Federal Republic of Nigeria

National Forest Reference Emission Level (FREL) for the Federal Republic of Nigeria

Federal Department of Forestry
Federal Ministry of Environment
Federal Republic of Nigeria

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CONTACT INFORMATION

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List of Acronyms

AGB	Aboveground Biomass
AD	Activity Data
BGB	Belowground Biomass
CO2	Carbon dioxide
CP	Conference of the Parties
DCC	Department of Climate Change
EF	Emission Factor
FAO	Food and Agriculture Organisation of the United Nations
FME	Federal Ministry of Environment
FORMECU	Forestry Management and Evaluation Coordinating Unit
FRA	Global Forest Resources Assessment
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
FRIN	Forestry Research Institute of Nigeria
GFOI	Global Forest Observations Initiative
GHG-I	Greenhouse gas Inventory
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Landuse, Landuse Change and Forestry
MCCF	Ministry of Climate Change and Forestry
MRV	Measurement, Reporting and Verification
NAGIS	Nasarawa State Geographic Information Services
NAMA	Nationally Appropriate Mitigation Actions
NASRDA	Nigerian Air Space Research and Development Agency
NDC	Nationally Determined Contribution
NESREA	National Environmental Standards & Regulations Enforcement Agency
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
SAE	Stratified Area Estimate
SEPAL	System for Earth Observation Data Access, Processing and Analysis for Land Monitoring
SLMS	Satellite Land Monitoring System
UNFCCC	United Nations Framework Convention on Climate Change

List of Appendices

1. Introduction

The Federal Republic of Nigeria welcomes the invitation to submit a Forest Reference Emission Levels (FREL) on a voluntary basis as expressed in Decision 12/CP.17, paragraph 13. This FREL submission is in the context of results-based payments for the implementation of reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+) under the United Nations Framework Convention on Climate Change (UNFCCC).

The government has followed the guidance provided by the UNFCCC through the decisions taken at the Conference of the Parties (CP), notably the modalities for forest reference emission levels and forest reference levels in Decision 12/CP.17 and the guidelines for submission of information on reference levels in the Annex of Decision 12/CP.17. This submission does not prejudge or modify any of Nigeria's Nationally Determined Contributions (NDCs) or Nationally Appropriate Mitigation Actions (NAMAs) pursuant to the Bali Action Plan.

The Government intends to take a step-wise approach to its national FREL development as stated in Decision 12/CP.17, paragraph 10. As such, the current FRL reflects the best available information at the time of submission at national level. The scope and methodologies applied can be modified whenever improved data becomes available; and taking into account the previously submitted sub-national FREL. The historical period considered, and/or the construction approach could also be revised.

2. FREL development process

The construction of the FREL in Nigeria began with the development of a sub-national FREL for Cross River State which was submitted to the UNFCCC for the technical assessment in 2018. The present national FREL is a follow up to the sub-national FREL, which up-scales it to national level. The entire FREL process was also subjected to a wider stakeholder consultation and review to ensure that it reflects the expectations of all stakeholders, and to also consider technical inputs from this broader group.

2.1 Description of relevant policies and plans

Community landuse plans (CLUPs) operational in some states as well as the National Forest policy (NFP) were used in the construction of FREL. The CLUPs are community-driven plans used to promote forest conservation and to safeguard community forests form being destroyed for agricultural purposes. While the NFP has the overall objective of achieving sustainable management of forests and forest resources that would ensure sustainable increase in the economic, social and environmental benefits for the present and future generation, including the need to among others (i) increase, maintain and enhance the national forest estate through sustainable and forest management practices; (ii) address the underlying causes of deforestation, forestland degradation and desertification. (iii) Ensure sustainable wildlife resources management, biodiversity conservation and environmental services of forest including carbon sequestration, and water and soil biodiversity conservation

(iv) promote and sustain good forest governance; (v) sustain and enhance the role of the forestry sector in climate change mitigation and adaptation, and stakeholders access to benefits;

3. Scale of FREL: Area covered

Nigeria's REDD+ Programme envisioned a two-track approach to achieve REDD+ readiness, based on: (i) the development of institutional and technical capacities at Federal level, and (ii) consolidating four key UNFCCC requirements for REDD+ Readiness (Warsaw Framework for REDD+ elements) on a pilot basis in Cross River State. The present FREL is national and draws from the sub-national FREL that Nigeria submitted to UNFCCC in 2018.

3.1 Geographical location, relief, climate, soils and Vegetation of Nigeria

The Federal Republic of Nigeria (henceforth referred to as Nigeria), is located on the West coast of Africa between latitudes 3°15' to 13°30' N and longitudes 2°59' to 15°00' E (**Figure 1**). It is bordered by Benin in the West, Niger in the North, Chad and Cameroon in the East, and the Gulf of Guinea in the Atlantic Ocean to the South. Nigeria is the 14th largest country in Africa with a land area of 923,768km^2 of which 910768 km^2 is land and 13,000 km^2 is water (FGoN, 2017[1]); and the most populated country in Africa, with an estimated population of over 182 million by late 2016 (cf. Vanguard, 2016 and Nigeria, NPC, 2017 in **FGoN, 2018**).

Nigeria is located mainly within the lowland humid tropics, characterized by high temperatures of up to 32^{o}C in the coastal south and up to 41^{o}C in the North. The climate varies from very wet

[1] FGoN (2017). Federal Republic of Nigeria. Retrieved June 15, 2017, from http://www.nigeria.gov.ng/

typical in coastal areas with annual rainfall greater than 3500mm to dry in the Sahel region in the North West and North-Eastern parts, with annual rainfall below 600mm.

Nigeria has two main relief regions: the high plateaux ranging between 300 and more than 900m above sea level, and the lowlands, which are generally less than 300 m.

The high plateaux include the North Central Plateau, the Eastern and North Eastern Highlands and the Western Uplands. The lowlands comprise the Sokoto Plains, the Niger-Benue Trough, the Chad Basin, the interior coastal lowlands of Western Nigeria, the lowlands and scarplands of South Eastern Nigeria and coastlands. Most of the country’s rivers take their sources from four main hydrological basins: the North Central Plateau (Sokoto-Rima, Hadejia, Gongola, and Kaduna rivers etc.), the Western Uplands (Moshi, Awun, Ogun, Osun, Osse rivers etc.), the Eastern Highlands (Katsina-Ala, Donga rivers, etc.) and the Uri Plateau (Anambra, Imo and Cross rivers etc.).

