,517	607,635	0	1,065,152
21	Albizia amara	0	6,481,513	220,901,089	0	227,382,602
22	Albizia anthelmintica	0	343,138	7,114,398	0	7,457,536
23	Albizia aylmeri	0	0	151,909	0	151,909
24	Anogeissus leiocarpus	0	1,029,414	157,694,133	363,147	159,086,694
25	Anogeissus sp.	0	0	341,794	0	341,794
26	Azadirachta indica	0	0	37,977	0	37,977
27	Azanza garckeana	0	0	151,909	0	151,909
28	Balanites aegyptiaca	1,949,263	19,444,538	177,480,338	1,365,426	200,239,565
29	Balanites sp.	0	0	37,977	0	37,977
30	Bauhinia rubescens	0	228,759	5,392,779	0	5,621,538
31	Bauhinia tomentosa	0	0	4,886,407	0	4,886,407
32	Borassus aethiopum	0	0	873,475	0	873,475
33	Boscia angustifolia	0	0	392,433	0	392,433
34	Boscia salicifolia	974,632	114,379	0	0	1,089,011
35	Boscia senegalensis	0	2,935,752	0	0	2,935,752
36	Boscia sp.	0	0	37,977	0	37,977
37	Boswellia papyrifera	0	0	44,218,195	0	44,218,195
38	Boswellia sp.	0	0	772,205	0	772,205
39	Butyrospermum paradoxum	0	0	1,278,569	0	1,278,569
40	Cadaba farinosa	974,632	0	0	0	974,632
41	Cadaba glandulosa	0	0	37,977	0	37,977
42	Cadaba rotundifolia	0	0	37,977	0	37,977
43	Calotropis procera	50,031,344	800,656	1,708,980	0	52,540,979
44	Capparis decidua	0	0	37,977	0	37,977

No	Species	Stratum				Total
		Stratum II (semi-desert ecosystems)	Stratum III (Low rainfall woodland Savannah)	Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	Stratum V (rivers and streams)	
45	Capparis sepiaria var. fischeri	974,632	0	37,977	0	1,012,609
46	Capparis spinosa	0	1,410,686	949,429	0	2,360,115
47	Cassia fistula	0	0	227,863	0	227,863
48	Cassia siamea	0	0	37,977	0	37,977
49	Cassia sieberiana	0	0	37,977	0	37,977
50	Cassia sp.	0	0	227,863	0	227,863
51	Celtis integrifolia	0	0	37,977	0	37,977
52	Citrus aurantifolia	0	0	75,954	0	75,954
53	Citrus paradise	0	343,138	0	0	343,138
54	Combretum aculeatum	0	4,422,684	27,179,059	0	31,601,743
55	Combretum adenogonium	0	0	455,726	0	455,726
56	Combretum capituliflorum	0	0	1,038,045	0	1,038,045
57	Combretum gallabatense	0	1,906,338	1,126,661	0	3,032,999
58	Combretum ghasalense	0	25,735,448	187,114,141	0	212,849,589
59	Combretum glutinosum	0	0	8,127,142	0	8,127,142
60	Combretum hartmannianum	0	114,379	21,558,448	0	21,672,827
61	Combretum lamprocarpum	0	0	5,177,570	0	5,177,570
62	Combretum molle	0	0	316,479	0	316,479
63	Combretum paniculatum	0	114,379	19,001,301	0	19,115,681
64	Combretum sp.	0	0	506,365	0	506,365
65	Commiphora abyssinica	0	0	113,931	0	113,931
66	Commiphora africana	0	2,287,587	1,025,391	0	3,312,978
67	Commiphora erythraea	0	0	37,977	0	37,977
68	Commiphora gileadensis	0	0	37,977	0	37,977
69	Commiphora pedunculata	0	0	1,670,995	0	1,670,995
70	Commiphora quadricincta	0	17,728,893	4,481,320	0	22,210,213
71	Cordia abyssinica	0	1,143,794	2,506,500	0	3,650,294
72	Cordia crenata	0	0	75,954	0	75,954

