REPUBLIC OF SUDAN

FOREST REFERENCE LEVEL (FRL)

SUBMISSION TO UNFCCC

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Sudan's Forests National Corporation (FNC)
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Acknowledgements

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Acronyms

AD	Activity Data
A/R	Afforestation and reforestation
AGB	Above-ground biomass
BGB	Below-ground biomass
BUR	Biennial Update Report
CEO	Collect Earth Online
CO2e	Carbon Dioxide equivalent
FAO	Food and Agriculture Organization of United Nation
FNC	Forests National Corporation
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
GDP	Gross domestic product
GHG	Greenhouse Gas
GLCN	Global land cover network
ha	Hectare
HCENR	Higher Council for Environment and Natural Resources
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
LUCF	Land use change and forestry
LULUCF	Land use land use change and forestry
NDCs	National determined contribution
NFI	National Forest Inventory
NFMA	National Monitoring and Assessment
NWFP	Non woody forest products
OBIA	Object base image analysis
QGIS	Quantum GIS
REDD+	Reducing Emissions from Deforestation and forest Degradation; and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks
RSSA	Remote Sensing and Seismology Authority
SLC	Scan Lune Corrector
SNC	Second National Communication
SU	Sampling Unit
t.C	Tonnes of Carbon
TNC	Third National Communication
UNFCCC	United Nations Framework Convention on Climate Change

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Summary

This document presents the modified version of the Sudan's first sub-national Forest Reference Level (FRL) that addresses the findings and observations made during the UNFCCC technical assessment. The proposed FRL includes the values of the average annual change in carbon stock due to deforestation (**1,223,286** t. CO2 /y) and the average annual accumulated CO_2 removals (-**288,229** t. CO2 /y) due to afforestation and reforestation (A/R) activities implemented in the FRL region (Sennar, El Gadarif and Blue Nile States), over the reference period (2006-2018). Table 1, below provides summary description of this FRL submission and its consistency with the UNFCCC guidance and summarizes the decisions made by the government of Sudan on the scale and the scope of this FRL. This FRL represents forest conditions in the dry lands of Sub Sahara Africa.

Table 1: Sudan's FREL/FRL compliance with the relevant UNFCCC decisions

UNFCCC reference	Description	Sudan's FREL/FRL
Decision 12/CP.17 Paragraph 1	Stepwise approach	- Sudan follows stepwise approach through sub mission of its first sub-national FRL covering an area of about 11% of total forest and about 7.2% of the area of Sudan. The main objective is to develop knowledge, resources and expertise within the related national institutions. Sudan intends to submit a national FREL/ FRL building on lessons learnt and institutional capacity built through this submission
Decision 12/CP.17 Annex, paragraph (c)	Pools and gases	- Aboveground and below ground biomass - CO_2
Decision 12/CP.17 Annex, paragraph (c)	Activities	- Deforestation - Enhancement of forest carbon stocks - Forest degradation is also a significant REDD activity in Sudan, however, currently there is no reliable data available to assess forest degradation
Decision 12/CP.17 Annex, paragraph (d)	Forest definition applied in the GHG inventories	- 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.

Decision 12/CP.17 Annex	The information contents are guided by the most recent IPCC guidance and guidelines)	- IPCC 2006 Guidelines for national GHGs inventories
Decision 12/CP. 17 II. Paragraph 9	Submission of information and rationale on the development of FRLs, about the details of national circumstances and their consideration	- Description of national circumstances provided - No adjustment has been done, - It assumed that the reference period is representative in terms of capturing the effects of the development in national circumstances on forest land

1. Introduction

Sudan is submitting its Forest Reference Level (FRL) in response to the invitation of the Conference of Parties to the UNFCCC, issued in paragraph 13 of decision 12.CP/16 and the request in paragraph 71(b) of decision 1.CP/16, for developing countries to develop and submit, on a voluntary basis, FREL/FRL, for consideration by the UNFCCC. This submission is intended for technical assessment in the context of results-based payments for reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+) under the UNFCCC. Sudan also considers the development of the FRL as very important for enhancing implementation of national forest programmes including REDD+ strategy and for contributing to the global climate change mitigation and adaptation objectives through preparation and implementation of NDCs.

Sudan is a country with a highly diverse vegetation cover and ecological zones where, the rainfall varies from zero in the northern desert to more than 1,200 mm in the High Rainfall Woodland Savannah in the far south-western part of the country. Five distinct ecological zones representing biomes with different ecological conditions and different vegetation cover, desert, semi-desert, woodland Savanah, flood region and montane vegetation.

Located in North Eastern Africa, the Republic of Sudan is bound by Egypt, The Red Sea, Eretria, Ethiopia, Republic of South Sudan (RSS), Central African Republic, Chad and Libya. The total area[1]* is 1,886,068 km^2, administratively the country is divided into 18 States (see Figure 1). The highest point in the country is Jebel Marra; 3,024 meters above sea level (m a.s.l.). The lowest is the Red Sea; 0.0 m a.s.l. The most salient geographical features are the Nubian and Bayuda Deserts in the north, the Nile Valley, Jebel Marra, Nuba, Ingessena & Red Sea Hills. The Blue Nile originates in the Ethiopian Highlands. The White Nile runs from the Equatorial Lakes. The two rivers unite at Khartoum and with their tributaries form the River Nile which runs north to the Mediterranean Sea. The vegetation can be divided into seven principal types which in general follow the isohyets and form consecutive series from north to south: 1. Desert; 2. Semi-Desert; 3. Acacia Short Grass Scrub; 4. Acacia Tall Grass Scrub; 5. Broad-leaved Woodlands & Forests; 6. Swamps (permanent swamps, seasonally inundated land), 7. Grassland and Mountain Meadow.

[1] *en.wikipedia-org/wiki/Sudan#Government_and_politics*

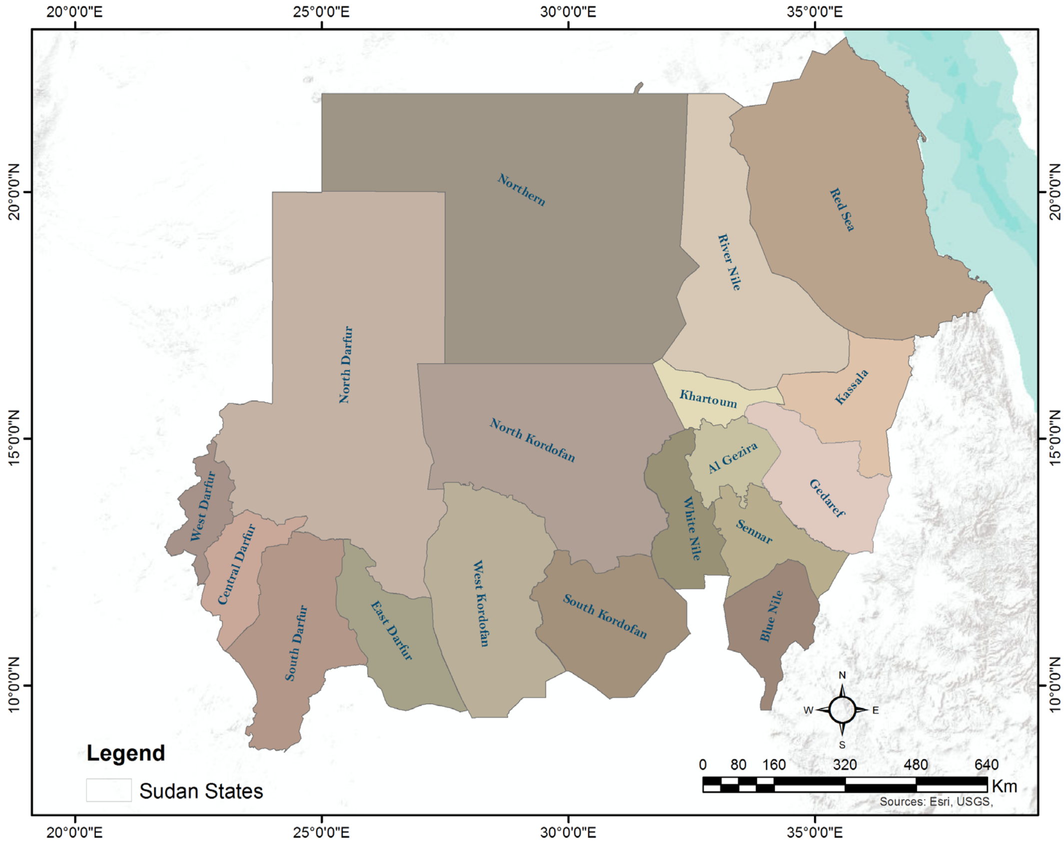

Figure 1: Sudan States

Sudan's forests cover is about 10.3 percent of its total land surface, with an estimated annual rate of net forest area loss of about 174,400 ha, or about 0.8 percent (FAO 2015). This deforestation rate is not comparable to the rate of 0.4 -0.7 million hectares reported in Sudan's SNC 2013. The deforestation rate in the Sudan's SNC is estimated based on FRA 2005, which was based on the forest statistics before the cessation of Sudan in year 2011, into two states Sudan and South Sudan. Forests have been facing encroachment by agriculture, urbanization, and have been subjected to unsustainable wood fuel extraction for several decades, since the late 1970s after the introduction of mechanized rainfed agriculture in east and central Sudan. The lack of integrated land use planning and coordination across institutions has resulted in uncontrolled land use changes and conversion of vast forest tracts into agricultural areas over the past 40 years.

Forests play a significant role in the current land use systems in Sudan in terms of their socio-economic, development and environmental protection functions. In addition, forests meet the needs of the various dependent stakeholder groups and supporting their livelihoods. About 70 percent of Sudan's total population (33.4 million) is rural & nomadic and considered as forest-dependent for livelihood, wood energy and on round timber for buildings. Contribution of forests sector to the national economy is under-estimated, the formal national accounts estimation of the forest sector contribution to the GDP is about 3 percent. The 1994 energy consumption study confirmed that the per capita consumption of fuel wood is 0.73 m^3/annum which, when converted into Ton/Oil Equivalent (TOE), could be valued at nearly 2.0 Billion US dollars. Moreover, Non-Woody Forest Products (NWFPs) are rich and diverse and have substantial direct contribution to the livelihood of rural people at the local (household) level as well as to the national economy in terms of exports.

Therefore, the contribution of forests to the national economy is grossly under estimated. The Bank of Sudan and Ministry of Finance tend to consider only the direct revenue realized by FNC and export proceeds from some forest products and estimate that to contribute 3.0 percent of GDP. This does not take into account:

- The value of total consumption of the country of wood at 0.73 m^2 per capita per annum (FAO 1995) derived from the country's forests, directly collected by people for their own consumption or addition income earning (selling in local markets),
- The contribution of forest to the fodder & animal feed of the national herd of 130 million heads derived from natural pastures, woodlands and forests, some sources estimate forest contribution at 30 percent of the animal feed.
- The monetary value of the environmental services, particularly the protection of watersheds & courses, wildlife, biodiversity, agricultural land and human habitats.
- The direct revenue from institutional, community or private forests which accrues to the owners of these forests.

2. Scale

To define the scale and the boundaries of the proposed Forest Reference Level, Sudan recalls paragraph 71(b) of Decision 1/CP.16 and paragraph 11 of Decision 12/CP.17. It states that Parties may elaborate a subnational Forest Reference Emission Level and/or Forest Reference Level (FREL/FREL), as an interim measure, while transitioning to a national FREL/FRL. Also recalling paragraph 10 of Decision 12/CP.17 in which the Conference of the Parties (CP) agreed that a stepwise approach to national FREL/FRL development may be useful, enabling Parties to improve their FREL/FRL by incorporating better data, improved methodologies and, where appropriate, additional pools, noting the importance of adequate and predictable support as referenced to by Decision 1/CP.16, paragraph 71.

Therefore, Sudan decided to follow a stepwise approach in the construction of its first national FRL, with the main objective of developing knowledge, resources and expertise within the related national institutions for developing the national FREL/FRL in the next step. Accordingly, the areas encompassing the forest lands of Sudan have been defined for potential two subnational FRELs/FRLs to be constructed in sequential manner, building on experiences, capacities, resources and lesson learned, see Figure 2. These two FREL/FRLs would cover all forest lands in Sudan.

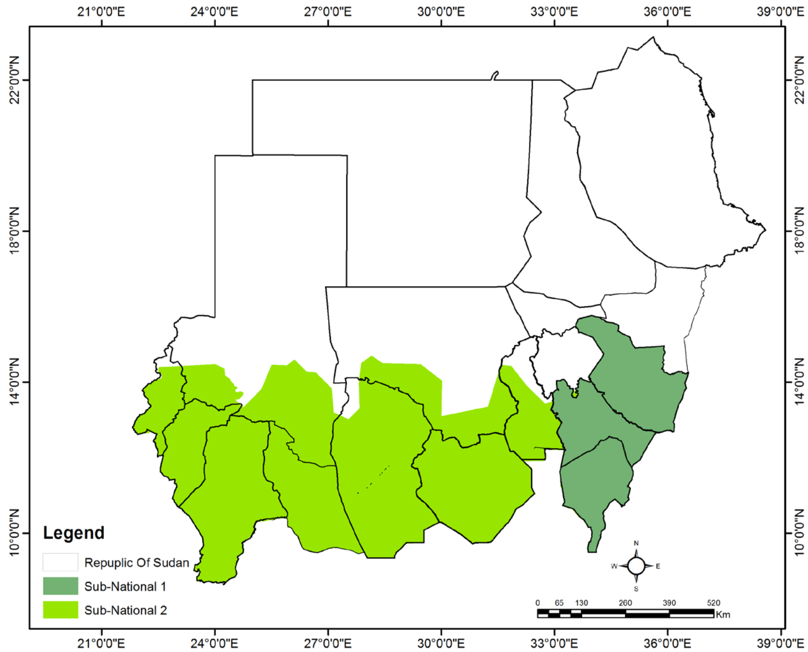

Figure 2: Sites of the two suggested FRELs/FRLs of Sudan

Sudan chose to construct its first subnational FRL in a region consisting of three States (subnational administrative units) namely, Blue Nile, Sinnar and El Gadarif States which covers an area of 134,918 km², (Blue Nile: 38,149 km², Sennar: 39, 241 km², El Gadarif: 57, 527 km²), about 7.2 percent of the country's total area, see Figure 3. As estimated by Africover (2012), forest area in this region represents 11 percent of the total forest land in Sudan. Most of the forests in the three states fall into one main stratum (# 4 in the recent in the NFI), which includes semi-arid, dry sub-humid, humid aridity zones. Forest and Woodland vegetation found in this strata, include mixed Acacia spp in most parts of the region, evergreen forest in southern parts and riverain forest ecosystem (*Acacia nilotica*) found along the banks on the rivers (Blue Nile, Dinder and Rahad Rivers).