Map No. 4228 Rev. 1 UNITED NATIONS
August 2014

Department of Field Support
Cartographic Section

Figure 1 Geographical Location of Nigeria in Africa

The soils in Nigeria (see Figure 2) can broadly be categorized into four groups: sandy soils in the Northern zone; lateritic soils in the interior zone; forest soils in the Southern belt; and alluvial soils. The Northern zone of sandy soils lies in the very Northern parts of the country, particularly in the Sudan and Sahel zones. In some parts, (e.g. Kano, Kaduna and Sokoto States), they are mainly fine sandy loam soils, friable, and relatively easy to cultivate and good for agricultural crops, particularly groundnuts. In some parts of the extreme Northern Guinea savanna and Southern Sudan savanna, (e.g. in Southern Kaduna State), there is a mixture of soils disintegrated from the local granite, and loess soils brought down by winds from the North. The fertile loam soils found in the Zaria region are particularly good for agricultural crops like cotton.

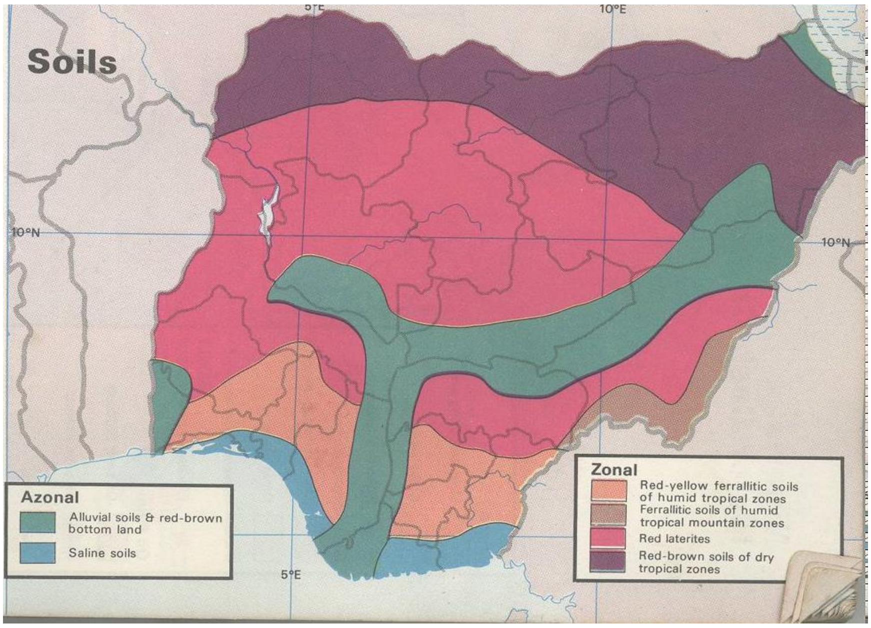


Figure 2 Soil map of Nigeria (Source: Nigeria Environmental Report)

The interior zones of lateritic soils are generally found in the guinea savanna, deeply corroded and grey or reddish in colour. The Guinea savanna also has rich lava soils (e. g. in Biu plateau) that are productive and offer good prospects for agricultural expansion. The Southern belt of forest soils coincides roughly with the high forest belt where the wet season is long; and where vegetation plays the double role of supplying humus to the soil and protecting it from erosion. The soils here are used to produce cash crops such as cocoa, palm produce and rubber. The zone of alluvial soils contains soils, which are formed by recent water deposits, and therefore are found on the flooded plains of rivers, or on deltas, or along the coastal flats. The zone extends from the coast inland,

and runs along the valleys of the Niger and the Benue, thus cutting across the vegetation belts. Along the courses of rivers, the soils are sandy, and often sterile.

3.2 Ecological Zones of Nigeria

The ecological zones in Nigeria are based on Keay (1949), and are defined from South to North as follows: Mangrove Swamp and Coastal Vegetation, Freshwater Swamp Forest, Lowland Rain Forest, Derived Savanna, Guinea Savanna, Sudan Savanna, and Sahel Savanna. A few mountainous areas are found in the Jos Plateau, Adamawa, Taraba and Northern part of Cross-River State (**Figure 3**).