No	Species	Stratum				Total
		Stratum II (semi-desert ecosystems)	Stratum III (Low rainfall woodland Savannah)	Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	Stratum V (rivers and streams)	
73	Cordia ovalis	0	0	37,977	0	37,977
74	Cordia sinensis	0	0	544,342	0	544,342
75	Crateva adansonii	0	0	468,387	0	468,387
76	Dalbergia boehmii	0	571,897	5,962,421	0	6,534,318
77	Dalbergia melanoxylon	0	114,379	67,308,398	0	67,422,777
78	Dalbergia sissoo	0	0	113,931	0	113,931
79	Delonix regia	0	0	37,977	0	37,977
80	Detarium macrocarpum	0	0	11,215,961	0	11,215,961
81	Dichrostachys cinerea	0	0	3,873,685	0	3,873,685
82	Diospyros abyssinica	0	0	949,429	0	949,429
83	Diospyros mespiliformis	0	0	2,822,971	0	2,822,971
84	Dobera glabra	0	457,517	341,794	0	799,312
85	Erythrina abyssinica	0	0	37,977	0	37,977
86	Ficus sycomorus	0	0	4,050,902	0	4,050,902
87	Gardenia aqualla	0	0	75,954	0	75,954
88	Gardenia erubescens	0	0	430,410	0	430,410
89	Gardenia lutea	0	0	1,873,550	0	1,873,550
90	Gardenia sp.	0	0	37,977	0	37,977
91	Grewia villosa	0	0	37,977	0	37,977
92	Guiera senegalensis	0	6,100,263	1,734,295	0	7,834,559
93	Hyphaene thebaica	0	0	3,304,020	43,577	3,347,598
94	Khaya senegalensis	0	0	886,136	0	886,136
95	Kigelia Africana	0	0	37,977	0	37,977
96	Lannea barteri	0	0	6,873,896	0	6,873,896
97	Lannea fruticosa	0	4,842,067	11,646,379	0	16,488,446
98	Lannea humilis	0	0	4,544,620	0	4,544,620
99	Lannea schimperi	0	0	10,671,604	0	10,671,604
100	Lannea schweinfurthii	0	2,630,725	24,824,506	0	27,455,231
101	Leptadenia arborea	0	114,379	0	0	114,379
102	Leptadenia pyrotechnica	0	686,276	0	0	686,276
103	Lonchocarpus laxiflorus	0	0	303,817	0	303,817
104	Maerua aethiopica	0	953,169	645,612	0	1,598,781
105	Maerua angolensis	0	0	227,863	0	227,863

No	Species	Stratum				Total
		Stratum II (semi-desert ecosystems)	Stratum III (Low rainfall woodland Savannah)	Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	Stratum V (rivers and streams)	
106	Maerua crassifolia	0	228,759	3,709,115	0	3,937,874
107	Maerua oblongifolia	0	0	189,886	0	189,886
108	Maerua pseudopetalosa	15,919,046	7,854,065	2,354,591	0	26,127,702
109	Mangifera indica	0	1,372,552	113,931	0	1,486,484
110	Mitragyna inermis	0	0	6,620,687	0	6,620,687
111	Moringa oleifera	0	0	113,931	0	113,931
112	NOT IN LIST	2,923,895	2,859,484	43,635,906	87,155	49,506,440
113	Parkinsonia aculeata	0	0	75,954	0	75,954
114	Phoenix reclinata	0	114,379	0	3,704,081	3,818,460
115	Piliostigma reticulatum	0	0	582,319	0	582,319
116	Piliostigma sp.	0	0	75,954	0	75,954
117	Piliostigma thonningii	0	114,379	18,229,104	0	18,343,484
118	Pithecellobium dulce	0	0	37,977	0	37,977
119	Polycarpaea corymbosa	0	0	113,931	0	113,931
120	Prosopis africana	0	0	27,862,694	0	27,862,694
121	Prosopis chilensis	974,632	0	0	0	974,632
122	Pseudocedrela kotschyi	0	0	13,887,039	0	13,887,039
123	Psidium guajava	0	457,517	0	0	457,517
124	Pterocarpus lucens	0	0	2,557,131	0	2,557,131
125	Ricinus communis	0	0	582,319	0	582,319
126	Salix subserrata	0	0	189,886	0	189,886
127	Sclerocarya birrea	0	1,601,311	34,166,872	0	35,768,183
128	Sesbania sesban	0	0	189,886	0	189,886
129	Sesbania tetraptera	0	0	113,931	0	113,931
130	Sterculia africana	0	0	1,911,519	0	1,911,519
131	Sterculia setigera	0	0	6,506,756	0	6,506,756
132	Stereospermum kunthianum	0	228,759	2,949,564	130,732	3,309,055
133	Strychnos spinosa	0	0	10,899,475	0	10,899,475
134	Suaeda monoica	0	0	379,772	0	379,772
135	Tamarindus indica	0	228,759	16,140,323	0	16,369,081
136	Tectona grandis	0	0	37,977	0	37,977
137	Terminalia arjuna	0	0	2,747,017	0	2,747,017
138	Terminalia brownii	0	0	39,395,103	0	39,395,103