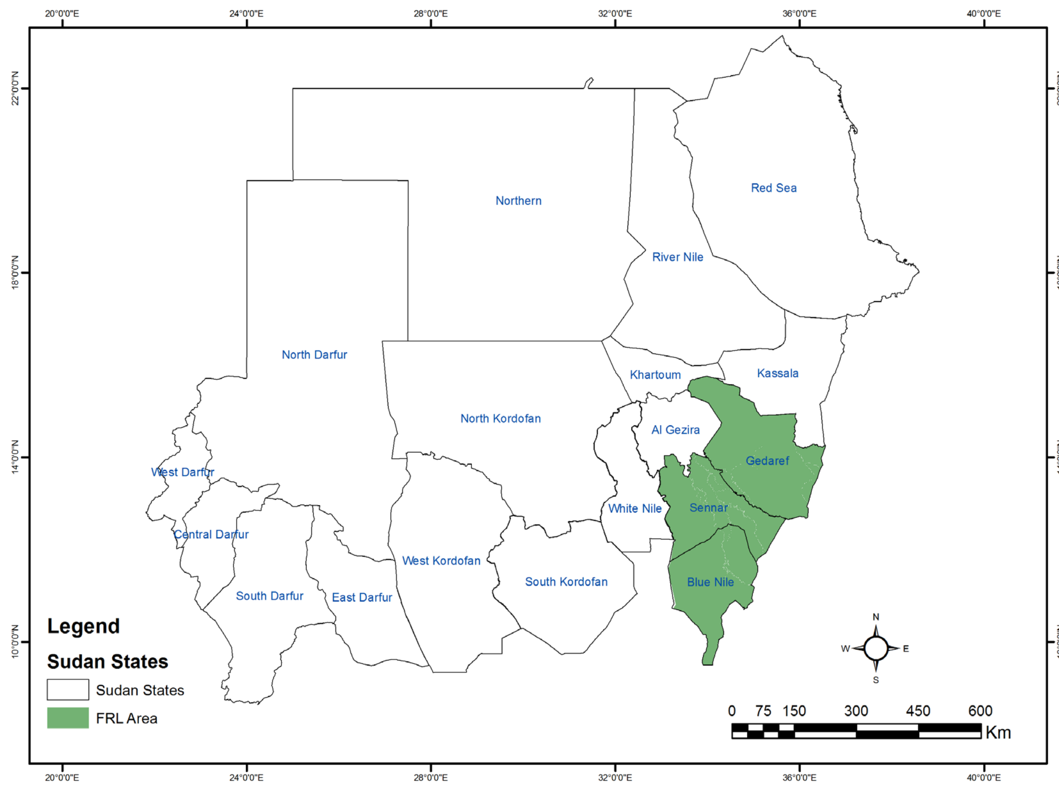

Figure 3: Area of the subnational FRL

3. Scope: Activities, Pools And Gases

In line with the stepwise approach, Sudan decided to define a limited scope, however, in line with the UNFCCC requirements. The aim is to test application of methods and tools, improve data, then to scale up by adding activities, pools and gases over time. The UNFCCC have not defined specific activities, pools or gases that are mandatory to be included in the FREL/FRL, however, decision 12CP.17 requires parties to include in their FREL/FRL significant activities (from the activities listed in decision 1/CP.16, paragraph 70), pools and gases and to justify omission of any significant activity, pool.

3.1. REDD+ activities in the FREL/FRL

In 2000 the Land use Change and Forestry sector (LUCF) accounted for about 12 percent of all GHG emissions in Sudan, mostly from forest and grassland conversion (SNC 2013). The data from the two national Greenhouse Gases inventories of the LUCF completed so far in Sudan confirms the LUCF sector as a net source of emissions, with 15,577 Gg CO_2 emissions in 1995 and 9,392 Gg CO_2 emissions in 2000 (INC 2003, SNC 2013). The forest and grassland conversions are the main source category in both inventory years, with a total 28,714 Gg CO_2 emissions in 1995 and 23,924 Gg CO_2 emissions in 2000, (see Table 2) below. The results of the recently conducted GHG inventory by the third national communication project showed similar trends in the GHG emissions from the land use and forestry sector (LULUCF).

Table 2: GHGs emissions/removal estimates of the LUCF in Sudan (1995 and 2000) in Gg

Sources sink category	Emissions CO_2		Removals CO_2		CH_4		N_2O	
	1995	2000	1995	2000	1995	2000	1995	2000
Total	28,714	23,924	-13,138	-15,906	90	59	1	0.4
Change in Forest and Other Woody Biomass Stocks	0	0	-9,700	-12,125	0	0	0	0
Forests and Grassland Conversions	28,714	23,924		0	90	59	1	0.4
Abandonment of Managed Lands	0	0	-3,438	-3,781	0	0	0	0

The SNC 2013 further indicated that the category conversion of forests and grasslands accounts for all CO_2e emissions from the LUCF sector. This is mostly due to the deforestation and degradation of forests associated with unsustainable biomass extraction in rural areas. In Sudan mechanized farming is also known as a main driver of forest and grass lands conversion. Energy consumption ranks second in the causes of deforestation and forest degradation as biomass energy represents a main source of energy especially in rural Sudan, contributing about 60 percent of the national energy demand. In addition, there are other factors contributing to deforestation and forest degradation such as over grazing, needs for construction materials, forest fires etc. (DoDD, 2018). The selected sub-national FRL states (Blue Nile, Sennar, El Gadarif) are also indicated as a hotspot area for deforestation, in which about 50 percent of all mechanized framing area is located and has been the main source of biomass energy supply for several decades to the major urban areas in central Sudan including the capital city i.e., Khartoum State (DoDD, 2018). The region also hosts a large portion of Sudan's animal resources and suffers from overgrazing (DoDD, 2018). Therefore, the vast areas of the mechanized framing are degraded or being degraded as a result of mal-cultivation practices, and large areas of which was left abandoned. These degraded farm lands represent a large potential for afforestation and reforestation programme and the government has a policy in place to convert 10 percent of mechanized farming lands into forests. In terms of data availability to support the preparation of first subnational FREL and the inclusion of these two REDD+ activities (deforestation and enhancement of forest carbon stocks), this region has better data sources on deforestation, A/R areas, mechanized farming and other forest management related data compared to the other regions delineated for preparation of the other subnational FREL(s) in Sudan. Although forest degradation is a significant REDD+ activity in Sudan, however, currently there is no data suitable for assessing and estimating the effect of forest degradation on the carbon stock, as this requires well established and repeated NFI data.

Based on the above assessment, Sudan decided that the most appropriate two[2] REDD+ activities to be included in the first subnational FREL in the region encompassing the three state of El Gadarif, Sinnar and Blue Nile are:

- Reducing emission from deforestation
- Enhancement of forest carbon stocks

The inclusion of these two activities is also consistent with the national REDD+ strategy, as they support the achievement of a number of REDD+ objectives and activities indicated in the national REDD+ strategy (see table 3 below). The REDD+ programme is currently working on developing emission reduction programmes in the same region to initiate the implementation phase of REDD+ in Sudan.

Table 3: Relevance of the proposed FREL/FRL with the National REDD+ Strategy

Objectives in the national REDD+ strategy	REDD+ activities included in the FREL/FRL
• **Enhance agricultural productivity and avail alternative income generating sources for rural communities and promotion of application of research, technologies, targeted financing and institutional reforms.** • **Adopt environmentally-friendly energy policies that promote renewable energy and energy efficiency in production and use including improved firewood & charcoal stoves and conversion of wood into charcoal.** • **Support of private sector investment in production and dissemination of solar cook stoves, investment in ethanol, biogas digesters and biogas cookers.** • **Increase production of firewood and charcoal from sustainably managed forest plantations** • **Promote sustainable fuelwood (Firewood & Charcoal) production, consumption and usage** • **Improve Policy towards refugees to address their humanitarian needs and guard against deforestation and land degradation**	Reducing emission from deforestation
• **Restoration of degraded (forest, grazing and farming) landscapes.** • **Carbon sequestration through restoration, avoided deforestation and conservation of biodiversity** • **Gum Arabic restocking and rehabilitation of the gum belt for carbon sequestration, climate resilience** • **Gums other than gum Arabic– resins production and commercialization**	Enhancement of forest

[2] *Reducing emissions from forest degradation in case there possible to conduct assessment of the change in forest carbon stock over the selected reference period for deforestation.*

• **Develop and implement master plan for tree-planting in major human settlements, agricultural holdings, highways and railroads** • **Establishment of shelterbelts, wind-breaks and woodlots in mechanized rainfed schemes**	carbon stocks

3.2. Carbon pools in the FRL

The UNFCCC has defined five pools to be considered in the estimation of carbon stock change and GHGs emissions in the LULUCF. The largest pools in terms of emissions/removal contribution are living biomass, divided into two pools aboveground biomass (AGB) and belowground biomass (BGB). Other pools are dead organic matter (DOM), which includes two pools, deadwood, litter and soil carbon stock (SOC). Estimating emissions and removal associated with carbon fluxes in these other pools requires good quality data and parameters that are not available, particularly for dead organic matter and SOC pools. The recent National Forest Inventory (NFI 2017) of Sudan developed good quality data on aboveground biomass, disaggregated by land use and states (administrative units), it also includes measurements of parameters required for estimation of deadwood and litter, and however, this is considered of less quality. Currently dead wood in Sudan and the FRL region is difficult to estimate with reasonable accuracy, because in all rural areas of Sudan, the significant amount of deadwood is collected directly by local communities living in proximity to the forests to meet their energy demands and this is not captured in available records. In Sudan, biomass energy represents more than 60 percent of the energy used balance. There is data available, in the Forest National Corporation (FNC), on wood removals, official harvest, however, these data records are not complete, since a significant amount of wood removal is happening through direct collection by local people for energy and other domestic uses, and these are not recorded by FNC. The NFI 2017 is expected to give Sudan the first indication on the amount of dead wood remaining in the forests. However, this is yet to be evaluated and there is need to complement it through household surveys in order to estimate the amount of dead wood directly collected by people from the forests.

The LULUCF GHG inventory in Sudan provides emissions/removals estimates mainly based on above and below ground carbon pools. Data is not available for estimating belowground biomass, however, root-shoot ratios from IPCC 2006 Guidelines can be used. Based on these circumstances, Sudan decided to include only above and below ground biomass pools in this first subnational FREL submission (see table 4) for future justifications.

Table 4: Pools included in the FRL submission

Pools	Inclusion in FRL	Justification
Aboveground biomass	Included	significant
Belowground biomass	Included	significant
Litter	Not included	Not significant in drylands, Lack of data
Deadwood	Not included	Not significant in case of the selected REDD+ activities, Lack of data

Soil organic carbon	Not included	Lack of data

3.3. Gases in the FRL

CO_2 is the only gas included in this first sub-national FREL estimation by Sudan. This is because currently there is no reliable data to include other activities, pools and to estimate other gases. CO_2 is also the main gas estimated in SNC and the GHGs inventory of the forthcoming Third National Communication (TNC) of Sudan. Following a stepwise approach provides a good opportunity to develop capacities, data collection and resources necessary for improving the FREL/FRL submission overtime.

4. Forest Definition / Definitions Used

Sudan's national forest definition defines forest as 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 percent. It includes wind-breaks and/or shelter-belts with a minimum of 20 m in width."

The forest definition has been developed recently to take into consideration the new situation in the forest resources after the separation of South Sudan (2011) with one third of the country's total area and about 60 percent of the forest resources. This situation raised the need for a definition that enhances and maximizes the protection and production functions of the remaining forest resources. The new definition also responds to climate change challenges and the role the forest resources in Sudan are envisioned to play in meeting Sudan's obligations under the UNFCCC and Paris Agreement.

The new forest definition is different from the one used in GHGs inventory published in the Sudan Second National Communication (SNC 2013). However, the new forest definition was used in the recent national forest inventory (NFI 2017), in the GHG inventory to be reported in the TNC and it will be used with NFI 2017 data in the update of the GHGs inventory to be reported in the first Biennial Update Report (BUR), to be submitted in 2020.

5. Consistency With GHG Inventory Reporting

Sudan submitted its Second National Communication (SNC) in 2013 and currently is embarking on the preparation of the third national communication (TNC) and the first biennial update report (BUR) both submitted to the UNFCCC secretariat in 2020. This FRL submission is not consistent with the GHGs inventory reported in the SNC, for number of reasons, these include:

- The methods used in the SNC is the IPCC 1996 and the FRL uses the IPCC 2006 guidelines, different methods
- The data sources are different, in the SNC (base year was 2000 data was mainly from secondary sources of the Forest National Corporation, Ministry of Agriculture and others. While in the FRL

submission updated data has been derived through mapping using remote sensing, spatial sample data collection and from the recent NFI 2017.

- Forest definition has changed, and as a result more areas have been included in the forest land category
- Sudan in the year 2011 was been divided into two countries, Sudan and South Sudan, therefore resulting in the new need to establish national decisions, like the forest definition, and posing challenges in disaggregating historical data

However, the FRL submission is consistent with the recently completed GHGs inventory (base year 2013) prepared under the current project of the TNC, in which the 2006 IPCC Guidelines were applied for the first time in Sudan. The updating of the GHG inventory of TNC for the purpose of preparing Sudan's forest BUR is also expected to be based on the NFI data 2017, which also consistent with the same emission factors data used in the construction of this submission. The recent GHG inventory and its update will be published in the TNC and first BUR in late 2020 or beginning of 2021, delays are also because of the COVID-19 Pandemic.

6. Information Used For FREL Construction

6.1. Activity Data for Deforestation:

Historically, the targeted region of the three states was subjected to large scale mechanised agriculture since early 1980s, where forest areas have been cleared of tree cover at a rapid pace and the land was subject to cultivation for a number of years after which they lost productivity and are now degraded and often times abandoned (DoD, 2018). Commercial mechanized agricultural activities are concentrated in the dry savannah in this region, where the mechanization of rain-fed agriculture was initiated by the British in the region (El Gadarif) in 1944 and continues up to now on clay soil by the government and private sector. In the late 1970s, about 2.2 million hectares of land had been allocated for mechanized farming, and about 420,000 hectares more had been occupied without official demarcation. However, today, mechanized agriculture occupies a large area of the clay plains in the high rainfall savannah belt estimated to be 6.5 million hectares, extending from the Butana plains in the east to Southern Kordofan in central Sudan (DoD 2018). The largest portion (48 percent) of mechanized farming in Sudan is in this region of the sub-national FREL/FRL, which also represents a high potential for implementation of the REDD+ activities of Enhancement of carbon stock through afforestation and reforestation, by the communities, private sector and the government.

6.1.1. Methodology and data used

Land cover maps of EL Gadarif, Sinnar and Blue Nile states were developed for the years of 2006, 2010, 2014 and 2018 to estimate forest area based on the national forest definition (as described above). Also, they cover the areas of forest remaining as forest, other land converted to forest and forest converted to other land for three time periods (i.e., 2006 to 2010, 2010 to 2014 and 2014 to 2018). The maps were developed using the same methods and same classification system. Based on the availability, there were some differences in the selection of satellite imagery used to develop the maps. In the following sections, land cover mapping development process is described and the description of steps followed to generate the activity data.

6.1.2. Development of land cover maps of 2006, 2010, 2014 and 2018

For the creation of individual land cover maps, the Global Land Cover Network (FAO/GLCN) approach was followed (GLCN/FAO) (http://www.fao.org/geospatial/projects/detail/en/c/1035672). Each single image (e.g. 2006, 2010, 2014 and 2018) was processed, interpreted, validated using available very high resolution images from Bing map in QGIS and Google earth. The reason of using GLCN approach is because country team was familiar with using this methodology since the development of national land cover map 2011 (Africover, 2012).

6.1.2.1. Image acquisition

For land cover mapping of 2010, 2014 and 2018 Landsat images of 30-meter spatial resolution were used. Due to data gaps caused by the Scan Line Corrector (SLC) failure, Landsat 7 images could not be used for 2006 land cover mapping, instead Aster 15-meter spatial resolution images were used. The images were downloaded from United State Geological Survey (USGS) www.usgs.gov/landsat, in the dry and wet seasons, with maximum cloud cover of 30 percent. Aster images were already combined on the website, the bands used for Landsat 7 were 4, 3, 2, and for Landsat 8 the bands were 5, 4, 3. The list of satellite imagery used for land cover mapping of different years are provided in annex 1.