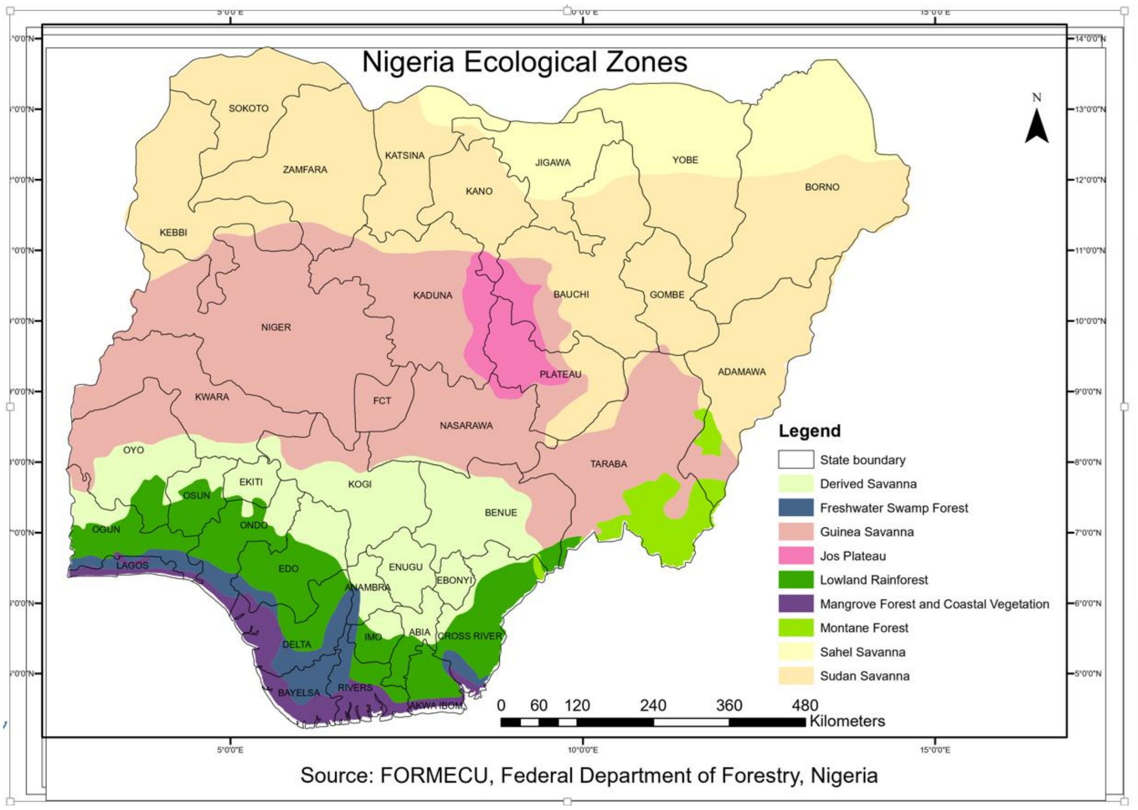


Figure 3 Ecological zones of Nigeria

3.2.1 Mangrove Forest and Coastal Ecological Zone

Mangrove forest is found along the coastal and delta areas of Nigeria where the water is brackish. The most prominent feature of the mangrove forest are the stilt roots of *Rhizophora spp.* which do not penetrate the ground but divide beneath the water surface to form a peculiar thick felt raft. Mangroves are dominated by the following species: *Rhizophora racemosa, R. mangle, R. harrisonii, Avicennia africana* and *Laguncularia racemosa. R. racemosa* is the biggest of the R*hizophora spp.,* and can attain heights of up to 40 meters and accounts for up to 95% of the species content of the mangrove forest. In Cross River State, the mangroves are threatened by the exotic Nypa Palm, *Nypa fruticans,* that was introduced into Calabar and Oron between 1906 and 1912, and has spread to other Niger states such as Rivers, Delta and Bayelsa. The palm tends to form pure stands and isolate endemic mangrove trees. Mangrove wood provides excellent fuel, which burns even when the wood is fresh (Udo, 1978), and because the wood is not readily attacked by termites, it is used for building, mining props and railway sleepers.

3.2.2 Freshwater Swamp Forest Ecological Zone

The Freshwater swamp forest forms a wide belt inland after the mangrove and coastal vegetation. The zone has more open canopy, which may reach 45 m in height, densely tangled, and almost impenetrable undergrowth. It is usually flooded during the wet season and dries out during the dry season leaving portions of dry forest floor interspersed with permanent pools of water. Much of this vegetation type has been converted to agricultural and urban lands, and the original swamp forest remains mostly on alluvial sites along the major rivers. Climbing palms with hooked spines are particularly characteristic as are clumps of large aroids such as *Cyrtospernia senegalense.* Large trees such as *Mitragyna ciliata, Spondianthus preussii, Lophira alata, Anthostema aubryanum* and *Alstonia congensis* occur with smaller trees such as *Nauclea gilletii, Berlinia spp., Grewia coriacea,* and *Uapaca spp.* A number of tree species in this ecological zone have stilted roots. The *Raphia* palm (*Raphia hookerii*) and *Lonchocarpus griffonianus* are usually abundant in the outer fringe vegetation which seldomly exceeds 14 m in height. Behind the fringe, the trees of the freshwater swamp may reach 30 m in height.

3.2.3 Lowland Rain Forest Ecological Zone

This Lowland Rain Forest is located north of the freshwater swamp forest and south of the Derived Savanna Ecological Zone to the North. It is an area of dense evergreen forest of tall trees with thick undergrowth consisting of three layers of trees: the emergent layer with trees more than 36 m high; the middle layer between 15-30 m; while the lowest layer is generally below 15

m. The understorey is a shrub stratum composed of single-stemmed shrubs. The forest in the Northern parts of the zone is characterised by a number of species belonging to the *Sterculiaceae* family, but the *Ulmaceae* and *Moraceae* families are also common. Characteristic species of the lowland rain forest are *Terminalia superba, Ricinodendron heudelotii*, *Aubrevillea kerstingii* and *Khaya ivorensis.* The families *Meliaceae* and *Fabaceae* make up a large proportion of the tree species in the wetter Southern areas of this zone. In still wetter areas the *Sapotaceae* are prominent and the timber trees *Lophira alata* and *Nauclea diderrichii* are often abundant. While a few areas of the rainforest remain untouched (undisturbed) with top canopy closely interlocked, most rainforest has been disturbed/degraded through conversion to agricultural farmlands, indiscriminate felling and wood removal, except for parts of the Cross River State. In some areas, tropical rain forests have become limited to forest reserves, national parks and game reserves, which are also encroached. The legend classes "disturbed forest" and "undisturbed forest" were also used in the delineation of this zone.

3.2.4 Derived Savanna Ecological Zone

The Derived Savanna constitute an east-west band between the Lowland Rain Forest and Guinea Savanna ecological zones, and is characterized by dense populations. The appearance and composition of Derived savanna, apart from the vestiges of Lowland rainforest, are much the same as in the Southern areas of Guinea Savanna. However, in some areas especially where man's impact on the forests has been high, there is a considerable reduction of vegetation/plant species. The impact of man has been so intense in this area that areas left to regrow tend to grow savanna type grasses, thus creating a "derived savanna". Remnants of the high forest may be present in upland or rocky areas that are not suitable for agriculture.

3.2.5 Guinea Savanna Ecological Zone

The Guinea savanna (or savanna woodland/wooded savanna) is the most extensive vegetation in the middle belt of Nigeria, and consist of a mixture of trees and grass. It receives annual rainfalls between 1000 – 1500 mm with about 6-8 months of rainfall. It contains parkland savanna, gallery forests and derived savanna. The typical vegetation is an open woodland with tall grasses (1 to 3m high) in open areas and trees (up to 15m high) usually with short boles and broad leaves. This vegetation is burnt almost annually by fierce fires in the dry season, therefore fire-resistant species predominate.

The parkland savanna is a by-product of centuries of tree devastation by man and fire, and a continuous attempt by plants to adapt themselves to the climatic environment, by developing long tap roots and thick barks, which enable them to survive the long dry season and resist bush fires.

Species in the Southern areas of the Guinea Savanna zone include *Lophira lanceolate, Terminalia glaucescens, Daniellia oliveri, Hymenocardia acida, Vitex doniana, Detarium microcarpum* and *Afzelia africana.* All these species have thick bark capable of resisting grass fires. Species of the Northern Guinea Savanna show close affinities with the East African "miombo" woodlands, and include, *Isoberlinia doka, ldalzielli, Monotes kerstingii* and *Uapaca togoensis.* Open canopy is dominated by grass, shrubs (e.g., *Gardenia spp.* and *Protes elliottii)* and woody climbers (e.g. *Opilia celtidifolia* and *Uvaria chamae)*.

3.2.6 Sudan Savanna Ecological Zone

The **Sudan savanna** belt is found to the Northern parts of Nigeria, and stretches from the Sokoto Plains through the Northern section of the High Plains of Nigeria to the Chad Basin. It includes areas around Sokoto, Kaduna, Kano and Borno States of Nigeria, comprising an area over a quarter of the country. Rainfall ranges from about 600-1000 mm and the relative humidity is generally below 40%, except for the few rainy months when this can rise to 60% and above. The zone experiences a dry season of about 4-6 months. The zone has the largest population density in Northern Nigeria, produces important economic crops such as groundnuts, cotton, millet, and maize and has the highest concentration of cattle in the country. Sudan savanna has consequently suffered great impact from man and livestock. The landscape has less vegetation than the Guinea savanna. Existing vegetation consist mainly of short grasses, about 1-2 m high, and some stunted tree species, such as Acacia species, the silk cotton *Ceiba pentandra* (silk cotton) and the *Adansonia digitata* (baobab).