No	Species	Stratum				Total
		Stratum II (semi-desert ecosystems)	Stratum III (Low rainfall woodland Savannah)	Stratum IV (semi-arid, dry sub-humid and humid aridity zones)	Stratum V (rivers and streams)	
139	Terminalia catappa	0	0	987,406	0	987,406
140	Terminalia glaucescens	0	0	3,202,750	0	3,202,750
141	Terminalia laxiflora	0	0	3,367,313	0	3,367,313
142	Terminalia macroptera	0	343,138	31,635,056	0	31,978,194
143	Vitex simplicifolia	0	0	151,909	0	151,909
144	Xeromphis nilotica	0	0	2,114,074	0	2,114,074
145	Ximenia americana	0	0	303,817	0	303,817
146	Ziziphus abyssinica	0	0	620,296	0	620,296
147	Ziziphus mauritiana	0	1,143,794	28,141,180	0	29,284,974
148	Ziziphus sp.	0	0	506,365	0	506,365
149	Ziziphus spina-christi	0	114,379	658,273	0	772,653
150	Ziziphus spina-christi var. microphylla	0	571,897	6,000,414	755,343	7,327,654
151	Ziziphus spina-christi var. spina-christi	0	3,431,381	19,343,111	130,732	22,905,224

ANNEX 4
THE NFI CREWS

FNC recognizes the efforts, commitment and dedication of the following forestry technical and supporting staff, and national and international experts in the field activities, data management, data analysis and report writing and review:

Training leaders:

1. Samia Bakheit-FNC-RS and Data Management
2. Salah El Mahi- FNC-RS and Data Management

Teams Supervision:

1. Hassan El Amin Hassan (Central Sector)
2. Mustafa Yousif Medawi (Kordofan Sector)
3. Balla Musa Yassin (eastern Sector)
4. Amna Ahmed Osman (Darfur Sector)
5. Hafiz Mohamed Al Habib(Northern Sector)

Crew leaders:

1. Hafiz Mohamed al Habib
2. Abu Bakr Mohamed Al Jedai
3. Mohamed Osman Abbakar
4. Noh Mohamed Abdel Gadir
5. Gamal Al Tayeb Ahmed Adam
6. Fatah Al Rahman Ahmed Mohamed
7. Abdel Ghani Ibrahim Mohamed
8. Yassir Yassin Seif eldeen
9. Yahia Mahmoud Issa
10. Adam Mohamed Adam
11. Mutasim Babiker Fadl Aseed

Data collection Crew members

1. Hafiz Mohamed Al Habib
2. Amir Mohamed Ahmed
3. Mutasim Fadl Aseed Babiker
4. Mutasim Mohamed Saeed
5. Abdel Ghani Mohamed Ibrahim
6. Al Bushra Al Imam Abbashar
7. Abdel Malek Mohamed Al Hassan
8. Gasim Abdel Wadoud Mahmoud
9. Hassan Issa Babiker-Range and Pasture
10. Fatah Al Rahman Ahmed Mohamed Al Bashir
11. Imad Ed Din Mohamed Daoud
12. Abdel Rahman Bakora Bakkar
13. Abdalla Dawel Beit Ismail
14. Ahmed Mohamed Tom-Range and Pasture
15. Noh Mohamed Abdel Gadir Haj
16. Mohamed Awad Mohamed Salih
17. Zahir Dafa Alla Abu Agla
18. Abdel Baggi Al Siddig Yousif
19. Ahmed Yousif Zakariya-Range and Pasture
20. Gamal El Tayeb Ahmed Adam
21. Mohamed Ahmed Mahgoub
22. Balla El Fadil Mohamed Abdel Halim
23. Hawa Jadain Gaffar
24. Mohamed Osman Abbakur
25. Osama Kamal Hassan Abdel Karim Shashog
26. Asmaa Al Amin Ali
27. Fatah Al Rahman Al Halawi
28. Abu Bakr Mohamed Aljidai
29. Mutasim Fadl Asseed Babiker
30. Bahaa Eddin Issa
31. Nazar Ahmed Omer
32. Yahia Mahmoud Issa
33. Anwar Haroun Turbo
34. Ali Abbakar Ali
35. Yasir Mohamed Al Dooma
36. Adam Mohamed Adam
37. Ameer Mohamed Ahmed
38. Muzamil Musa
39. Hashim Abdalla Abdel Rahman
40. Yasir Yassin Seif Aldeen
41. Khalid Ahmed
42. El Sadig Al Amin Ahmed Adam
43. El Sadig Suleiman Haroun

Drivers

1. Mohamed Saeed Taialla
2. Abdel Gadir Ahmed Hassan
3. Balla Mohamed al Hassan
4. Moneer Ahmed Adam
5. Isam Mohamed Ahmed
6. Abdalla Yaqoub
7. Ameer Abdalla Mohamed Khatir
8. Al Gali Gibreel Al Gali
9. Adam Issa Hussein
10. Azhari Mohamed

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2. Selmi Khemaies (International consultant)
3. Marco Piazza (FAO HQ)
4. Asdrúbal Calderon (International consultant)

National experts

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2. Elyass Daak (National Consultant)

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SUDAN NATIONAL FOREST INVENTORY

FINAL REPORT

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With financial support of:

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WORLD BANK GROUP