6.1.2.2. Image segmentation and land cover interpretation

Object-based image analysis (OBIA) approach was used for image segmentation, in which objects were defined by spectral, textural and border properties. The resulted vector layer of objects (i.e., image segments) represent regions with similar pixel values with respect to some characteristic or computed property such as colour, intensity or texture and pattern. Segmentation processing was done using eCognition, with a minimum mapping unit (MMU) of 0.4 hectares (ha) based on the national forest definition. Objects smaller than 0.4 ha were merged to comply with the defined requirements for MMU. Then overlapping areas were corrected and the layer was made ready for interpretation. Because of the difference in images resolutions (Landsat 30m and ASTER 15m), different scales were applied for segmentation suitable to each resolution in the segmentation process. However, it is not excluded that these different resolutions could have an impact on the map areas and statistics, even if the above measures are expected to result in these differences being minimal. In case some differences remain in the map areas, these are corrected for with the spatial assessment units (MMU).

The image segments developed were used as the basic unit of classification (labelling and assigning each segment to the target land cover class). All the interpreters were trained to have a clear understanding of the land cover legend based on Land Cover Classification System (LCCS) and of all conditions and criteria to detect each class. The land cover labels were manually assigned to each polygon (i.e., image object) during the visual interpretation using LCCS 3 Basic Coder plugin in QGIS. Further quality check of land cover interpretation by the photo interpreters has been conducted by more experienced experts. Such quality checking of land cover interpretation was an integral part while developing the individual land cover map. The classes of the land cover are seven classes as described in table 5 below.

Table 5: Land cover classes

Code	Classes for mapping	Description
AG	Agriculture	Agriculture in terrestrial and aquatic/regularly flooded land
TCO	Forest	Trees closed-to-sparse in terrestrial and aquatic/regularly flooded land
SCO	Shrubs	Shrubs closed-to-sparse in terrestrial and aquatic/regularly flooded land
HCO	Herbaceous	Herbaceous closed-to-sparse in terrestrial and aquatic/regularly flooded land
URB	Urban areas	Urban areas
BS	Bare Rocks and Soil	Bare Rocks and Soil and/or Other Unconsolidated Material(s)
WAT	Water Bodies	Seasonal/perennial, natural/artificial Water bodies

6.1.2.3. Preparation of forest maps

Sudan, like other dryland countries where remote sensing is defined by unique challenges such as low vegetation signal-to-noise ratios, high soil background reflectance, presence of photosynthetic soils (i.e., biological soil crusts), high spatial heterogeneity from plot to regional scales, and irregular growing seasons due to unpredictable seasonal rainfall and frequent periods of drought. The forests are composed of open vegetation with low canopy cover. These conditions make it challenging to detect changes using medium resolution free public images such as Landsat. As such, it was expected that the area estimates, coming from the change map produced for the initial FRL submission, could be over or underestimated as a result of mis-classifications that would be corrected during the accuracy assessment process, with very high resolution imagery available through public databases (Google Earth, Here Maps, Bing Maps) for visualization.

Land cover maps for different years were produced, based on Sudan's new forest definition and land cover classes (Table 5 above). The shrub class (SCO) lands that meet the national forest definition were merged with the forest class (TCO) as a forest class (F) and the other classes were merged to non-forest class (NF). The lands classified (including shrubs and small trees) using the SCO code are only lands that meet the national forest definition, recently adopted by the government of Sudan. In this national forest definition, there are no specific definitions for tree and shrub.

6.1.3. Results forest area change detection

The forest maps of 2006, 2010, 2014 and 2018 were overlaid to obtain a change map in which each polygon contains:

- Forest / non-forest class in 2006
- Forest / non-forest class in 2010
- Forest / non-forest class in 2014
- Forest / non-forest class in 2018
- Area in hectares (ha)
- State name (in which the polygon is located)

These classes were aggregated into stable forest overall, stable non-forest overall, loss (forest converted to non-forest) for 3 periods and gain (non-forest converted to forest, mostly natural regeneration of trees on abandoned agriculture lands or shifting cultivation areas) for 3 periods. Polygon with loss or gain in only one time period was classified as loss or gain in that time period. Polygons with no change were classified as stable. The remaining polygons had both loss and gain. Depending on the land cover status in 2018, these polygons were classified as either stable forest overall (forest in 2018) or stable non-forest overall (non-forest in 2018). Table (6) below shows the resulting areas estimates.
Note: F = Forest, NF = Non-forest.

Table 6: Areas (in hectares) of aggregated change classes

Aggregated change class	Area
Gain (2006 – 2010)	150 922.7
Gain (2010 – 2014)	124327.2
Gain (2014 – 2018)	125 324.1
Loss (2006 – 2010)	362 543.5
Loss (2010 – 2014)	96 385.1
Loss (2014 – 2018)	264 138.8
Stable forest overall	4 059 584.6
Stable non-forest overall	8,308566.7

6.1.4. Improvement of change Map

After the submission in January and before starting the accuracy assessment, the change map was further checked for potential areas of improvement. This improvement work involved identifying and checking potential areas of misclassification. Polygons for checking were identified based on normalized difference vegetation index (NDVI) analysis for the months of January and February of the mapping years[3] based on Landsat imagery. January and February were considered to separate the effect of grass and crops from forest to the extent possible considering the phenology and cropping pattern in the area. For each of the map polygons median NDVI was calculated.

In the first round of checking, polygons with area greater than two hectares and NDVI values lower or higher than the threshold for forest or non-forest class, respectively, in all years were selected for checking. About 0.65 million ha of area (about 5 percent of total area) were checked and reclassified, where deemed necessary, using visual interpretation at this stage. Of the remaining potential polygons, additional 1000 polygons with large area were checked and reclassified, as necessary. Table 7 presents the comparison of map areas before and after the improvement and figure 4 shows the change map 2006-2018 after the improvements.

Table 7: Comparison of map areas before and after improvement of change map

Map Class	**Area (ha)**	
	In January submission	**After improvement**
Gain (2006 – 2010)	150,923	127,586
Gain (2010 – 2014)	124,327	86,727
Gain (2014 – 2018)	125,324	130,865
Loss (2006 – 2010)	362,543	383,797
Loss (2010 – 2014)	96,385	120,694
Loss (2014 – 2018)	264,139	230,709
Stable forest overall	4,059,585	3,657,541
Stable non-forest overall	8,308,567	8,753,874
Total	**13,491,793**	**13,491,793**

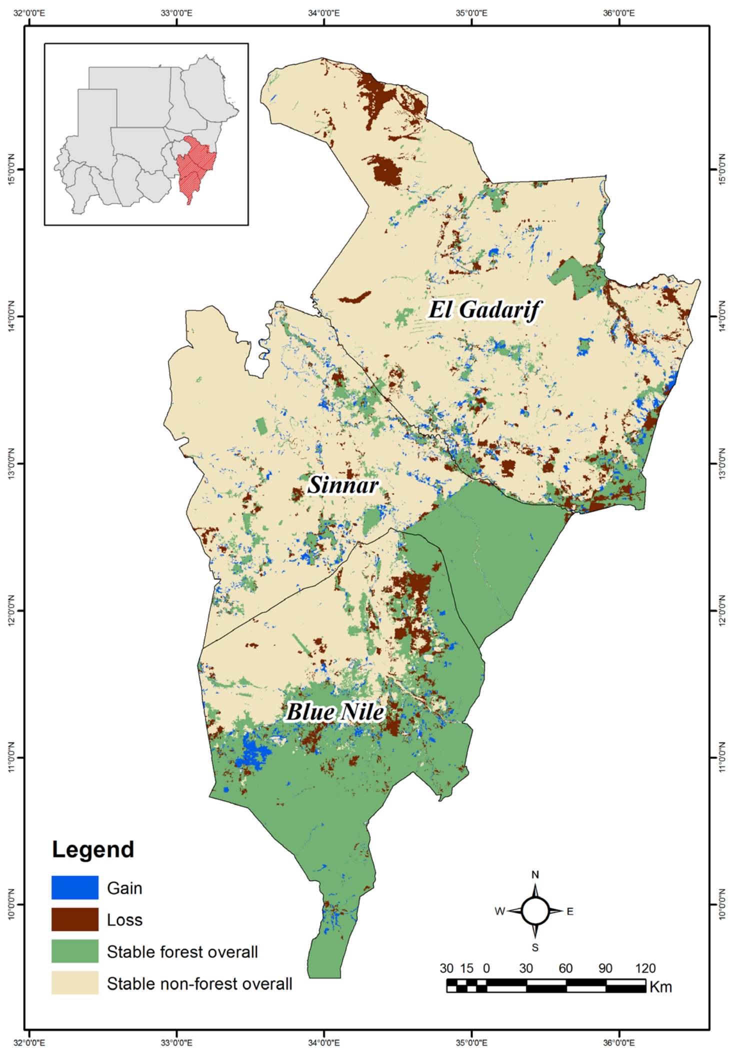

Figure 4: Change map 2006-2018

6.1.5. Accuracy assessment of change map

The objectives of the map accuracy assessment were to assess accuracy and estimate error-adjusted areas (with uncertainty) of land change (e.g., deforestation). Hence, accuracy assessment of the change map from 2006 to 2018 prepared for sub-national FRL was conducted. The key steps taken, and methods followed along with the results (i.e., accuracy and error-adjusted areas with uncertainty) are presented below.

6.1.5.1. Sampling design

A probability sampling design i.e., stratified random sampling was implemented. The classes of change map were used to construct strata. The following equations (Cochran, 1977) were used to calculate an adequate overall sample size (n) for stratified random sampling.

$$n = \frac{(\sum W_i S_i)^2}{[S(\hat{O})]^2 + (\frac{1}{N}) \sum W_i S_i^2}$$ (Equation 1)

$$S_i = \sqrt{EUA_i * (1 - EUA_i)}$$ (Equation 2)

Where,

i is activity class
N is number of units in the area of interest
$S(\hat{O})$ is the standard error of the estimated overall accuracy,
W_i is the mapped proportion of area of class i,
S_i is the standard deviation of stratum i,
EUA_i is expected user accuracy of stratum i.

The standard error of the estimated overall accuracy $S(\hat{O})$ was set to 0.01. Stable and rare classes (i.e., change classes) are expected to have high and low user accuracy, respectively (FAO, 2016). Accordingly, for stable classes (i.e., stable forest and stable non-forest) expected user accuracy was set to 0.9 and for change classes (i.e., gain and loss) this was set to 0.7. The overall minimum sample size was found to be 974. The minimum sample size was distributed proportionally among the classes, with an increase of minimum sample size of at least 100 samples per class to ensure that rare change classes were sufficiently sampled. This resulted in total 1499 samples for which reference data was to be collected. Table 8 shows the allocation of sample size to strata along with the distribution reference data included in analysis (discussed in response design below). Column B presents the proportional distribution of minimum sample size. Column C presents the allocated samples with an increase of minimum sample to 100. Column D presents the distribution of reference data included in the analysis. Figure 5 shows the distribution of allocated samples over map classes.

Table 8: Sample size allocation to strata

(A)	Number of samples		
Map class	(B) Proportional	(C) Adjusted	(D) Reference data included in analysis*
Gain_06_10	9	100	62

Gain_10_14	6	100	68
Gain_14_18	9	100	72
Loss_06_10	27	100	87
Loss_10_14	8	100	72
Loss_14_18	16	100	69
Stable forest overall	265	265	200
Stable non-forest overall	634	634	510
Total	**974**	**1499**	**1140**

**359 samples were excluded from analysis due to unavailability of suitable image and low confidence in interpretation*

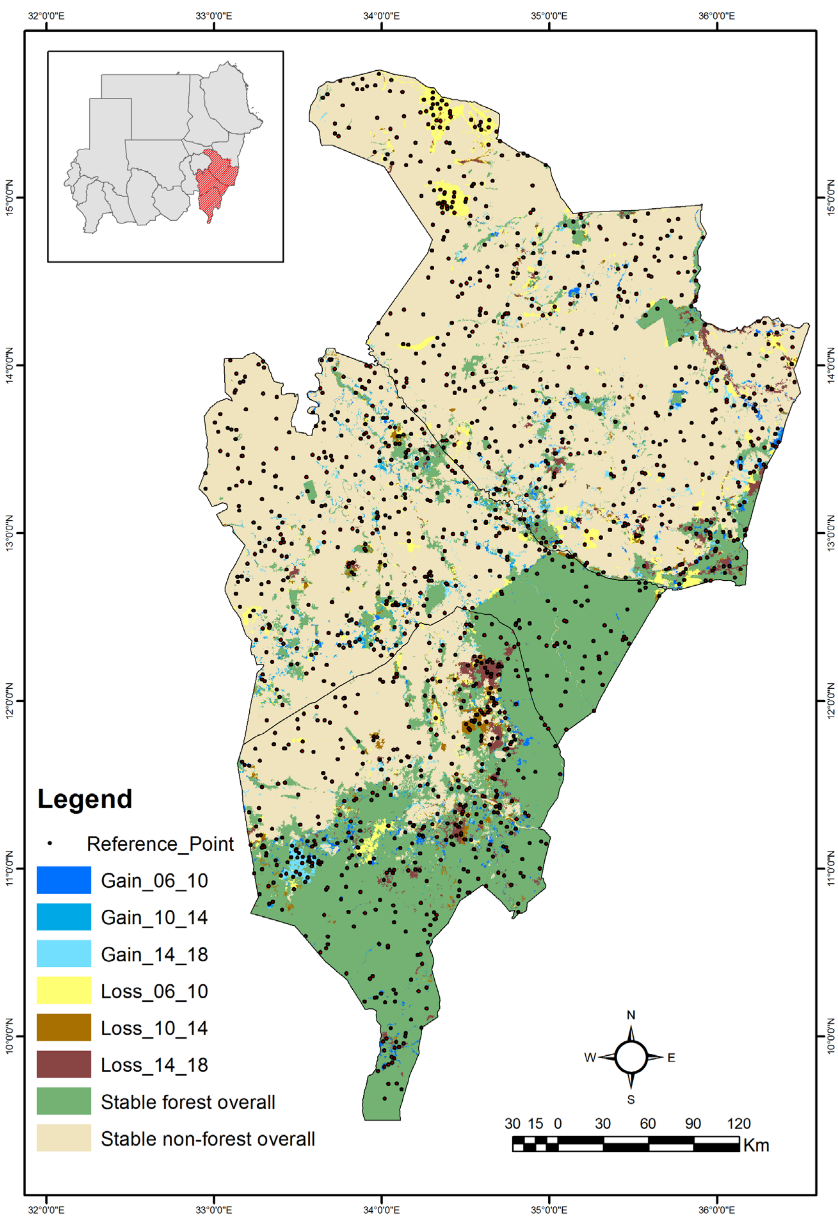

Figure 5: Distribution of samples over change classes

6.1.5.2. Response design

The response design encompasses all steps of the protocol that lead to a decision regarding agreement or disagreement of the reference and map classifications (Olofsson et al., 2014). The four major features of the response design (i.e., the spatial assessment unit, the sources of information used to determine the reference classification, the labeling protocol for the reference classification, and a definition of agreement) are discussed in the following subsections.

6.1.5.3. Spatial assessment unit

Pixels, blocks of pixels and polygons are all potentially viable spatial assessment units for conducting an accuracy assessment. Stehman and Wickham (2011) discuss several challenges associated with implementation and analysis of block and polygon-based accuracy assessment. Block of pixels and polygons are less likely to be homogeneous, so the response design and analysis protocols are more complex to account for within-unit heterogeneity. Pixel-based assessment (assuming within-unit homogeneity), on the other hand, can easily accommodate sampling designs employing strata. A traditional error matrix analysis can be readily applied to the case of homogeneous assessment units. Moreover, for an area-based accuracy assessment, preservation of the areas of agreement and disagreement is one of the critical requirements, which is comparatively well preserved by smallest possible spatial assessment unit. Considering these, 30m by 30m spatial assessment unit was used for reference data collection. Spatial assessment units were randomly allocated to strata according to the adjusted sample size (as shown in Table 8) using point sampling protocol.