3.2.7 Jos Plateau Ecological Zone

Jos Plateau Ecological Zone is based on the distinctness of the vegetation of the plateau (altitude about 1200 m) for two reasons. First, the high plateau has suffered widespread degradation by man so that only relics of Guinea woodland remain. Presently, the plateau is almost devoid of trees. Second, the flora on the Plateau is peculiar with many species of woody and herbaceous plants not found elsewhere in West Africa, alongside many typical Guinea Savanna species. The endemic species peculiar to the Jos Plateau include *Terminalia brozenii, Morea zambesiaca* and the orchids *Disperis johnstoni* and *Disa hircicornis.*

3.2.8 Montane Region Ecological Zone

These highlands and plateaus are characterized by grassland vegetation at the base, forest vegetation on the windward slope and grassland vegetation on the Plateaux. The lower slopes of highlands located in the forest belt such as Bamenda Highlands (in Cameroon) and the Obudu Hills are covered with forest vegetation, while the upper slopes and the plateau surfaces have grassland vegetation, which normally supports cattle population.

This region is found along the southEastern border of Nigeria in the Cameroon mountains. Forest vegetation extends as high as 1600 to 2400 m and ecotone with mountain grassland. There are two main types of montane forest. From about 1000 to 1800 m altitude the forest is enveloped in mist for long periods and is referred to as Mist Forest. The tree canopy is irregular and is composed of species such as *Polyscias ferruginea, Entandrophragma angolense, Turreanthus africanus* and at higher altitudes *Schefflera hookeriana* and species of *Ficus* and *Conopharyugia.* The high humidity results in a profusion of mosses and various kinds of epiphytes. Above the mist zone the forest is drier, more stunted, and more susceptible to fire. Typical tree species include *Syzygium standtii, Schefflera abyssinica, Schefflera mannii, Lachnopylis mannii* and *Pittosporum mannii.* Masses of lichens beard the branches of the trees. At the upper limit of the forest there is a scrubby zone of *Rapanca neurophylla, Agauria saheifolia* and *Laisiosiphon glaucus.* In the lower grasslands most of the grasses are tussocky, have flat leaves, and reach 0.6 m in height, or slightly more. The family *Compositae* is well represented in this grassland. At about 3000 m there is a marked change, the flat-leaved tussocky grasses, such as *Andropogon distachvus* are replaced by grasses with more compact shorter tussocks of narrow rolled leaves, such as *Festuca abyssinica.* Trees are absent from this upper grassland, with only a few bushy plants such as *Blaeria mannii, Senecio clarenceanus* and *Helichrysum mannii.*

3.2.9 Sahel Savanna Ecological Zone

The **Sahel** savanna, is found to the extreme Northwest and Northeast of the country, where the annual rainfall is less than 600 mm and with dry seasons exceeding 8 months. Typically the vegetation consists of grasses, open thorn shrub savanna with scattered trees, 4 to 9 m in height most of them are thorny, and extensive sparse grasses. Main tree species include *Acacia raddianna, A. Senegal, A. laeta* and *Commiphora africana;* the shrubs are *Salvadora persica, Leptadenia pyrotechnica,* and four species of Grewia; while the grasses include *Aristida stipoides, Schoenefeldia gracilis* and *Chloris priean.* The legend class "dominantly grasses with discontinuous shrubs and scattered trees" was the primary class used to delineate this ecological zone. The class extensive small holder rainfed agriculture with denuded areas" was also common in this ecological zone.

3.3 Description of Land use /land cover classification scheme for Nigeria

The classification system adopted is based on a national land use and cover classification scheme developed in 1995 mapping project in Nigeria (FORMECU, 1998), The classification consisted of 36 land use/land cover classes, but it was deemed necessary to aggregate the classes into a few easily mapped classes that can be distinguished with high confidence on satellite imagery. In consultation with relevant stakeholders working in the land base sector in Nigeria (e.g. the National Space Research and Development Agency (NASRDA), the 36 classes were aggregated into 12 classes which were further grouped into forest and non-forest classes. The forest classes include, Undisturbed Forest (UF), Disturbed Forest (DF), Mangroves (M), Forested Freshwater Swamp (FWS), and Forest Plantation (FP). The non-forest classes include Arable land (AL), Grassland (G), Savannah Woodland (SW), Tree Crop Plantation (TCP), Settlements (S), Bare Surfaces (BS) and Water Body (WB). **Figure 4** shows the aggregated FORMECU Vegetation/Land Use Map (1993/1995) using the 12 land use classes. It is important to emphasise that the classification system described in this section does not affect the generation of the activity data used for the development of this FREL. Sections 3.2 and 3.3 were included essentially to provide information on how Nigeria arrived at its classification system for multi-class landuse/landcover mapping but was never in any way considered in this FREL due to the Country's preference for GFC map leading to the production of the three-class map (Stable Forest, Stable Non-forest, and Forest Loss) used in the FREL. (See Chapter 6) *i.* ***Undisturbed Forest (UF):*** This forest type include high forest of evergreenhydrophilic (water tolerant) plant of high species diversity, the canopy can be of three layers with the topmost (emergent layer) of 24-50 meters high which may consist of scattered, very tall trees that do not form a continuous canopy. The middle layer (16-40 m high) is also discontinuous but taken together with the upper layer form a continuous canopy. The lower tree layer (10-16m high) forms a more or less continuous canopy. Below the trees are the shrubs and herbs layers that contain young trees and seedlings with the canopy closure of at least 70%. This could be found mainly in the southern Nigeria.