6.1.5.4. Sources of reference data

The two ways to ensure better quality of reference classification than the map classification (Olofsson et al., 2014) are to ensure that the reference source is of higher quality (e.g., higher resolution satellite imagery) than what was used to create the map classification and in case of using the same source material for both the map and reference classifications (e.g., both classifications rely on Landsat data), to ensure that the process to create the reference classification is more accurate than the process used to create the classification being evaluated. Potential sources of reference classification can be ground visits to the sample locations or the use of aerial photography or satellite imagery. Practical considerations (e.g., costs) were influencing factors in the selection of sources of reference data for the accuracy assessment of change map.

Collect Earth Online (CEO) platform (Saah et al., 2019) was used for collecting reference data (Figure 6). Collect Earth Online (CEO) is an open-source, web-based, crowd-sourcing technology for Earth Science analyses allowing users to collect reference data using a variety of imagery resources and processing capabilities. Very high-resolution imagery available through Google Earth (linked with CEO) historical imagery were used as primary source of information for reference classification. In addition, available images of Landsat (for 2006, 2010 and 2014) and Sentinel 2 (for 2018) and normalized difference vegetation index (NDVI) time series from 2006 to 2018 were used to facilitate reference classification.

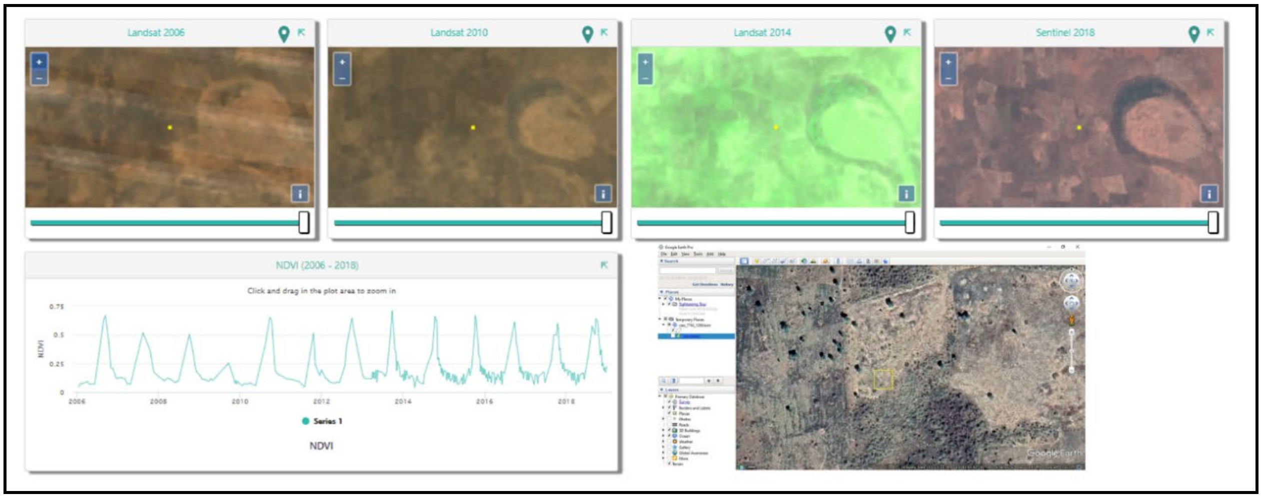

Figure 6: Reference data collection employing Collect Earth Online and Google Earth

6.1.5.5. Labeling protocol

Each spatial assessment unit was assigned either forest or non-forest class for the years of 2006, 2010, 2014 and 2018 based on visual interpretation of available high-resolution image and local knowledge of the analysts. Availability of high-resolution image for specific year was a major concern for collecting reference data. In case of unavailability of high-resolution image for a specific year, images (if available) for years immediately before or after were used for interpretation.

If a spatial assessment unit was found impure (i.e., representing an area of more than one class), the majority class was assigned. If a spatial assessment unit could not be classified due to lack of suitable images, local knowledge, etc., the unit was noted as of no confidence, and hence excluded from analysis. In total, reference data from 1140 spatial assessment units (Table 8) were included in the analysis.

6.1.5.6. Defining agreement

Consideration of high-resolution images from the years other than the mapping years for reference data collection has implications particularly for gains and losses which were disaggregated in three time periods (i.e., Gain 2006-10, Gain 2010-14, Gain 2014-18, Loss 2006-10, Loss 2010-14 and Loss 2014-18) in the change map – gain/loss of one time period may fall in gain/loss in other time period resulting increase of omission/commission errors. Table 9 presents the error matrix in terms of sample counts (n_{ij}) where the map categories (i =1,2,...,q) are represented by rows and the reference categories (j=1,2,...,q) by columns. The cells in bold represent the correct classifications where map and reference data agree in their classification. Mapped areas and the proportions of the areas are also presented.

Table 9: Error matrix in terms of sample counts (n_{ij})

		Reference				Total	Map area in ha ($A_{m,i}$)	$W_i = A_{m,i}/A_{tot}$
		Gain	Loss	Stable forest overall	Stable non-forest overall			
Map	Gain	**20**	14	67	101	202	345,178	0.03
	Loss	7	**43**	68	110	228	735,200	0.05
	Stable forest overall	8	11	**158**	23	200	3,657,541	0.27
	Stable non-forest overall	7	12	17	**474**	510	8,753,874	0.65
Total		42	80	310	708	1140	13,491,793	1

Three measures of accuracy (i.e., overall, producer's and user's accuracy) and error-adjusted areas were estimated using the formula provided by Olofsson et al. (2014) and Olofsson, Foody, Stehman, and Woodcock (2013). Table 10 presents the error matrix in terms of estimated area proportion in cell i, j of the error matrix:

$\hat{p}_{ij} = W_i \frac{n_{ij}}{n_{i.}}$ Equation 3

Where the total area of the map is A_{tot}, the mapped area of category i is $A_{m,i}$ (subscript m denotes "mapped"), and the proportion of the area mapped as category i is $W_i = A_{m,i}/A_{tot}$.

User's ($\hat{U}_i$) and producer's ($\hat{P}_j$) accuracy for each category and overall map accuracy ($\hat{O}$) were estimated as

$\hat{U}_i = \hat{p}_{ii}/\hat{p}_{i.}$ Equation 4

$\hat{P}_j = \hat{p}_{jj}/\hat{p}_{.j}$ Equation 5

$\hat{O} = \sum_{j=1}^{q} \hat{p}_{1j}$ Equation 6

An unbiased estimator of the total area (based on the reference classification) of category j was calculated as:

$$\hat{A}_j = A_{tot} \times \hat{p}_{\cdot j} = A_{tot} \sum_i W_i \frac{n_{ij}}{n_{i\cdot}} \qquad \text{Equation 7}$$

Table 10: Error matrix expressed as the estimated proportion of area ($\hat{p}_{ij}$), estimated user and producer accuracy and error-adjusted area

Reference / Map	Gain	Loss	Stable forest overall	Stable non-forest overall	$\hat{p}_{i\cdot}$ (total)	$\hat{p}_{\cdot j}$ (total)	UA $\ddot{U}_i = \hat{p}_{ii}/\hat{p}_{i\cdot}$	PA $\ddot{P}_j = \hat{p}_{jj}/\hat{p}_{\cdot j}$	Error-adjusted Area ($A_{tot} \times \hat{p}_{\cdot j}$)
Gain	**0.0025**	0.0018	0.0085	0.0128	0.03	0.0240	0.099	0.106	323,201
Loss	0.0017	**0.0103**	0.0163	0.0263	0.05	0.0422	0.189	0.243	569,718
Stable forest overall	0.0108	0.0149	**0.2142**	0.0312	0.27	0.2605	0.790	0.822	3,515,013
Stable non-forest overall	0.0089	0.0153	0.0216	**0.6030**	0.65	0.6733	0.929	0.896	9,083,861
OA ($\ddot{O} = \sum_{j=1}^{q} \hat{p}_{jj}$) = 0.83									

The standard error of the error-adjusted estimated area was calculated as:

$$S(\hat{A}_j) = A_{tot} \times \sqrt{\sum_{i=1}^{q} W_i^2 \frac{\frac{n_{ij}}{n_{i\cdot}}\left(1 - \frac{n_{ij}}{n_{i\cdot}}\right)}{n_{i\cdot} - 1}} \qquad \text{Equation 8}$$

The 95% confidence interval for $\ddot{A}_j$ was calculated as:

$$CI_{95} = \hat{A}_j \pm 1.96 \times S(\hat{A}_j) \qquad \text{Equation 9}$$

Where the margin of error is defined as the z-score (i.e., a percentile from the standard normal distribution, for 95 percent confidence level, z=1.96) multiplied by the standard error.

Areas at State level were estimated using two adjustment ratios. First areas were adjusted using accuracy assessment adjustment ratio (i.e., class specific adjustment ratio of stratified area to map area of the whole region). Then the adjustment ratio for the state area (i.e., state specific adjustment ratio of map area to stratified area of the state) was applied. Results are presented in Tables 11 and 12.

Table 11: Accuracy and area estimates

Class	Accuracy			Area (ha)			
	Producer's accuracy	User's accuracy	Overall Accuracy	Map area	Stratified area estimate	Standard error	95% confidence interval
Gain	0.106	0.099	0.83	345,178	323,201	68,871	± 134,986
Loss	0.243	0.189		735,200	569,718	85,765	± 168,099
Stable forest overall	0.822	0.790		3,657,541	3,515,013	128,970	± 252,782
Stable non-forest overall	0.896	0.929		8,753,874	9,083,861	132,142	± 258,998

Table 12: Estimated error-adjusted areas by states

Class	Blue Nile			El Gadarif			Sinnar		
	Error-adj. area (ha)	95% CI (ha)	90% CI (ha)	Error adj. area (ha)	95% CI (ha)	90% CI (ha)	Error adj. area (ha)	95% CI (ha)	90% CI (ha)
Gain	111,351	± 46,506	± 39,032	123,498	± 51,580	± 43,290	89,111	± 37,218	± 31,236
Loss	198,042	± 58,434	± 49,043	302,801	± 89,343	± 74,985	70,146	± 20,697	± 17,371
Stable forest overall	2,207,637	± 158,762	± 133,247	417,590	± 30,031	± 25,205	936,253	± 67,331	± 56,510
Stable non-forest	1,297,880	± 37,005	± 31,058	4,908,856	± 139,961	± 117,467	2,828,629	± 80,649	± 67,688

overall									

6.2. Activity Data for Enhancement of Forest Carbon Stocks:

In Sudan, afforestation occurs on land that was not forest before, such as cropland, abandoned lands, etc. On the other hand, reforestation occurs inside reserve forests in areas that was cleared of their tree cover through deforestation and forest degradation and human related activities and the cleared forest areas cannot regenerate naturally without human intervention, because of various reasons including the continuation of the same activities that causes their clearance. Therefore, implementation of enhancement activities of Afforestation and Reforestation (A/R) are a result of planting of trees through seeds, seedlings and related land preparation. Forest gains associated with forest land remaining forest land and other gains detected through mapping, are not included in this FRL submission. Enhancement on forest land remaining forest land in Sudan is mainly a result of natural regeneration on abandonment mechanized agriculture lands and/or recovery of areas subjected to shifting cultivation, which is a common practice in many parts of the country. Generally, it is quite challenging to assess gains accurately through remote sensing, especially in dry conditions with slow growing stands. The gain areas data from the mapping using remote sensing techniques presented in table 12 above, includes natural regeneration of forest land remaining forest land, natural regeneration on agricultural schemes (croplands) left uncultivated (abandoned) for some years, natural regeneration on shifting cultivation areas and it is likely to also include the planned A/R areas. The natural regeneration occurring on abandoned agriculture schemes and shifting cultivation lands most likely will disappears in subsequent years, because framers will come back again to clear the trees and forests that grew on their lands and continue cultivating them. Therefore, to ensure excluding the gain on such lands in this FRL submission, Sudan used only the data from the records of FNC on planned A/R plantations, to ensure that other gains related to natural regeneration from forest land remaining forest land and on agricultural lands is excluded.

Data for Enhancement of forest carbon stocks through A/R activities is obtained from the Forest National Corporation (FNC) offices at the three states where the subnational FRL is established. The A/R data is recorded annually for FNC official annual A/R programme, which is implemented inside forest reserves, in addition to afforestation on agriculture schemes (cropland) in collaboration with farmers. Such afforestation is supported by forest Act (2002) which stipulates that 10 percent and 5 percent of the rainfed and the irrigated agriculture farms, respectively, are to be allocated to forest plantations. This is in addition to FNC records on afforestation activities by the local communities in the area, which is also supported by FNC in terms of seeds, seedlings and extension services. FNC keeps good records on planting and management of the A/R areas, which either are inside reserved forest lands or owned by farmers and communities. The records are based on annual reporting by FNC state level offices and reports of supervision visits regularly done to assess the success of the annual A/R activities. The available records (ANNEX 2) cover the period 2000-2018, with few gaps in some years such as 2000, 2002, and 2003 in Sinnar state, and year 2000 in El Gadarif state. However, for the selected reference period (2006-2018) complete data is available.

Sudan estimated the A/R part of its FRL as the annual accumulated increment (removals) from the A/R activities during the reference period. All land areas, in the three states, planted in years 2006 to 2018 were taken into account. For example, in year 2008, removals equal area planted in years 2006, 2007 and 2008 multiplied by mean annual increment. Then, the FRL was estimated as the average annual accumulated removals in these A/R areas planted during the reference period (2006-2018). Table 13 below shows the actual A/R areas annually planted during the reference period in each state.

Table 13[4]: Afforestation and reforestation areas planted during the reference period (2006-2018)

Years	Sinnar State	Blue Nile State	El Gadarif State
2006	3690.9	3065.0	3037.5
2007	3818.5	2035.0	2739.5
2008	7590.6	4541.8	7607.0
2009	3198.8	3457.5	4356.5
2010	3537.3	927.5	3149.5
2011	5804.5	562.0	4451.0
2012	4456.3	889.8	4336.5
2013	11724.0	2131.5	3972.5
2014	4470.5	2352.3	2919.8
2015	5842.8	1741.5	2251.6
2016	2789.3	1172.8	3492.0
2017	5830.8	5008.0	3401.9
2018	7293.0	2341.1	4176.4

Wood removal due to harvest and fuel wood collection has not been included in the estimation of the removal from A/R areas. The rotations for managing the four main Acacia species used in A/R activities are different ranging between 15-20 years for *A. mellifera*, 17-23 years to *A. seyal*, 20-23 for *A. senegal,* and 25-30 for *A. nilotica*. These species are managed for specific purposes, e.g., *A. Sayel* is for production of Gum and wood fuel, *A. Senegal* is for production of Gum Arabic, *A. mellifera* is for animal fodder and *A. nilotica* is for production of railway sleepers and wood fuel. The wood harvest occurs mainly on plantation-managed forests, where according to rotations areas with mature trees are cleared and replanted. The A/R areas are managed for the specific purposes and rotations mentioned above and in some cases of the Gum production, these plantations are even kept for longer periods e.g., *A. sayel* up to 28 years and *A. senegal* up to 25 years. Therefore, wood harvesting is not expected to occur during the reference period, this is also because the A/R areas used in the calculation of the accumulated removals are the areas actually planted during the reference period 2006-2018.

The wood collections mostly take place in natural forests that are only subjected to protection provided for in the Forest Act, however, without proper management planning. Data on wood collected from natural forests, for commercial purposes, are mostly based on the records of Royalties collection by FNC

[4] Source of data: Forest National Corporation of Sudan

and because of the purpose, data is not adequate. In addition, data is not available on wood collected directly by local people for energy and other domestic uses and this is considered a significant amount, according to the forest products demand study (1996). The only disturbance event occurs in the region is fires and it has very minimum effects on the Acacia species trees, it mostly affects the understory vegetation.

Currently Sudan does not have a functioning system in place to monitor forest-harvesting activities based on land cover mapping. However, as explained in section 5.1, the largest potential for A/R activities is in the rainfed agriculture lands, which requires Sudan to build a system of forest monitoring based on land cover mapping. The REDD+ readiness programme with the technical support of FAO is now working on establishing the basis for such a system.

IPCC 2006 methodology was applied in the estimation of the removal on the A/R land areas, in particular equations 2.9 and 2.10, for estimating the changes in biomass carbon stocks associated with A/R activities. According to FNC assessment records, the survival rate of the A/R is between 55 and 65 percent, accordingly the removals from A/R over the reference period have been adjusted by 60 percent.

Equation 1: Total removal from accumulated afforestation and reforestation areas in the three states of the subnational FRL

$$Total\ Removal = \Delta C_G \left(A_{Sinnar} + A_{Blue\ Nile} + A_{Gedarif}\right) * 0.60 * 44/12$$

Where:

ΔC_G= annual increase in biomass carbon stocks due to biomass growth in land remaining in the same land-use

A = A/R area in Sinnar, Blue Nile and El Gadarif states, accumulated over the reference period (2006-2018), ha

0.60 = percentage of the survival rate of the A/R (FNC evaluation reports)

44/12 = the ratio of the molecular weights to C to CO_2

Equation 2: Annual increase in biomass carbon stocks due to biomass increment in land subjected to A/R activities:

$$\Delta C_G = \Sigma_i (G_{TOTAL_i} * CF)$$

Where:

ΔC_G= weighted average annual increase in biomass carbon stocks due to biomass growth in A/R area category by vegetation type (4 species), tonnes C yr^{-1}

G_{TOTAL}= mean annual biomass growth, tonnes d. m. ha^{-1} yr^{-1}

i = species

CF = carbon fraction of dry matter, tonnes C (tonne d. m.)$^{-1}$

Equation 3: Average[5] annual increment in biomass of the four *Acacia* spp:

$$G_{TOTAL_i} = G_i * WD_i * (1 + R)$$

Where:

G_{TOTAL} = average annual biomass growth above and below-ground, (4 species) tonnes d. m. ha^{-1} yr^{-1}

G_W = Mean annual increment (merchantable volume)[6] over rotation for species, m3/ha/yr (IPCC 2006 table 4.11B)

WD*i* = Wood density of specific species, t. d. m /ha (country specific data)

R = ratio of belowground biomass to aboveground biomass for a specific vegetation type, in tonne d. m. belowground biomass (ton d. m. aboveground biomass)$^{-1}$.

6.3. Emission factors for deforestation

6.3.1. Description of NFI

The primary source of data used to derive emission factors was the current National Forest Inventory (NFI 2017), initiated by the National REDD+ Program supported by the World Bank and implemented by the Food and Agriculture Organization of the United Nations (FAO). The NFI methodology follows the approach developed by the Support to National Forest Resources Monitoring and Assessment (NFMA) program of the FAO that is based on countrywide sampling and field data collection as well as on remote sensing.

6.3.2. Stratification

Different maps and datasets have been used to create not-overlapping strata in the GIS environment. The base map is the Aridity zones from CGIAR-CSI to derive the main zones in the country (according to precipitation and evapotranspiration factors). The aridity zones map elaborated by CGIAR-CSI[7] (in the context of land suitability analysis to delineate CDM-AR suitable areas[8]) was used to capture the main country landscapes, characterized by a climate that ranges from hyper-arid in the north to tropical wet

[5] Weighted Average rate is based on the fact that 25% of the area planted with Acacia nilotica (with higher increment) compare to the 3 Acacia spp of similar increment

[6] Merchantable volume in the case of the Acacia species used in the A/R in Sudan is equivalent to whole aboveground volume because these species are mostly used for energy purposes (fuel wood) including A. nilotica, which in the past used also for production of railway sleepers, however, now is mostly used as fuel wood.

[7] http://www.cgiar-csi.org/data/global-aridity-and-pet-database

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

and dry in the far southwest. Methodology is well documented in Zomer et al., 2006, 2007 and 2008. A further division of the second strata was possible applying Africover 2000 and Harrison and Jackson (1958) maps. To the resulting four strata, a separate fifth stratum was assigned to the main rivers and selected streams. To make a sharp division between semi-arid zone and savanna Harrison and Jackson (1958) and Africover (2000) have been overlaid 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, analysed and drafted using very high-resolution images (VHRI). In regard to the river layer, a separate shapefile has been used and database with rivers names completed with the knowledge of the colleagues in the field where buffer of 1.5 km 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 final result has been integrated in the original layer and dissolve has been applied, after removing sliver polygons in the fifth strata.

The resulting map used for stratification is shown in Figure 7, and description of the Strata and corresponding areas are in Table 14 and Annex 4.

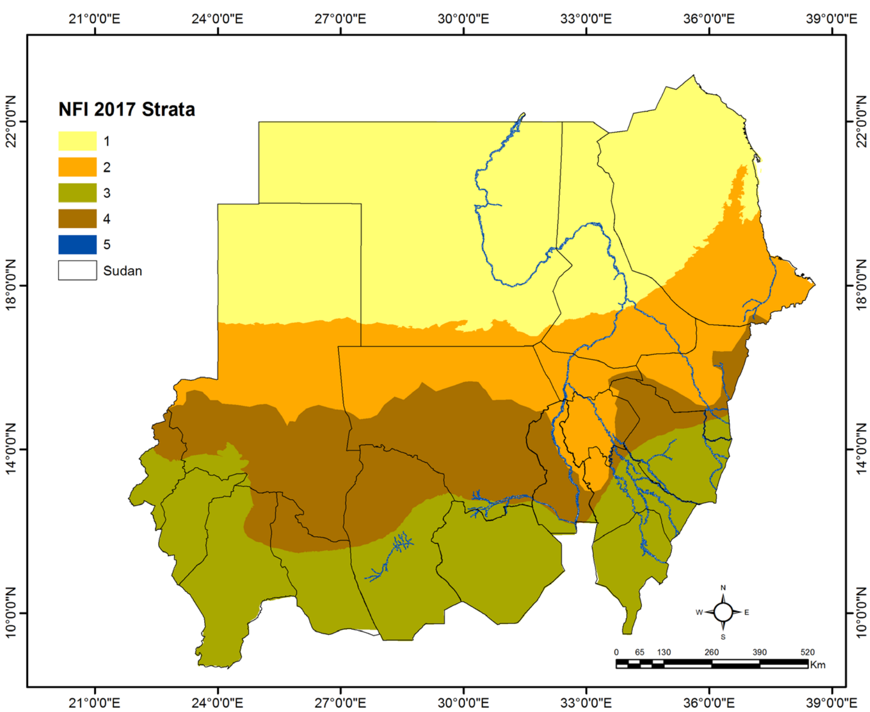

Figure 7: NFI 2017 strata

Table 14: Description of the Strata

Stratum	Description	Area (ha)	Area (%)

I	The stratum that mostly comprised Deserts	67,327,512	36
II	The stratum characterized by semi-desert ecosystems (e.g. few Acacia trees and thorny bushes and zerophytes)	38,802,725	21
III	The stratum indicated as 'Low rainfall woodland Savannah' by Harrison and Jackson (1958)	35,695,771	19
IV	This stratum includes semi-arid, dry sub-humid, humid aridity zones. Forest and Woodland vegetation are mostly found here.	42,743,777	23
V	This stratum includes rivers and streams. It is probably the most heterogeneous since it is the stratum where human activities are dominated, and patch of vegetation (natural and not) found as riverine vegetation. This layer crosses all the latitudes of the country.	2,438,969	1

6.3.3. Sampling Design

The sampling design adopted for the NFMA in Sudan was systematic. Sampling units selected at the intersection of every degree of the latitude longitude grid. The number of sampling units (1755 SUs) or tracts to be surveyed is determined by the required statistical reliability of the data, the available financial and human resources for the assessment, and with a view to enabling periodic monitoring. Sample units (SU) were allocated to each stratum according to their vegetation density as shown in table 15 and figure 8 below.

For the location of the Sampling Units in the field, two main grids of points were used in the country, the first with a point distribution of 80km x 80km and the second grid with a distribution of 40km x 40km. Based on the first grid, the distribution of Sampling Units was made for strata I and II, however, stratum I was not included in the measurements realized. For strata III, IV and V the second grid (40km x 40 km) was used. In a process of intensification other grid of points combinations were used, table 15 show the area and sampling unit distribution.

The NFI team made a plan to visit 968 out of 1755 SUs, based on available resources and locations of forest lands, focuses mainly on strata 4 and 3 where most of the forest lands area located. The plan does not include strata 1 (desert) and includes only 23 SUs in strata 2 (mostly grass crop, bare lands). Out of the 968 planned SUs, 184 were found inaccessible and 784 SUs were the accessible and actually visited ones, consisting of 3,132 sample plots. The nine field crews had surveyed a cumulative area of 1,461.51 ha in 22 months, which include about 42,217 trees and 1800 stumps were recorded and analysed. Measurements relevant to the FRL include the following parameters:

- Trees: All trees living or dead, standing or fallen with at least 10 cm of diameter at breast height (DBH) found within the plot are measured.
- Parameters measured: Tree diameter is measured over bark, at 1.3 m breast height above the ground. Tree height measurement carried out using Vertex Laser Clinometer.
- Small tree and tree regeneration (tree height ≥ 1.3 m and DBH < 10 cm) are only counted by species within Circular subplot.

- No measurements have been done for below-ground part of the trees

The forests formation in the FRL region encompassing the 3 states is considered of reasonably high homogeneity, as more than 80% of region area fall within one strata (4#) of the NFI 2017, see map (figure 8) below. A total number of 153 sample units (SUs) out 784 SUs of the NFI 2017, fall in this region, each consists of 4 sample plots of an area of (0.5 ha) each, located in the centre of SUs, see annex 3a in the current FRL submission. 70 SUs out of the 153 SUs in the region fall within the forest land use. 37 SUs out of the 153 SUs in the region, were inaccessible and therefore not visited (for security reasons), these are mostly located in productive forest areas. However, because of the homogeneity of the forest formation in the region the number of SUs actually visited considered representative, particularly to the areas where most of the deforestation activities is actually occurring.

Table 15: Area, Sample Units, their distribution and actual measurements

No.	Strata	Area (ha)	Planned SU[9]	Actually Visited SUs
1	*Stratum II*: The stratum characterized by semi-desert ecosystems (e.g., few Acacia trees and thorny bushes and zerophytes)	38,985,259.6	389,853	20
2	*Stratum III*: The stratum indicated as 'Low rainfall woodland Savannah' by Harrison and Jackson (1958)	35,972,311.37	359,723	159
3	*Stratum IV*: This stratum includes semi-arid, dry sub-humid, humid aridity zones. Forest and Woodland vegetation are mostly found here.	43,145,919.18	431,459	577
4	*Stratum V*: This stratum includes rivers and streams.	2,829,233.88	28,292	28
Total		**120,932,724.03**	**1,209,327**	**784**

[9] Is the number of SU that fit un the area of the stratum; each SU has 100 hectares (1km x 1 km). The result is the area divide by the area of one SU.

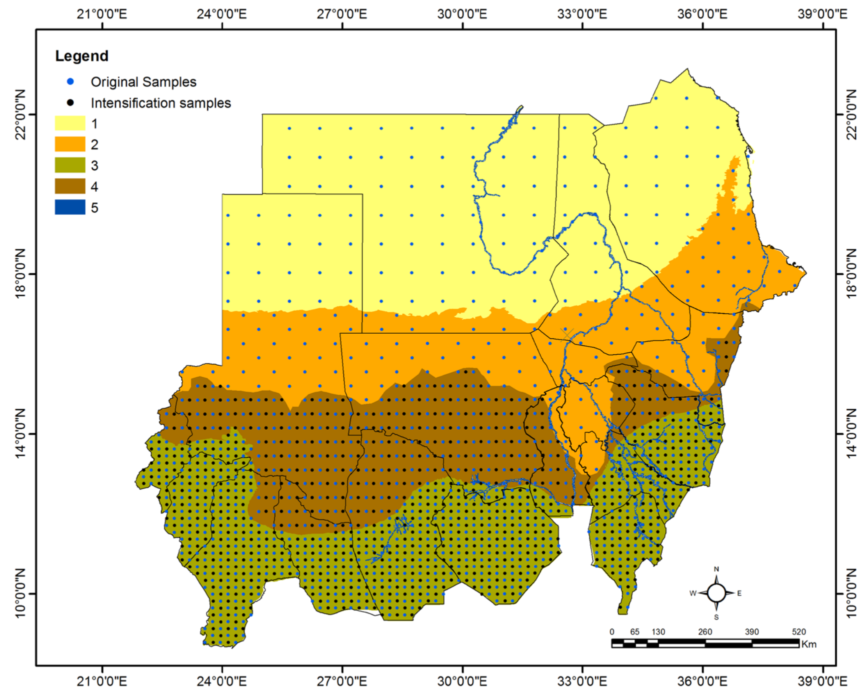

Figure 8: Distribution of sample units of the NFI 2017

6.3.4. Analysis of collected NFI data

A calculation procedures for Sudan NFI 2017 was developed, this document provides detailed descriptions of the main calculation procedures and statistical estimates, as well as the equations used in the calculation of volume, biomass and carbon of the National Forest Inventory of Sudan.

In total 784 Sampling Units were measured in the field, the design used for the NFI is the one that traditionally has been promoted by FAO in several countries, in this design each Sampling Unit (cluster) is located in an area of 1km x 1km. Each Sampling Unit consists of a series of nested plots of different sizes that is used to measure the variables identified in the NFI design. The information of the NFI of Sudan (2017) was stored in table/files (e.g., trees >10 cm, small trees<10cm, stumps, etc.) using the Open Foris Collect platform, see FAO website (www.fao.org/forestry/fma/openforis/en/).

The data from each table was exported from Open Foris Collect to an Excel format. In order to facilitate the calculation procedures, the decision was to use MS Access database with the format and structure of the *Silva Metricus* software. Silva Metricus is a special software to design, maintain and calculate forest inventories. The software *Silva Metricus*[10] can be downloaded from http://www.silvahn.com. The data generated by Open Foris was imported into the MS Access database.

[10] The database used by *Silva Metricus* have general structure and theirs can be used for calculations with other software and the data can be exported to programs like Excel or CSV format.

Taking into consideration the design of the NFI 2017, the *Random Stratification* equations were used during the calculation and analysis process. The process of calculations was disaggregated by land use (forest and non-forest) and then by state (administrative unit). The calculations involved separate steps for trees>10 cm DBH, small trees <10 cm DBH, as follows:

Trees >10 cm DBH: The calculation of the number of trees per hectare represented by each tree in the Sampling Unit, is based on the land use, whether the tree is located in a forest LUC or non-forest, this is defined in the data table.

Basal area: The basal area per hectare representing each of the trees measured in the field is calculated using the formula:

$$G = \left({}^{DBH}/_{100}\right)^2 * 0.7854 * N$$

Where:

G: Basal area in m2/ha

DBH: Reference Diameter (1.3 m of height)

N: Number of trees per hectare (calculated in previous section)

Total volume and volume of bole: For the calculation of the total volume and the bole volume the form factors of each of the tree species are used. Data on form factors was obtained from FAO and national sources (see Annex 5). In cases when the trees had large branches that contributed significant amount of the volume, the branches diameter and length were measured. The total volume and volume of the bole are then calculated using the following formulas:

$$Vt = G * th * ff + Vbr$$

Or

$$Vb = G * bh * ff$$

Where:

Vt: Total volume in m^3/ha.