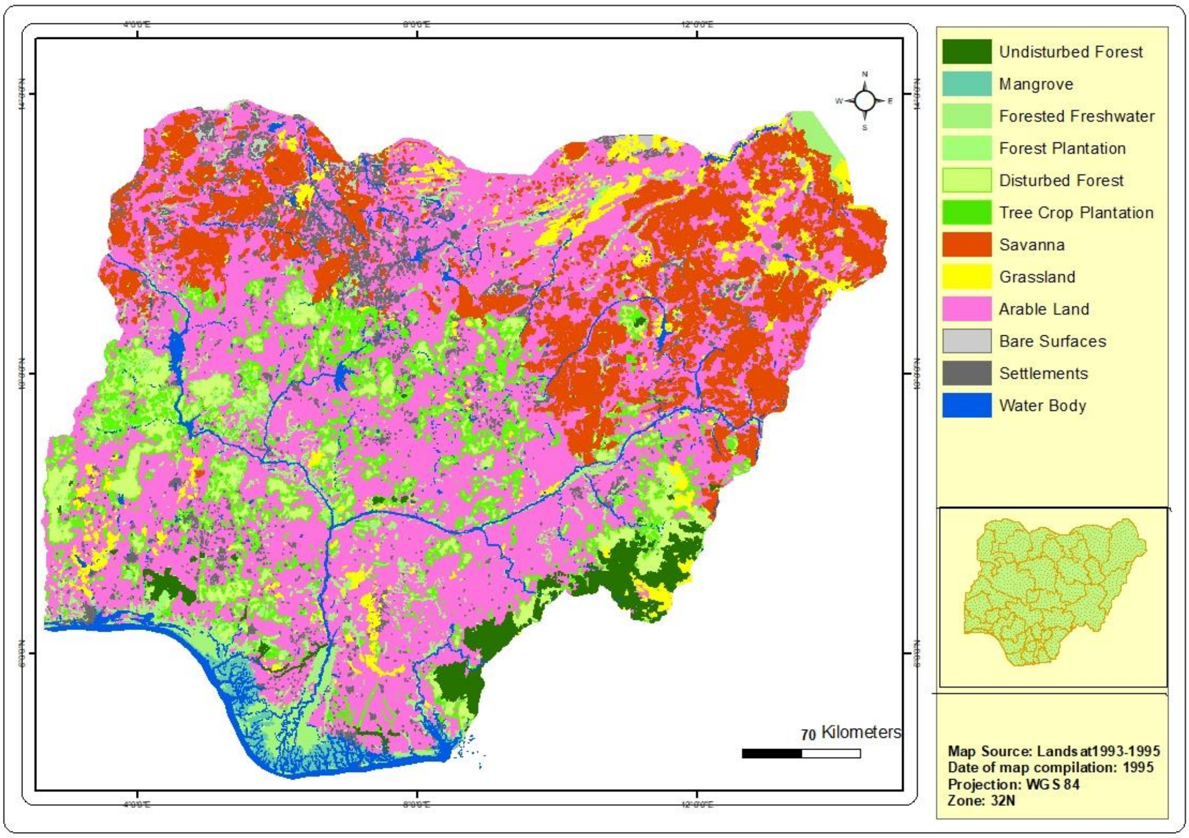


Figure 4 Nigeria Land cover 1995 (Source: FORMECU)

ii. ***Disturbed Forest (DF)****:* The forest type is similar to the undisturbed forest except that it has been degraded by cultural activities. The canopy can be two or three layers but usually the topmost layer comprises of scattered trees and the canopy closure is between 30% and less than 70%. This is usually referred to as secondary vegetation as it can include abandoned farmlands and fallow lands.

iii. ***Freshwater Swamp (FWS)****:* This land cover types comprise of all type of vegetation along the freshwater, river banks and marshy areas. The canopy closure can range between 60 to 100 percent depending on the nature of cultural activities taking place. They are usually inaccessible for logging but fuel wood harvest is common and can be found in the lower course of the big river channel. The signatures in the medium resolution images are similar to the disturbed forest but they are usually found in close proximity to fresh water river channels.

iv. ***Mangrove Forest (M):*** Mangrove forest is marine vegetation type found in close proximity to the ocean, creeks and estuaries. They can be pure stand or with mixture of other vegetation such as Nypa palm, Raphia and other vegetative bluff. The canopy closure is usually between 30% and 70% depending on the nature of logging activities taking place in the creeks.

v. ***Forest Plantation (FP):*** This represents forest cover that was planted for commercial logging or conservation purposes, which includes both public and private owned forest plantation estate scattered across the country. The signatures of forest plantation on the images are similar to the disturbed forest or tree crop plantation but the canopy closure usually ranges between 60% and 70% and can contain one or more layers. The canopy closures in matured forest plantation can be less due to logging and fuel wood harvesting.

vi. ***Arable Land (AL)***: This type of land cover represents all lands for arable agriculture and are represented by regular boundaries of cultivation which are distinct from fallow land and secondary vegetation. This is one of the most varied land use classes in the country. The crops often grown include millet, sorghum, and maize in the northern parts of Nigeria, while yam, cocoyam, and cassava, intermixed with maize are the dominant crops in the southern part of Nigeria. The land use and cover types include intensive row crops with minor grazing, large assemblages of small plot farms. The signature of cropland varies markedly as you progress from south to the north.

vii. ***Savanna Woodland (SW):*** This non forest class is mainly found in the Guinea and Sudan Savanna ecological zones of Nigeria which includes grasslands but with scattered trees. The presence of trees can range between 4 to 10 trees per hectare and have signatures that are very similar to grassland and bare land depending on the period or seasons of data capture.

viii. ***Grassland (G):*** This non forest class represent continuous grassland often interspersed with patches of bare soil. It is predominant in most parts of northern Nigeria especially where overgrazing and wood harvest have degraded savannah woodland to largely grassland; and where erosion processes can further degrade them to bare land.

ix. ***Tree Crop Plantation (TCP)****:* Tree crop plantations are characterized by regular boundaries similar to arable land but usually have very tall tree crop and have two or three layers of vegetal storeys. The tree crop plantation includes cocoa, rubber and palm plantations, mostly found in the southern rainforest, mangrove and forested freshwater areas. The signatures on the satellite images are similar to disturbed forest but they could be distinguished by their regular shaped boundaries. A typical tree crop plantation can have a canopy closure of up to 70% depending on the nature of the tree crop and the farming system used.

x. ***Bare Surfaces (BS):*** This class represents land surfaces with no plant cover. It may be covered with aeolian deposits or sand dunes; or could be an overgrazed area or area of massive wind or water erosion.

xi. ***Settlements(S)****:* Settlements represent human habitation in form of villages, towns and cities which are scattered all over the country and have signatures of very high tones. The signatures of the roof tops of cities in the southern part of Nigeria especially the older part of the city is relatively brownish while the tone in the northern parts are greyish.

xii. ***Water Bodies (WB):*** This class represents all types of water including, streams, rivers, lake, ponds, dams and oceans etc. The signature can vary according to the location, size and depth.

4.0 Scope: Activities, Pools and gases included

4.1 Activities included

The Cancun Agreement defines REDD+ activities as follows: reduction of emissions from deforestation, reduction of emissions from forest degradation, sustainable management of forests, enhancement of forest carbon stocks, and conservation of forest carbon stocks. Deforestation is the conversion of forest land to non-forest land (cropland, grassland, settlement, wetlands and other lands). Forestland is considered as in the forest definition adopted for Nigeria (see **section 5**), and any conversion below the threshold of forest definition is considered deforestation. Deforestation is currently the only REDD+ activity included in the submission due to the fact that this is considered the most significant REDD+ activity and the lack of reliable data to assess the remaining REDD+ activities with sufficient reliability.