Vbr: Volume of branches m3/ha

Vb: Bole volume in m3/ha

G: Basal area m^2/ha

th: Total height in meters

bh: Bole height in meters

ff: Form factor (total or bole)

Volume of small trees: The calculation of the volume of small trees was also based on land use and number of trees. A 5 cm class mark is used, which is the midpoint of the DBH class of 0 to 9.99 cm in which small trees are classified. For the calculation of the height of the midpoint of the class (5cm) a regression model (DBH-Height) was fitted using the data from the table aa_shrubs from the database and the model h = 1.9973 + 0.1742 * DBH was obtained. The height corresponding to 5cm is 2.86 meters. With these values, the volume was calculated using the following equation:

$$V = \left(DBH/_{100}\right)^2 * 0.7854 * h * ff * N$$

Where:

V: volume in m^3/ha
DBH: diameter of midpoint of the DBH class (5cm)
H: height of the class in meters (2.86m)
ff: form factor
N: number of small trees per hectare (calculated in previous section)

The calculations of the NFI data were first performed by national and external experts in December 2019. The results of the initial calculations, in particular the values of the volume per hectare for the three states were then used in the estimation of initial FRL submission. However, the results of the initial calculations were subjected to intensive review and discussion by FNC and experts from the research and academia. As a result, FNC and FAO decided to conduct comprehensive quality review of the data processing including data entry, cleansing, and issues related to data transformation between different software. A number of issues and gaps were identified, including the need to review entry of some data using field data (hard copies), entry and correction of volume data of some species including of small trees <10 cm and review of areas of land uses. Accordingly, FAO/FNC decided to conduct recalculations of the NFI results with the support of an international expert, applying improved approach/methods (calculation procedures).

The new results of the recalculation of the NFI data for the FRL region (see table 16 below, annex 6), in particular the values of V/ha of the forest landuse disaggregated by states, are used in the estimation of this modified FRL submissions. The new results of NFI data correspond well to the national forest definition and is considered more representative of the actual situation of the forests in this region, given all the observations that triggered the review and quality check mentioned above. The new data shows higher values for V/ha of the growing stock in the three states compared to initial results. In addition, the volume per hectare of the small trees is also included in the new NFI results, which was not case in the initial NFI data. However, the values of the forest stock are still low compared to the IPCC values for this region in Africa and there are differences in the growing stock in the three states, particularly El Gadarif State. This is mainly due to factors causing deforestation and forest degradation, such as unsustainable extraction of wood, agriculture expansion and overgrazing (this region possess large number of livestock).

The forests formation in the region encompassing the three states is generally characterized by high homogeneity, enjoying similar growth climatic (average annual 450-690 mm) and soils conditions. The forests are mostly dominated by associations of the same mixed Acacia spp. Also, about 80percent of region area falls within one strata (4#) of the NFI 2017, except small areas in north El Gadarif and Sinnar states (fall in strata 3 and 2), these small areas are grazing land with scattered trees, see figure 9. However, despite the homogeneity of the forest cover in the region, the new recalculated NFI data as well as the previous initial NFI data used for initial FRL submission, show comparable values of V/ha for Blue Nile and Sinnar states, however in El Gadarif state the V/ha is low and not comparable to V/ha of the two other states, see table 16 below. This is mainly attributed to the fact that forests in El Gadarif state are highly subjected to the above-mentioned factors, causing deforestation and forest degradation. El Gadarif is the largest crop production state in Sudan (Sorghum, Sesame, etc), in which agriculture expansion is very significant deriver affecting both forests and traditional grazing lands, in addition wood extraction from the already shrinking forest areas and overgrazing of the forests are also other significant derivers causing deforestation and forest degradation.

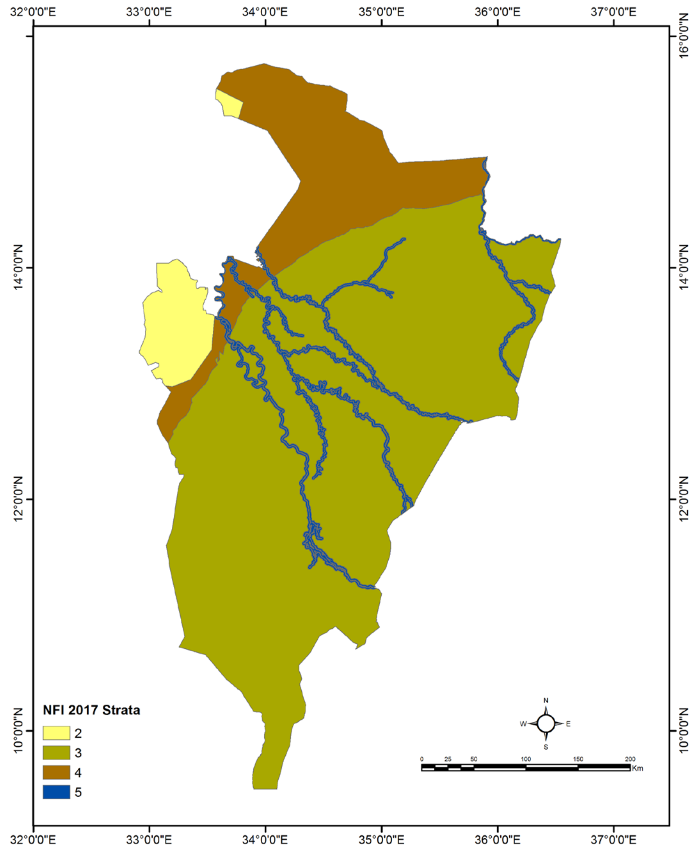

Figure 9: Area of FRL region falls within strata 4#

Table 16: NFI results of aboveground V/ha of forest land use disaggregated by state:

States	Initial NFI results	New recalculated NFI results (m^3/ha)			
	(m^3/ha)	trees> 10 cm DBH	Sample error %	Trees < 10 Cm DBH	Sample error %
Blue Nile	11.94	18.19	46.72	3.56	39.11
El Gadarif	2.9	3.65	96.31	2.77	86.24
Sennar	9.22	20.94	51.51	1.16	78.35

Sample Error: During the fieldwork stage, every effort was made to minimize measurement errors through training processes for the crew members, as well as the use of the best available measurement instruments. This is in addition to the review and quality checks performed twice for data entry, cleansing, transition to software and recalculations. One of the main weaknesses is lack of volume equations for the different species in Sudan. For the calculations of the sampling errors and others, the software Silva Metricus was used. The sampling errors are calculated using the approach of "ratio estimator."

It is important to note that the forest inventory realized is a national level, the overall variability of the NFI is very low, e.g., 9.11 percent for forest land use, because all the 784 Sampling Units are considered. However, when the calculation is more specific, for example disaggregated to State level, the number of sampling units that participate in the calculation decrease and therefore the variability increase. The calculation has following main steps:

- Calculation of the variance (random stratified) for the variable of interest (example: volume).
- Calculation of the variance (random stratified) of the area (Land use collected in field).
- Calculation of the covariance with the previous items (variable of interest/area).
- For the calculation by state (e.g., volume/tree or area forest), in the database each record has the value of the state; then the software use 'dataframes' to split the dataset by state (or other variable as needed) to do the calculation.

6.3.5. Results and proposed emission factors

Sudan applies methods of the IPCC 2006 guideline for estimation of the emission factors for deforestation in the three states of the FRL, in particular equation 2.15 of Chapter two, with country-specific data of stock density (V/ha) obtained from the NFI 2017 and country specific data on wood density, in addition to the IPCC 2006 default data for root shoot ratio and carbon fraction (section 4.5, tables 4.3 and 4.4), see table 17 below. Sudan used only the V/ha data from the NFI, not the biomass data of NFI, which was also available from the NFI data. The NFI approach to estimate biomass is based on default data mostly from the 2006 IPCC guidelines table 4.13 and DRYAD. It is worth mentioning that the default values of table 4.13 do not include most of the trees species in this region of Sudan. Therefore, Sudan used national wood density data of 11 main species of this region (included in annex 4# to the current FRL submission) together with default R-values from table 4.4 of the 2006 IPCC guidelines to estimate biomass and then the EF factors used in the estimation of deforestation. In Sudan's view, this approach gives accurate estimates of biomass than the approached used in the NFI.

Carbon stocks in biomass immediately after conversion (B_{AFTER}) are assumed to be zero, since the land is cleared of all vegetation before it is turned into other land uses, in the case of this region the change is mostly to annual crops cultivation. Therefore, change in biomass of annual crops, in subsequent years, is also considered zero because carbon gains in biomass from annual growth are offset by losses from harvesting, and there is no good quality data available to estimate soil carbon stock in general in Sudan including this region.

Equation 1: Average change in biomass carbon stock on forest land converted to other land use

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

Where:

ΔC_B= change in carbon stocks in biomass on forest land converted to other land-use category, in tonnes C /ha

ΔC_G= annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, in tonnes C yr^{-1}

$\Delta C_{CONVERSION}$ = initial change in carbon stocks in biomass on land converted to other land-use category, in tonnes C/ha

ΔC_L = annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tonnes C/ha (assumed equal to zero)

Equation 2: Initial carbon stock on forest land after conversion to another land use

$$\Delta C_{CONVERSION} = \sum (B_{After_j} - B_{Before_j}) * CF$$

$$B_{Before_j} = V_{AG_j} * WD_j * (1 + R)$$

Where:

$\Delta C_{CONVERSION}$ = initial change in biomass carbon stocks on forest land converted to non-forest land, tonnes C/ha

B_{AFTER_i} = biomass stocks on land type *i* immediately after the conversion, tonnes d.m/ ha (assumed equal zero)

B_{BEFORE_i} = biomass stocks on land type *i* before the conversion, tonnes d.m/ ha^{-1}

V_{AG} = above ground biomass m3 /ha

WD= wood density t. d. m /ha

CF = carbon fraction of dry matter, tonne C (tonnes d.m.)$^{-1}$

i = species

Table 17: Emission factors for deforestation

:

States	Average Growing Volume (m^3/ha)		Wood[11] density	Root-shoot Ratio	Carbon Fraction of dry matter	Carbon stock	Emission Factor
	Trees> 10 cm DBH	Trees< 10 cm DBH	t. d.m/m^3	R		t C / ha	t CO2 / ha

[11] Average wood density of eleven dominant species see ANNEX 4

Bule Nile	18.19	3.56	0.7	0.56	0.47	11.2	40.9
El Gadarif	3.65	2.77	0.7	0.56	0.47	3.3	12.1
Sinnar	20.94	1.16	0.7	0.56	0.47	11.3	41.6

6.4. Removal factor for enhancement of forest carbon stocks:

In the estimation of the removals associated with the carbon stocks enhancement (A/R) activities, Sudan applied country specific wood density values and default IPCC data from the 2006 IPCC Guidelines.

The areas of the enhancement (A/R) activities are well protected and managed plantations, with higher stocking density compared to natural forests, as their conditions described under section (5.3.4) above. FNC keeps good annual records of A/R areas and date of planting, as mentioned in section 5.2. However, there is no records of regular (measurements) inventory data on their stocking density in order to estimate their annual growth rate. The NFI 2017 data does provide estimates for the annual growth rate of A/R areas and the estimates of V/ha values from the NFI 2017 are not representative of the growth conditions in the A/R areas and will lead to underestimation of their actual removals. Therefore, Sudan decided to use conservative default MAI values from table 4.11B of chapter 4 of the 2006 IPCC Guidelines, which provides MAI values for the same Acacia species used in A/R activities.

When selecting the MAI value for the four Acacia spps used in the enhancement activities, two options in table 4.11B of the IPCC guidelines were discussed "Productive semi-natural forests" and "Protective Semi-natural Plantations." This is because forests in the FRL region have an important function of protecting the watershed in this region where the Blue Nile and all its tributaries are located and the Blue Nile River provides about 80% of total flow (water) of the main River Nile, which runs across Sudan and Egypt to the Mediterranean Sea. In particular *A. nilotica*, which is planted and also found naturally in the flood basins along the banks of the rivers and other watercourses. In addition, all the four Acacia *spps* have important production functions, particularly the non-wood forest products such as Gum Arabic (*A. senegal* and *A. sayel*) a very important product to the local and national economy. Animal fodder (*A. mellifera* and *A. sayel*) is also a very important product to feed the large animal population in the region. In addition, the forests also supply wood fuel *(A. sayel*, *A. nilotica* and *A. mellifera*) and time for construction (*A. nilotica*). In most cases and because of the importance of the non-wood products to local economies and livelihoods in the FRL region, these species are grown for their maximum rotation, as explained in section 5.2. Also because of the importance of the production of Gum, fodder and other fruits, the forests are well protected, however, mostly not under proper management (such as silvicultural treatments), except the *A. nilotica* plantations managed by FNC for the production of railway sleepers and wood for construction.

However, national experts and available studies, suggest that the growth conditions in the region have generally changed affected by variability in rainfall and climate change in the FRL region and the adjacent Ethiopian mountains. In recent years, there are more frequent events of flooding and dry years, this in turn has affected run-off, river flow dynamics and the growth conditions of the forests and vegetation in the region, such as the typical flood basin sites where *A. nilotica* grows, Elsiddig and Abdel Magid (2008). Based on the above-mentioned circumstances and also on the technical exchange during the UNFCCC Technical Assessment, Sudan decided to use average values from the range the values of "Productive Semi-natural forests" in table 4.11B of the IPCC Guidelines, see table 18 below. Fortunately, these IPCC values are for the same four species in this same region of Africa, which ensure their suitability for estimating the removals in the FRL. Sudan also considered using average values from the range of selected values to be conservative and more representative of the growth conditions in the FRL region.

The wood density values of the four main species used in A/R activities, as included in Table 11 below, have been obtained from national research (Annex 4). The values of the root-shoot ratio, the mean annual increment (MAI) and the Carbon Fraction was obtained from the 2006 IPCC Guidelines, section 4.5, tables 4.4, 4.11B and 4.3 respectively. Based on these data a weighted average emission factor was estimated and used in the calculations of carbon removals of the A/R activities in the three states. Annual growth rates (t.d.m./ha/yr) were estimated first separately for each of the four species (see table 11). Then weighted average annual growth rate (1.64 t C/ha/yr) was estimated because about 25% of the A/R area is planted by *A. nilotica*, which has the largest volume, while the other three Acacia *spps* have comparable volumes per hectare. There are no records on the exact planted areas of each of the other three Acacia species (*A. sayel, A. senegal* and *A. mellifera*) and in many cases these are planted in associations mixed in the same plantation. While, *A. nilotica* is planted separately on flood basin areas near the banks of the rivers and close to other water courses. There is no significant variation in the growth conditions of the forests in the three states. According to the NFI stratification, more than 80% of the land area of the three states fall within stratum (#4), and the average annual rainfall in the region of the three states is 450-690 mm. Accordingly, the same weighted average annual growth rate of 1.64 t C/ha, in table (18) has been used in the estimation of the removals associated with A/R activities in the three states as shown by the results presented in Table 19.

Table 18: Emission factors data used in the estimation of carbon removals

Tree type	Average rate		Growth	Wood Density	Root shoot ratio	Carbon Fraction of dry matter	Growth rate	Growth rate (weighted average)[12]
Units	**m³/ha/yr**			**t.d.m/m³**	**R**		**t.C /ha/yr**	**t.C /ha/yr**
Source	Table 4.11B Min - Max		Averg.	National data	Table 4.4.	Table 4.3	calculated	calculated
Acacia nilotica	12.5	20	16.25	0.8	0.56	0.47	9.53	1.64

[12] 25% of the A/R area is planted with Acacia nilotica, which has significantly more volume per hectare compared to the other 3 Acacia species which have comparable stocking density

Acacia seyal	1.8	3.2	2.5	0.7	0.56	0.47	1.28	
Acacia senegal	1.1	2.4	1.75	0.7	0.56	0.47	0.90	
Acacia mellifera	1.9	3.5	2.7	0.7	0.56	0.47	1.39	

7. Details on National Circumstances

Forestry activities started in the Sudan in 1901 and, the Woods & Forests Ordinance was promulgated in 1901 and the Department of Woodlands & Forests established in 1902. The 1901 Ordinance was replaced in 1908 by the First Forest Act. Adoption and implementation of administrative & 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.

The first national forest policy in Sudan was declared in 1932. The main objective of that policy was the protection and establishment of forests together with the development of their resources in order to sustain their protective, environmental and productive role to meet the population needs in terms of forest products and services. To this end, so many approaches, scientific techniques, and administrative procedures have been followed in order to assign responsibilities to central and state level institutions regarding the management of forest resources.

The 1932 Forest Policy was reviewed in (1986) and the new policy encourages forest reservation and conservation and community and private sector participation in forestry development and management. The Forest Policy 1986 also responded to the new concepts and approaches of forest managements, which emphasis environmental protection, popular participation and multiple purposes forest management. The 1986 forest policy recognizes new forms of forest tenure including private, community, and institutional forests. Sets a target of 20 percent of the area of the country as forest reserves. It stresses the role of forests in environmental protection by creating new obligations in semi-mechanized farming or irrigated area to maintain or establish green belts. It emphasizes the role of public participation and community integration in afforestation and sustainable management of forests. It also recognizes the role of research in forest development and emphasizes the role of forest extension.

The current forest act is the Forests and Renewable Natural Resources Act 2002. It promotes an inter-sectoral approach to natural resources management involving forests, range and pasture and agriculture. The act supports agroforestry and includes a requirement for 5 percent of irrigated agricultural land to be planted with trees and 10 percent of rainfed agricultural land to be planted with trees. The Act recognises three categories of forest ownership – private, community and institutional but places all types of registered forests under the technical supervision of the FNC. It recognises the role of the native administration and traditional leaders and local communities and it recognises the multiple uses of trees and forests and usufruct rights of communities living around forest reserves.

Sudan 2006 National Forest policy Statement, developed through technical support of FAO, is the recent update of Sudan's Forestry Policy1986. The 2006 policy statement made important changes in forest development and management. As it incorporates objectives of poverty reduction and amelioration of physical environment and combating desertification. Other policies forest related include Water Policy, Forest Outlook, Sudan's Commitment to Social Development and Population Policy.

The Comprehensive National Strategies (CNS 1992 – 2002 and 2003 - 2027) are both concerned with the importance of forestry in environmental conservation and as a source of goods and services for the country and local communities. The CNS supported an increase in forest cover, range and nature reserves to an area equivalent to 25 percent of Sudan area. Since 1992, Sudan also put in place several strategies, policies and programmes aimed at sustainable development including the forest sector. These include:

- The National Comprehensive Strategy (1992 – 2002 & 2003-2027)
- The Natural Resources Strategy (2003-2027)
- Sudan's Forest Products Strategy (2003- 2027)
- National Action Plan to combat Desertification (2003),
- Sudan Intended Nationally Determined Contribution (2015)
- National Biodiversity Strategy and Action Plan (2001, 2017),
- National Adaptation Plan (NAP 2016)

It can be concluded that the conservation and enhancement of the forest cover is a priority of the Government of Sudan as stated in the constitution and Forest & Environmental and related policies where, FNC and other related institutions obliged to work and achieve forest land area and tree cover of 20 [percent of the total country area by 2027.

8. Proposed FRL

Sudan's first sub-national FRL is constructed based on two main significant REDD+ activities, Deforestation and Enhancement of Forest Carbon Stocks. The selected historical reference period of 2006 – 2018, is considered representative of the effect of relevant policies and development in national circumstances on forest land including implementation of A/R activities. Sudan applied the 2006 IPCC Guidelines for national GHGs inventory in the estimation of emissions from deforestation and removals associated with enhancement activities included in the FRL. The activity data for Deforestation was developed using Remote Sensing data on detection of changes in forest area in three change assessment points within the reference period (forest loss data in Table 12). Activity data for enhancements (A/R) was obtained from the annual records of the FNC (Table 13). However, as explained in section 6.2, the average annual removals are estimated based on the accumulated removals in areas planted since 2006 and till 2018, adjusted by 60 percent (survival rate). For estimating Deforestation FRL, Sudan used country specific emission factors from NFI 2017 and wood density data, in addition to 2006 IPCC defaults values for Root-Shoot Ratio (Table 17). For the estimating the Enhancement FRL, Sudan used MAI and Root-Shoot Ratio values from the 2006 IPCC Guidelines in addition to national wood density data (Table 18). The FRL includes the value of the net average annual change in carbon stock due to deforestation and the value of the average annual accumulated CO_2 removals from the A/R activities, both during the same reference period (2006-2018), as shown in Table 19 below.

Table 19: Sudan's Proposed Subnational FRL

States	Enhancement of Forest Carbon Stocks (A/R)	Deforestation	
	t CO_2/yr	**t CO_2 / yr**	**CI in 95% perc**
Sinnar	**-128,054**	**243,138**	**47%**
El Gadarif	**-100,529**	**304,542**	**57%**
Blue Nile	**-59,646**	**675,605**	**41%**
Total	**- 288,229**	**1,223,286**	**46%**

9. Historical Period Considered

Sudan selected relatively a longer reference period (2006-2018) to ensure covering important development in its national polices and circumstances that have led to deforestation and forest degradation in the area of the sub-national level, but also similarly affected forest areas in other parts of the country. This includes the effect of the green revolution policies implemented in late 1970s, 1980s and till mid 1990s, when fast forest and woodland areas have been cleared for crop production, the so call mechanized rainfed agriculture. The affected land areas continued to be cultivated in the absence of proper extension services and appropriate cultivation practices, a situation led to a large area of lost productivity in central Sudan (highest population intensity area) and is now severely degraded or degrading. Another example is the agriculture investment policies, which led to large foreign investment in agricultural sector both rainfed and irrigated farming. The secession of South Sudan in 2011 with its richest forest resources also happened during this period. A final example, is the forest Act issued 2002, which allocate 10% of the rainfed agricultural schemes and 5% of the irrigated agricultural farms to forestry. Given the development in national policies and circumstances in the country as indicated above, and also taking into consideration the guidance from UNFCCC, FCPF and REDD+ financing communities (e.g. GCF) Sudan selected a reference period of 13 years starting 2006 and ending 2018 when REDD+ programme has started its implementation phase.

10. Adjustment for National Circumstances

Sudan's current forest and related policies development framework is considered conducive for REDD+ implementation. However, future reforms in the current forest and related policies are also underway as a result of the outcomes of the REDD+ readiness programme. The reference period selected for this sub-national FREL/FRL, is considered representative in terms of capturing the effect of the development in forest and related policies and regulations. Accordingly, Sudan does see the need to future undertake an adjustment to the propose FREL/FRL in this submission. However, further work on the effects of policy development on forest management and implementation of REDD+ activities will be studied in the future submission of the national FREL/FRL.

11. Updating Frequency

The sub-national FREL/FRL is planned to be updated as part of the development on the national FREL/FRL, in line with the expected development in the activity data and other parameters based on the completion of the NFI and the work currently undertaken by the REDD+ readiness programme and the national inventory team of Higher Council for Environment and Natural Resources (HCENR). Also updating of the FREL/FRL is expected based on experiences gained and improvements in the methods used and their application. Further updates in future will depend on the development on NFI, remote sensing and related research data, in addition to the development in the international guidance, methods and standards.

12. Future Improvements

Sudan followed a stepwise approach as guided the UNFCCC decisions and started at the sub-national level in order to develop required knowledge, experience, resources and capacities within its national institutions. The experience gained in the preparation of the current FREL/FRL, reveal the need to improve application of methods and tools, activity data, emission factors and other parameters to inform and improve the development of the national FREL/FRL.

12.1. Improvement of Activity Data

The activity data (AD) used in the construction of the present sub national FREL/FRL was based on the accessible remote sensing data and technologies, current institutional capacities and expertise. The US sanctions hindered Sudan ability to access and utilize cost-effective, high-resolution imageries that could have further improved the quality of the activity data. However, this situation is expected to improve after the current political change in Sudan and expected to result in a better access to advanced technology in remote sensing.

Specific activities will be planned for the improvement of AD, in particular land cover classification, in order to provide high quality data and information for future national FREL/FRL submission. This will include provision of high-resolution imageries, strengthening the capacity of the staff, providing technical support on the up-to-date remote sensing and GIS technology and their application in forest monitoring. In addition, to use the permanent sample plots network (land truthing). Sudan also planning to use advanced remote sensing technologies such as RADAR and LIDAR for mapping and biomass estimation.

12.2. Improvement of Emission Factors

The emission factors and other parameters used in this submission were derived from the ongoing National Forest Inventory (NFI 2017) and available published data. NFI (2017), which is still being finalized, provides a good opportunity though establishing permanent sample plots network all over the country, to improve the available field data. The network of permanent plots is distributed in a grid across the country and will be assessed on a regular cycle of measurements, thus enabling a time-series database to be established. Measurements will provide accurate data including on stand volume, biomass, increment, and tree species in addition to site productivity and biological diversity. Moreover, country specific allometric equations to calculate biomass and volume will be developed to increase accuracy of volume estimates. The ongoing project on NFI is also planning to develop country specific parameters such as wood density and root shoot ratio for number of dominant tree species in the country.

12.3. Inclusion of other REDD+ Activities

This FREL/FRL submission covers only two activities: deforestation and enhancement of carbon stocks (A/R), other REDD+ activities are not yet covered, mainly because of lack of data. Forest degradation is a significant REDD+ activity in Sudan, however, it was not included in this submission. For assessing deforestation, used accessible historical Landsat images (TM, ETM, OLI 30 m and SPOT 20 m) to create land-cover maps that are suitable for detection of deforestation with good accuracy. However, these are not suitable to monitoring forest degradation with the same level of accuracy.

Sudan intends to undertake further work to include forest degradation its national FREL/FRL through improving relevant national records, developing ground observations data including through the permanent sample plots established by the recent NFI (2017), and to use very high spectral and spatial resolution remote sensing data. The role of conservation and sustainable management (SFM) of forest also has a potential to be included in future improvements of the national FREL/FRL since these approaches have been introduced in Sudan since 1932.

12.4. Inclusion of deadwood

Currently dead wood in Sudan and the FRL region is difficult to estimate with reasonable accuracy, because in all rural areas of Sudan the significant amount of deadwood is collected directly by local communities living in proximity to the forests to meet their energy demands and this is not captured in available records. In Sudan biomass energy represents more than 60% of the energy balance. There is data available, in the Forest National Corporation (FNC), on wood removals, official harvest and based on collection of royalties. However, wood removals are mostly extractions from live forests (natural or plantations) and used directly as wood fuel or converted to charcoal, the data records of FNC are not complete, since significant amount of wood removals is happening through direct collection by local people for energy and other domestic needs, and these are not recorded by FNC. The NFI 2017 is expected to give Sudan the first indication on the amount of dead wood remaining in the forests. However, this is yet to be evaluated and there is obvious need to conduct a household surveys in order to estimate the amount of dead wood directly collected by people from the forests, which according to national experts is significant. Sudan intends to review and improving the data on deadwood based on the NFI 2017 results and considers the inclusion of this pool in its future FREL/FRL submission.

12.5. Inclusion of forest Fires

In the context of Sudan, forest fires are considered important by the REDD+ readiness programme, however, the effects of forest fires on the forest carbon stocks need to be understood and estimated in the future. Most of the Acacia species that are dominant in the forest cover are less affected by forest fires e.g. *A. Seyal*. However, there are some other species in natural forests and plantations (e.g Eucalyptus) sensitive to forest fires. Sudan Still has no comprehensive fire management strategy and the current fire related activities are limited to opening of fire lines within some forest reserves and protected areas.

In February 2019, in the framework of its REDD+ readiness in Sudan, Food and Agriculture Organization of the United Nations (FAO) in collaboration with the Forests National Corporation (FNC) and the Remote Sensing & Seismology Authority (RSSA) initiated a series of workshops targeting the states that are most affected by forest fires including Darfur, Kordofan, and Blue Nile. The intention of the workshops was to initiate discussions with natural resources specialists, stakeholder, beneficiaries and local leaders about the current situation of fire management, as well as means and ways to establish a well-equipped national fire monitoring system including institutional arrangements. The REDD+ readiness programme-initiated work on forest fire monitoring system, using Remote Sensing techniques, aiming to prepare historic forest fire maps for the period 2000-2018 in order to identify and visualize forest fire hotspots. These maps are expected to provide data suitable for consideration of the effects of forest fires in future National Forest Reference (Emission) Level and national Greenhouse Gas Inventories.

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14. ANNEXES:

ANNEX (1): List of images used for AD

ASTER	Landsat

1	AST_L1T_00302262006081408_20150513081112.tif	171051_20181220
2	AST_L1T_00304062006081350_20150508151807.tif	172050_20180226
3	AST_L1T_00304062006081358_20150508151822.tif	173050_20181218
4	AST_L1T_00304062006081407_20150508151822.tif	172053_20181211
5	AST_L1T_00304062006081416_20150508151822.tif	171052_20181227
6	AST_L1T_00304062006081425_20150508151822.tif	171053_20181220
7	AST_L1T_00304062006081434_20150508151829.tif	172051_20181211
8	AST_L1T_00304062006081443_20150508151839.tif	172052_20181211
9	AST_L1T_00304062006081502_20150522052405.tif	172049_20181227
10	AST_L1T_00304062006081949_20150512033116.tif	171050_20181211
11	AST_L1T_00304062006081951_20150508122625.tif	173049_20181227
12	AST_L1T_00304062006081958_20150512033116.tif	173051_20181227
13	AST_L1T_00304062006082000_20150508122628.tif	172049_20141216
14	AST_L1T_00304062006082006_20150508173616.tif	171053_20141225
15	AST_L1T_00304062006082007_20150512033114.tif	171051_20141209
16	AST_L1T_00304062006082016_20150512033125.tif	171050_20141225
17	AST_L1T_00304062006082601_20150508144452.tif	171052_20141209
18	AST_L1T_00304062006082609_20150508144452.tif	172050_20141216
19	AST_L1T_00304062006082615_20150512054143.tif	172051_20141216
20	AST_L1T_00304062006082624_20150512054144.tif	172053_20141216
21	AST_L1T_00312182006080822_20150522074030.tif	172052_20141216
22	AST_L1T_00312182006080830_20150522074048.tif	173049_20141216
23	AST_L1T_00312182006080839_20150522074038.tif	173050_20141216
24	AST_L1T_00312182006080848_20150522074045.tif	173051_20141216
25	AST_L1T_00312182006080857_20150522074050.tif	171050_20100128
26	AST_L1T_00312182006080906_20150522074058.tif	171051_20100128
27	AST_L1T_00312182006081433_20150522125849.tif	171052_20100112
28	AST_L1T_00312182006081442_20150522125844.tif	171053_20100128
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30	AST_L1T_00312182006081453_20150522052356.tif	172051_20100204
31	AST_L1T_00312182006081500_20150522125852.tif	172052_20100204
32	AST_L1T_00312182006081504_20150517195634.tif	172049_20100204
33	AST_L1T_00312182006081508_20150522125848.tif	172053_20100204
34	AST_L1T_00312182006081513_20150517195634.tif	173049_20100219
35	AST_L1T_00312182006081517_20150522125848.tif	173050_20100126
36	AST_L1T_00312182006082019_20150521224623.tif	173051_20100211
37	AST_L1T_00312182006082025_20150517115848.tif	
38	AST_L1T_00312182006082028_20150521224623.tif	
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42	AST_L1T_00312182006082102_20150518034649.tif	
43	AST_L1T_00312182006082110_20150518034649.tif	