Forest degradation results in the loss of carbon stocks and biodiversity in the forest remaining forests category, while enhancement is both the enrichment in carbon stocks and biodiversity in forest remaining forest and non forest land converted to forest land. Nigeria believes that all carbon fluxes from forest are covered through the activities deforestation (forest land to non forest land), degradation (emissions from forest land remaining forest land) and enhancement (both non forest land converted to forest land and removals in forest land remaining forest land). The activities sustainable management of forest and conservation fully overlap with these three activities.

4.1.1 Omission of forest degradation

While forest degradation (from logging, fuel wood extraction, charcoal production, forest fires, etc.) may constitute a significant source of emissions, it has not been included in the present FREL due to lack of reliable, accurate and consistent data at state and federal levels. It is envisaged that forest degradation will eventually be included in a stepwise manner, as data becomes available.

4.1.2 Omission of enhancement of forest carbon stocks

Nigeria considers the REDD+ activity “enhancement of forest carbon stocks” to be both enrichment in carbon stocks in forest remaining forest, as well as enrichment in carbon stocks through afforestation/reforestation and natural regeneration of forest. The country has promoted natural forest restoration and plantation silviculture that leads to reduction in emissions from deforestation and forest degradation. However, no reliable data on forest enhancement is available, so this REDD+ activity has not been included in the present FREL submission. Nigeria would like to include this activity in the future in order to assess the performance of its afforestation and restoration efforts.

4.2 Pools included

While IPCC recognises five carbon pools: above ground (live tree) biomass, belowground (live tree) biomass, deadwood (standing and lying/down), litter, and soil organic carbon; only significant pools need to be included (cf. SBSTA Decision from COP17). Key category analysis is needed to determine which carbon pools should be included to capture significant emissions and removals from changes in forest cover, taking into account their magnitude and cost-effectiveness to monitor the pools. The above-ground biomass constitutes the main component/largest pool and has been included in the FRELs/FRLs. Belowground biomass constitutes a significant pool however, its estimation is expensive and was indirectly undertaken using IPCC default root-to-shoot (R/S) ratio. With the present national forest inventory design, data was collected to estimate deadwood pool and this pool is now included.

4.2.1 Omission of litter

Litter and non-herbaceous biomass pools constitute a small proportion of biomass and has not been included. For tropical forests litter pools are usually small except for peatlands. According to the 2006 IPCC Guidelines, litter pool can be estimated at a tier 1 level for deforestation. The 2006 IPCC Guidelines provides a default value of 2.1 tC/ha for tropical broadleaf deciduous forests (see Table 2.2: Chapter 2, IPCC 2006). During the inventory undertaken, litter and non-herbaceous pool was sampled on $1m^2$ quadrats in some plots in the Derived Savanna, Lowland Rainforest, and Montane, and the analysis found that litter contents was 1.61 tC/ha for Derived Savanna, 2.06tC/ha for Lowland Rainforest, 8.65 tC/ha for Montane (4.96tC/ha for the aggregated Lowland Rainforest and Montane); corresponding to 2.3%, 2.1%, 7.5% (4.9% aggregate) respectively of the total live biomass estimated for the different ecological zones. These percentages are low, and could be omitted, given the tedious and cost incurred to sample the litter pool.

4.2.2 Omission of soil organic carbon

Soil organic carbon (SOC) is an important carbon pool, however major changes in the soil carbon stock only occur when forest is converted to non-forest, and the emissions occur over a long period of time. IPCC distinguishes between mineral soils and organic soils (peatlands). According to the harmonized world soil database (HWSD: Batjes, 2009) Nigeria has mainly low activity clay (LAC) soils, high activity clay (HAC) and wetland soils in the coastal region, which are mineral soils. Nigeria estimated emissions from deforestation happening on mineral soils and explored further data to confirm the absence of peatlands in the country.

Estimation of emissions from mineral soils

Deforestation in Nigeria is most common in the Guinea Savanna forest and Lowland Rainforest (see section 6). To estimate per hectare emissions from soils associated with deforestation, Nigeria follows IPCC Equation 2.25:

$$\Delta C_{Mineral} = \frac{\left(SOC_0 - SOC_{(0-T)}\right)}{D}$$

$$SOC = \sum_{c,s,i} \left(SOC_{REF_{c,s,i}} \times F_{LU_{c,s,i}} \times F_{MG_{c,s,i}} \times F_{I_{c,s,i}}\right)$$

Where:

ΔC Mineral = annual change in carbon stocks in mineral soils, tons C yr-1

SOC_0 = soil organic carbon stock in the last year of an inventory time period, tons C

$SOC_{(0-T)}$ = soil organic carbon stock at the beginning of the inventory time period, tons C

SOC_0 and $SOC_{(0-T)}$ are calculated using the SOC equation in the box where the reference carbon stocks and stock change factors are assigned according to the land-use and management activities and corresponding areas at each of the points in time (time = 0 and time = 0-T)

T = number of years over a single inventory time period, yr

D = Time dependence of stock change factors which is the default time period for transition between equilibrium SOC values, yr. Commonly 20 years, but depends on assumptions made in computing the factors FLU, FMG and FI. If T exceeds D, use the value for T to obtain an annual rate of change over the inventory time period (0-T years).

c = represents the climate zones, *s* the soil types, and *i* the set of management systems that are present in a country.

SOC_{REF} = the reference carbon stock, tons C ha^{-1}

F_{LU} = stock change factor for land-use systems or sub-system for a particular land-use, dimensionless

F_{MG} = stock change factor for management regime, dimensionless

F_I = stock change factor for input of organic matter, dimensionless

Instead of the default IPCC reference carbon stock, Nigeria uses a recent study by Akpa *et al.* (2016) that estimates forest soils (0-30cm) to contain 49.9 tC/ha in Nigeria. The values for F_{LU}, F_{MG} and F_I are selected from IPCC 2006 guidelines (Table 5.5). The F_{LU} value varies between 0.58 – 1, the F_{MG} value between 0.93 – 1 and the F_I value between 0.88-1, suggesting per hectare emissions from soil to be in the range of 0.44 – 1.05 tCO_2/ha/yr. The weighted average EF for deforestation is 198 tCO_2/ha meaning even after 20 years the cumulative emissions from soil would still be <10% of emissions from the other pools for deforestation. As such, emissions from soil are estimated not to be significant.

Potential emissions from organic soils

Nigeria reviewed different literature sources which estimate the extent of peatland in the country. The estimates range according to one source between 120 km^2-7000 km^2 (Page *et al* 2011), or between 1,100 km^2 (Joosten, 2009) and more than 21,000 km^2 (CIFOR). However, the area suggested by the CIFOR study (**Figure 5**) appears to be the mangrove and fresh water swamp ecological zone in Nigeria. Part of these may be on peatlands but it is more likely that the CIFOR study approximated potential peatlands including all locations with wet soils and therefore the estimate of 21,000 km^2 is likely an overestimation. Nonetheless, if there is any peatland in Nigeria it would likely occur in the Mangrove/Freshwater swamp ecozone. Deforestation in this ecozone is not widespread, with only 4% of the country's deforestation occurring in this ecozone (see section 6) and only a fraction of that could be potentially on peat soils. Furthermore, in addition to deforesting the land it would also need to be drained for peat soil emissions to occur. Therefore, with the current available data it seems emissions from deforestation happening on peat soils are not significant and can be omitted.

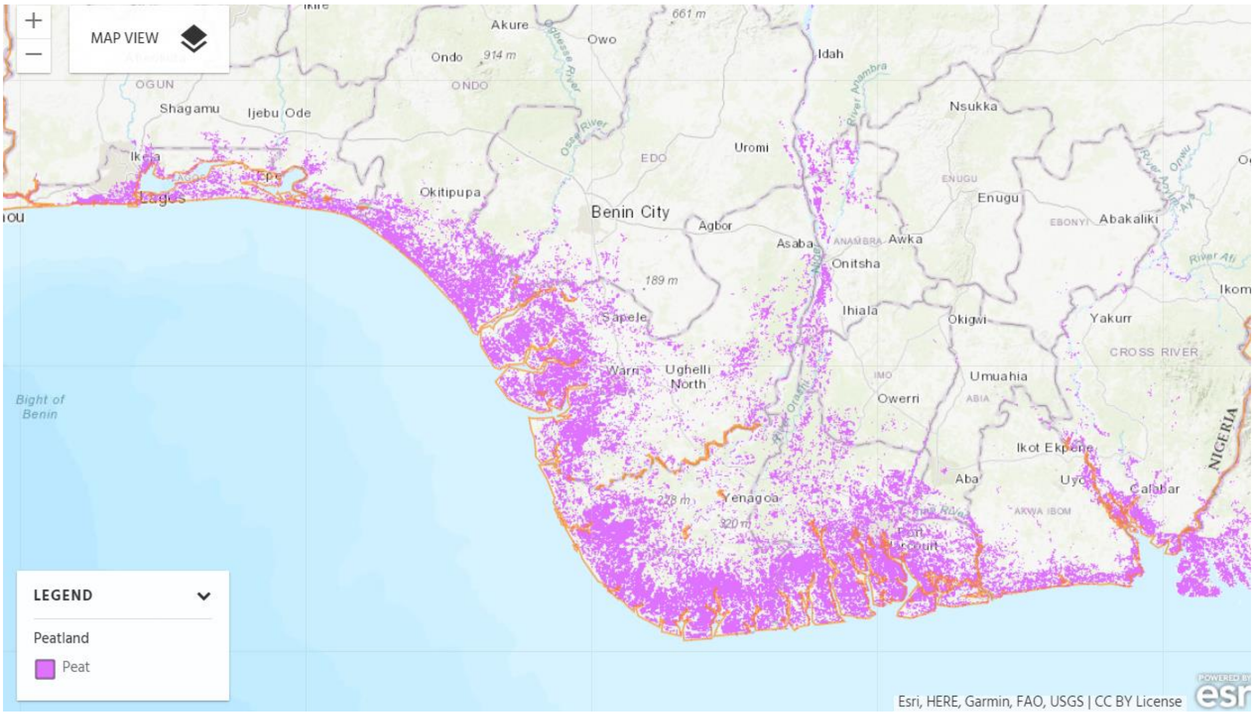


Figure 5 Potential areas of peatlands in Nigeria (Source : https://www.cifor.org/global-wetlands/)

4.3 Gases included

Among the three greenhouse gases associated with land use change emissions, namely carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), CO_2 is the main gas emitted in the forest sector. However, significant non-CO_2 gases (CH_4 and N_2O) can also be emitted when land use change is as a result of fire incidences. Unfortunately, no data exist on forest fire. However, based on our knowledge of the region we can conclude that fires are relatively controlled and not very frequent, as such emissions from fire are not expected to be significant. Methane is also produced when mangroves are disturbed, but no data exist in Nigeria at the moment. Therefore, only CO_2 emissions have been considered in the present submission.

4.3.1 Omission of non-CO_2 gases

To assess whether non-CO2 emissions from fire are significant or not, Nigeria has used IPCC equation 2.27 using the average burned forest area as estimated by FAO (FRA 2015) for Nigeria for the years falling in the reference period of the FREL (2006-2016) for which data is available in FRA 2015 (2006-2012).

$$L_{Fire} = A \times M_B \times C_f \times G_{ef}$$

Where:

L_{fire} = amount of greenhouse gas emissions from fire, tons of each GHG e.g., CH_4, N_2O, etc.

A = area burnt, ha

M_B = mass of fuel available for combustion, tons ha^{-1}. This includes biomass, ground litter and dead wood.

C_f = combustion factor, dimensionless

G_{ef} = emission factor, g kg^{-1} dry matter burnt

As such, the average burned forest area, A, is approximately 12,571 ha per year. For M_B, Nigeria uses the weighted EF for deforestation (115 tdm/ha) as obtained from the NFI. For C_f the value 0.59 is taken from the default values provided by IPCC in Table 2.5 and for G_{ef} the values 104, 6.8 and 0.2 are taken for CO, CH_4 and N_2O respectively from IPCC Table 2.5. Finally the values are converted into CO_2 equivalent multiplying with 2, 21 and 310 for CO, CH_4 and N_2O respectively. The final estimate suggests emissions from non-CO_2 gases associated with forest fire consist of 352,348 tCO_2 per year or 1.1% of the total emissions. Nigeria therefore concludes that emissions from non-CO_2 gases are not significant.

5.0 Forest Definition

When submitting a FRELs/FRLs to the United Nations Framework Convention on Climate Change (UNFCCC), countries are expected to provide a definition of what they mean by forest in their FREL/FRL construction and, demonstrate how the definition is in line with the definition used in the national GHG inventory or in other international reporting. Forest definition in the context of REDD+ has to take into account UNFCCC thresholds which are currently defined as follows:

- Minimum tree crown cover between 10 and 30%
- Minimum land area between 0.05 and 1 hectare
- Minimum tree height between 2 and 5 meters (at maturity *in situ*)

Nigeria had no country-specific forest definition, but had been using the FAO FRA default definition for forests, which is defined as follows:

"Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use".