44	AST_L1T_00312182006082119_20150518034650.tif	
45	AST_L1T_00312182006082128_20150518034650.tif	
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53	AST_L1T_00303302006081502_20150513183821.tif	
54	AST_L1T_00303302006081511_20150513183818.tif	
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57	AST_L1T_00304062006081443_20150508101313.tif	
58	AST_L1T_00304062006081452_20150508101323.tif	
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64	AST_L1T_00306042006081425_20150508101323.tif	
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66	AST_L1T_00312182006081520_20150522052418.tif	
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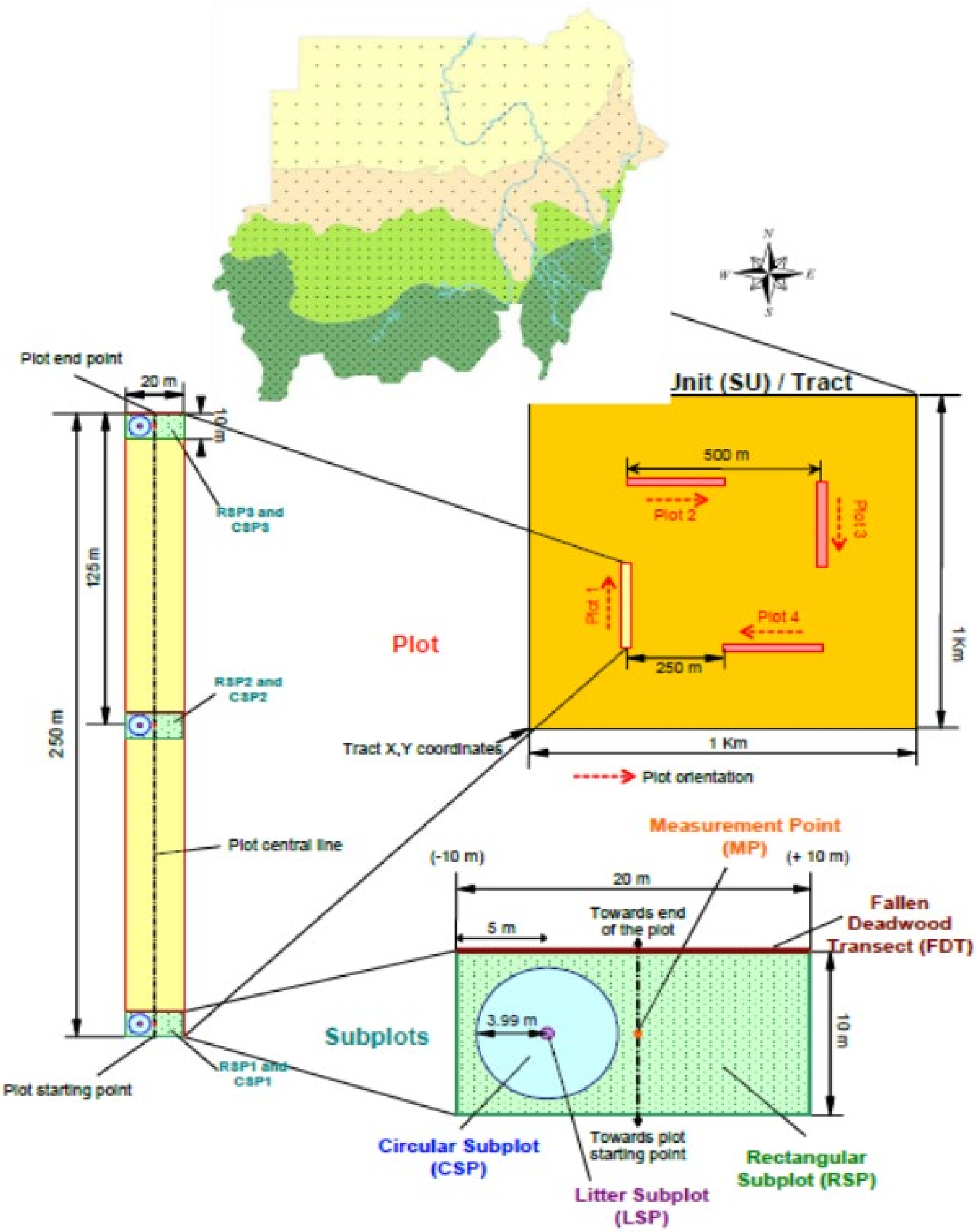
109	AST_L1T_00304062006081520_20150522052418.tif	
110	AST_L1T_00304062006082049_20150513205500.tif	

ANNEX (2) Afforestation and Reforestation 2000 - 2018

Sinnar State																				
Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Official A/R	3090	3464	3664	3645	398	4280	3638	3369	7337	2982	3514	5771	4402	6697	3980	4630	1576	5655	7134	
Popular A/R	124	161	179	160	30	92	53	450	254	217	23	34	55	5027	491	1213	1213	176	160	
total	3214.5	3624.5	3843.4	3805.1	428.2	4371.4	3690.9	3818.5	7590.6	3198.8	3537.3	5804.5	4456.3	11724.0	4470.5	5842.8	2789.3	5830.8	7293.0	
Blue Nile State																				
Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Official A/R	425	400	2915	825	375	425	1315	1285	3541.75	2502.5	302.5	196	307.25	381.5	602.25	360	314.75	343	841.05	
Popular A/R	250	750	1000	750	750	1000	1750	750	1000	955	625	366	582.5	1750	1750	1381.5	858	4665	1500	
Total	675.0	1150.0	3915.0	1575.0	1125.0	1425.0	3065.0	2035.0	4541.8	3457.5	927.5	562.0	889.8	2131.5	2352.3	1741.5	1172.8	5008.0	2341.1	
Gedarif State																				
Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Official A/R	3675	3818	4192	3336	3628	4085	2563	2405	7107	3857	2900	3951	3837	3723	2506	1846	3077	2998	3784	
Popular A/R	341	361	119	600	250	250	475	335	500	500	250	500	500	250	414	406	415	404	392	
Total	4016.4	4178.7	4310.5	3935.5	3877.5	4335.0	3037.5	2739.5	7607.0	4356.5	3149.5	4451.0	4336.5	3972.5	2919.8	2251.6	3492.0	3401.9	4176.4	

ANNEX (3a): Description of the sample unit



ANNEX (3b): Land Use Classes (LUCs)

<table>
<tr><th>Level 1</th><th>Level 2</th><th>Level 3</th><th>Brief description</th><th>Code</th></tr>
<tr><td rowspan="10">Forest</td><td colspan="3"><u>National Definition</u>: Forest means land bearing a vegetative association and spanning more than 0.5 ha (or 0.42 ha =an equivalent of a Sudanese feddan) with trees at least 2m high and a minimum tree canopy cover of 10%; or young forests stands that have not yet reached but are expected to attain these thresholds in situ. It does not include land that is predominantly under agricultural and/or agro-forestry production systems or urban land use.</td><td>F</td></tr>
<tr><td rowspan="6">Natural regenerated forest</td><td colspan="3">Forest predominantly composed of trees established through natural regeneration.</td></tr>
<tr><td>Evergreen forest</td><td>Naturally regenerated forest composed of more than 75% of evergreen trees species. Includes :
• Moist forest
• Dry forest</td><td>FE</td></tr>
<tr><td>Deciduous forest</td><td>Naturally regenerated forest composed of more than 75% of deciduous trees species. Includes :
• Moist forest
• Dry forest
• Secondary young</td><td>FD</td></tr>
<tr><td>Semi-deciduous forest</td><td>Naturally regenerated forest where trees are at least 25% each of evergreen and deciduous species. Includes :
• Moist forest
• Dry forest
• Secondary young</td><td>FSD</td></tr>
<tr><td>Bamboo forest</td><td>Naturally regenerated forest predominantly composed of bamboo vegetation.</td><td>FB</td></tr>
<tr><td>Raffia/Palms</td><td>Naturally regenerated forest predominantly composed of palm or raffia vegetation.</td><td>FRP</td></tr>
<tr><td rowspan="3">Plantation</td><td colspan="3">Forest predominantly composed of trees established through planting and/or deliberate seeding. Includes coppice from trees that were originally planted or seeded.</td></tr>
<tr><td>Broadleaved planted forest</td><td>Planted forest composed of more than 75% of broadleaved species.
Includes:
• Eucalyptus sp.
• Acacia sp.
• Gravillia</td><td>FPB</td></tr>
<tr><td>Coniferous planted forest</td><td>Planted forest composed of more than 75% of coniferous species.
Includes :
• Cupressus lusita.
• Juniperus
• Pinus patula</td><td>FPC</td></tr>
</table>

		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%**			***W***
	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***
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).***			***O***
	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 areas spanning between 0.2 and 0.5 ha ,*	***OWB***

Level 1	***Level 2***	***Level 3***	***Brief description***	***Code***
Forest	***<u>National Definition</u>: Forest means land bearing a vegetative association and spanning more than 0.5 ha (or 0.42 ha =an equivalent of a Sudanese feddan) with trees at least 2m high and a minimum tree canopy cover of 10%; or young forests stands that have not yet reached, but are expected to attain these thresholds in situ. It does not include land that is predominantly under agricultural and/or agro-forestry production systems or urban land use.***			***F***
	Natural regenerated forest	***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	*Naturally regenerated forest where trees are at least 25% each of evergreen and deciduous species.* Includes :	***FSD***
Water	**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***

		forest	• Moist forest • Dry forest • Secondary young	
		Bamboo forest	*Naturally regenerated forest predominantly composed of bamboo vegetation.*	***FB***
		Raffia/Palms	*Naturally regenerated forest predominantly composed of palm or raffia vegetation.*	***FRP***
	Plantation	***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%**			***W***
	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***
	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).			***O***
	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*	***OG***

			and herbaceous vegetation.	
		Marsh	*Land seasonally or permanently covered by water and dominated by natural growth of graminea, reed and other herbaceous.*	***OM***
Other Land	**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.***			***IW***
	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 (4): Wood Density of Species dominant in deforested area

Species	WD	Source
Acacia tortilis f. raddiana	0.44	FNC 2019, Integrated Carbon Sequestration Project Establishment of Biomass Carbon Baseline
Boswellia papyrifera	0.720	Robert Nygård*and Björn Elfving (1999), Stem basic density and bark proportion of 45 woody species in young savanna coppice forests in Burkina Faso. https://hal.archives-ouvertes.fr/hal-00883170/document.
Dalbergia melanoxylon	0.817	Robert Nygård*and Björn Elfving (1999), Stem basic density and bark proportion of 45 woody species in young savanna coppice forests in Burkina Faso. https://hal.archives-ouvertes.fr/hal-00883170/document.
Albizia Amara	0.7	FAO: Appendix 1 - List of wood densities for tree species from tropical America, Africa, and Asia. http://www.fao.org/3/w4095e/w4095e0c.htm Also in the IPCC 2006, chapter 4 table 4.13
Anogeissus leiocarpus	0.73	Ogunwusi, A.A. and Onwualu,A.P and 2Ogunsanwo, O.Y (2013) Comparative Analysis of Wood Properties of Afzelia africana and Anogeissus leiocarpus Growing in Nigeria. Chemistry and Materials Research www.iiste.org ISSN 2224- 3224 (Print) ISSN 2225- 0956 (Online) Vol.3 No.3, 2013
Balanites aegyptiaca	0.63	IPCC 2006, Chapter 4, table 4.13
Albizia amara	0.70	IPCC 2006, Chapter 4, table 4.13
Acacia Seyal	0.7	Tarig O. Khider and Osman T. Elsaki, 2012. Heat Value of Four Hardwood Species from Sudan, JOURNAL OF FOREST PRODUCTS & INDUSTRIES, 2012, 1(2), 5-9
Acacia Senegal	0.7	Tarig O. Khider and Osman T. Elsaki, 2012. Heat Value of Four Hardwood Species from Sudan, JOURNAL OF FOREST PRODUCTS & INDUSTRIES, 2012, 1(2), 5-9
Acacia Mellifera	0.7	Tarig O. Khider and Osman T. Elsaki, 2012.

		Heat Value of Four Hardwood Species from Sudan, JOURNAL OF FOREST PRODUCTS & INDUSTRIES, 2012, 1(2), 5-9
Acacia Nilotica	0.8	M. A. Elfdl, 1985. Biomass estimation and energy content of acacia nilotica in the Blue Nile Master thesis , University of Khratoum

ANNEX 5: Form Factors

Spp	Form factor	Sources
Acacia seyal	0.5 Okalma 0.45 khor Domya	El Dool, Y. M. (1988). Status report on existing reserved forests. Prepared for the World Bank/IDA Sudan Forestry Project. Khartoum: Forests Administration, Sudan.
Acacia seyal	0.42	Anwar Sidahmed et al., (2020), Inference of Tree Biophysical Parameter, Volume and Carbon using Synthetic Aperture Radar data
Acacia seyal	0.45	Aamir Osman Ali Elmaleeh, 2003. An approach for study wood supply from Acacia seyal stands on El Gadarif State, A case study: Wad Elkheseid natural forest reserve A Thesis for the Degree of Master of Science in Forestry, UOK
Acacia seyal	0.56 to 0.66 plantation	Dafa-Alla Mohamed Dafa-Alla and Eltayib H. M. A. Abidallha, 2014. Management of Acacia seyal plantations for charcoal production: Local economies and sustainability U. of K. J. Agric. Sci. 22(2), 208-223
Acacia Senegal	0.4 khor donya and Okalma	El Dool, Y. M. (1988). Status report on existing reserved forests. Prepared for the World Bank/IDA Sudan Forestry Project. Khartoum: Forests Administration, Sudan.
Balanites Eagyptiaca	0.6	El Dool, Y. M. (1988). Status report on existing reserved forests. Prepared for the World Bank/IDA Sudan Forestry Project. Khartoum: Forests Administration, Sudan.
Combretum sp	0.5 in khor donya	El Dool, Y. M. (1988). Status report on existing reserved forests. Prepared for the World Bank/IDA Sudan Forestry Project. Khartoum: Forests Administration, Sudan.
Euclyptus microtheca	0.8 khor donya	El Dool, Y. M. (1988). Status report on existing reserved forests. Prepared for the World Bank/IDA Sudan Forestry Project. Khartoum: Forests Administration, Sudan.

Acacia seyal	Okalma 0.45	Esmat ,H, A. 2015. Comparative Study on Application of Volume Tables and Tariff equations for Selected Tree Species in Sudan, Master thesis, University of Khaartum
Acacia nilotica	0.54	FNC

ANNEX 6: NFI 2017 data on V/ha for the FRL region

Averages Trees Volume m³/hectare

Land use level 1 and State				
Averages Volume m³/hectare				
State	**Land use level 1**			
	Forest	**Other Wooded Land**	**Other Land**	**Inland Water**
Mature Tree > 10 cm				
1. Blue Nile	18.194866	2.164891	0.84065	2.705591
2. El Gadarif	3.647553	3.334519	0.425862	10.569581
3.Sennar	20.941668	0.618516	0.013418	0
Small tree < 10 cm				
1. Blue Nile	3.55838	4.305307	0.561333	0.825826
2. El Gadarif	2.765726	0.958464	0.031599	0
3) Sennar	1.160902	0	0.15248	0

Sampling error (%) of Volume, at 95% CI

Land use level 1 and State				
Sampling error (%) of Volume				
State	**Land use level 1**			
	Forest	**Other Wooded Land**	**Other Land**	**Inland Water**
Mature Tree > 10 cm				
1. Blue Nile	46.72	64.01	80.87	272.40
2. El Gadarif	96.31	70.13	49.26	140.83
3.Sennar	51.51	200.58	192.05	0
Small tree < 10 cm				
1. Blue Nile	39.11	3.22	58.19	272.40
2. El Gadarif	86.24	45.99	105.77	
3) Sennar	78.35		71.08	0

ANNEX 7: List of Contributors

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