During the workshop of 24th to 26th May 2016, participants went through brain storming sessions in order to craft a forest definition for FREL purposes. An initial stage involved an appraisal of existing definitions and/or descriptions of forest in the forest laws, policies and Acts and other documents. They explored and reviewed some policy documents, at Federal and State levels, in order to have an in-depth understanding of what the law and policies documents consider as forest across the different States. Based on the above background information, participants arrived at the following functional forest definition for FREL/FRL in Nigeria.

*An ecological community predominated by trees and other layers of woody plants with a minimum area of **0.5ha**, a minimum tree height of **3metres**, and a minimum tree canopy cover of **15%**, or stands with potentials to reach the above thresholds in situ.*

The above Forest Definition applies to the entire country and was provided after due consideration for the ecological variations including the characteristic strong latitudinal zones which become progressively drier as one moves North from the coast. In other words, the definition has to a large extent, taken care of the progressive variations from the Mangrove Swamp and Coastal Vegetation in the south to the Sahel Savanna in the North. It is important to note that, the definition would be used in future GHG inventory reporting such as national communications and the Biennial Update Reports (BUR).

Further details on the consultations and processes undertaken to arrive at the forest definition were detailed in the sub-national FREL submitted by Nigeria to UNFCCC in January 2018.

Nigeria's position is to discourage policy decisions that could catalyse deliberate clearing of natural forest for plantation. In line with this, the issue of including forest plantation was critically considered during the forest definition crafting sessions consequent to which it was decided to exclude forest plantation and tree crop plantation from the definition. But while applying this definition during the image interpretation, it became challenging to differentiate between natural forest and plantation forest especially where the latter is consistent with the natural forest boundaries, this was made even more complex by the fact that separate class was not created to map forest plantation.

On this note, Nigeria wishes to affirm that forest plantation is part of what was considered as stable forest and forest loss in its FREL submission. Tree crop plantation comprising of cocoa, kolanuts, oil palm, etc. was apparently excluded as locations of most of such feature are known to the interpreters. Besides, the ground truth points collected on the field focussed more on such areas and formed part of stable non-forest in the reference data used for the stratified map.

6. Estimation of Historical Emissions

IPCC (Guidelines for National GHG Inventories in AFOLU, 2006) provides the framework for estimating emissions and removals of CO_2 in the AFOLU sector. Two basic inputs needed are: Activity data (AD: the extent of human activities resulting in forest emissions/removals e.g. area of deforestation) and emission factors (EF/RF: that is, emissions/removals per unit 'activity', e.g. tCO_2/ha of deforestation). The product of AD by EF/RF produces an estimate of the amount of emissions/removals in a given year as a result of the activity.

6.1 Activity Data

Activity data is mostly obtained from land use change studies using satellite imagery. Several land use studies have been undertaken in Nigeria; however, their use is limited due to the fact that they were sample-based (not '*wall-to-wall*'), and used different methodologies and classification systems. The only study that produced wall-to-wall estimates of land use change was the 1976/78 and 1993/95 Vegetation and Land use Assessment by FORMECU, Federal Department of Forestry. The study also produced a national classification system for Nigeria that is being used for reporting of global forest assessment (e.g. FRA (2015) for Nigeria). These datasets are also outdated and obsolete.

6.1.1 Reference period

The initial reference period will include data from 2006 to 2016 and annual historical deforestation rates have been considered for this period. Nigeria has chosen this period seeking to follow guidance from the FCPF methodological framework (which suggests a preference for a recent 10-year period) and the GCF scorecard (which suggests a preference for a 10-15 year period).

6.1.2 General description of approach taken to collect AD

The approach taken for assessing the activity data (deforestation) over the reference period (2006-2016) is a stratified random sampling approach (Olofsson et al. 2013, 2014). The approach uses a land cover change map to stratify reference data points to be collected and the resulting statistics are referred to as stratified area estimators. Reference data was obtained through interpretation of very high spatial and temporal resolution satellite data which was carefully visually interpreted by experts skilled in interpreting remote sensing imagery and with good knowledge of the situation of the ground.

The points were further intersected with the ecological zone map to breakdown the activity data by ecozone class. The activity data per ecozone was calculated according to the methods for post-stratification of a stratified random sample as described in Stehman (2014). As Stehman (2014) notes, some of the post-strata (activity data class within the ecozones) are represented by few or no sample units. Nigeria identifies as area for improvement in the AD, the use of a larger sample size and consideration of the ecozones in the stratified random sampling design, to increase the accuracy of the emission estimates.

6.1.3 Creation of forest area change map used for stratification

A change map based on the Global Forest Change (GFC) tree cover and loss year layers (Hansen et al. 2013), and taking into account the national definition of forests in Nigeria was first established. The Nigeria map was created from Landsats 7 and 8, 30-metre resolution imagery using the following three classes: stable forest, stable non-forest, forest loss based on the GFC map with a tree cover threshold of 15% and a loss period from 2006-2016. The activity data (AD) is however derived from the reference data, the map is only used for stratification and the final estimates do not correspond to the areas in the map.

The layers from the version 1.4 of the Global Forest Change product (https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.4.html) were combined into a forest change map.

The criteria corresponding to the national definition of forests are:

i. 15% canopy cover;
ii. 0.5 ha minimum mapping unit.

The “treecover2000” layer from GFC, which contains information on percent tree cover in each 30m pixel for the year 2000, was first filtered with a value of 15% tree cover to match the canopy cover threshold in the forest definition. Next, all tree cover change between 2001 and 2005 was combined with the 2000 tree cover/non-tree cover to reclassify change before 2006 as non-tree cover and create a 2006 tree cover/non-tree cover map. In addition, adjacent pixels with the same value were grouped into patches and any tree cover patch smaller than 6 pixels were excluded from the forest class and considered “trees outside forest”, while all tree cover patches with size 6 pixels and above were considered “forest”. Using patch size and canopy cover to distinguish between tree cover and forest harmonizes the map classes with the forest definition. The minimum mapping unit (MMU) of the forest definition is 0.5 hectare, and the GFC product pixel size is 27.5m, grouped into six pixels as the minimum size does not underestimate the forest areas (27.5*27.5*6 = 0.45 ha).

Similarly, the “lossyear” layer was filtered for all values between 6 and 15 to only consider the loss occurring between 2006 and 2015. As the process applied to distinguish forest from non-forest, all tree cover losses with patch size 6 pixels or larger were considered “deforestation”.

For the final stratification, the map was aggregated into 3 classes of interest for the activity data estimates: stable forest, stable non-forest and deforestation. A probability based sample design, stratified by the 3 map classes, was used to distribute 1,215 samples to assess the area of deforestation, following the recommendations of Olofsson et al. (2013). The degradation pixel count was used as a preliminary indicator of the magnitude of degradation at the national scale.

The processing chain was implemented in the SEPAL cloud computing platform. A screenshot of the resulting forest change map (or activity data map) is provided in **Figure 7**.

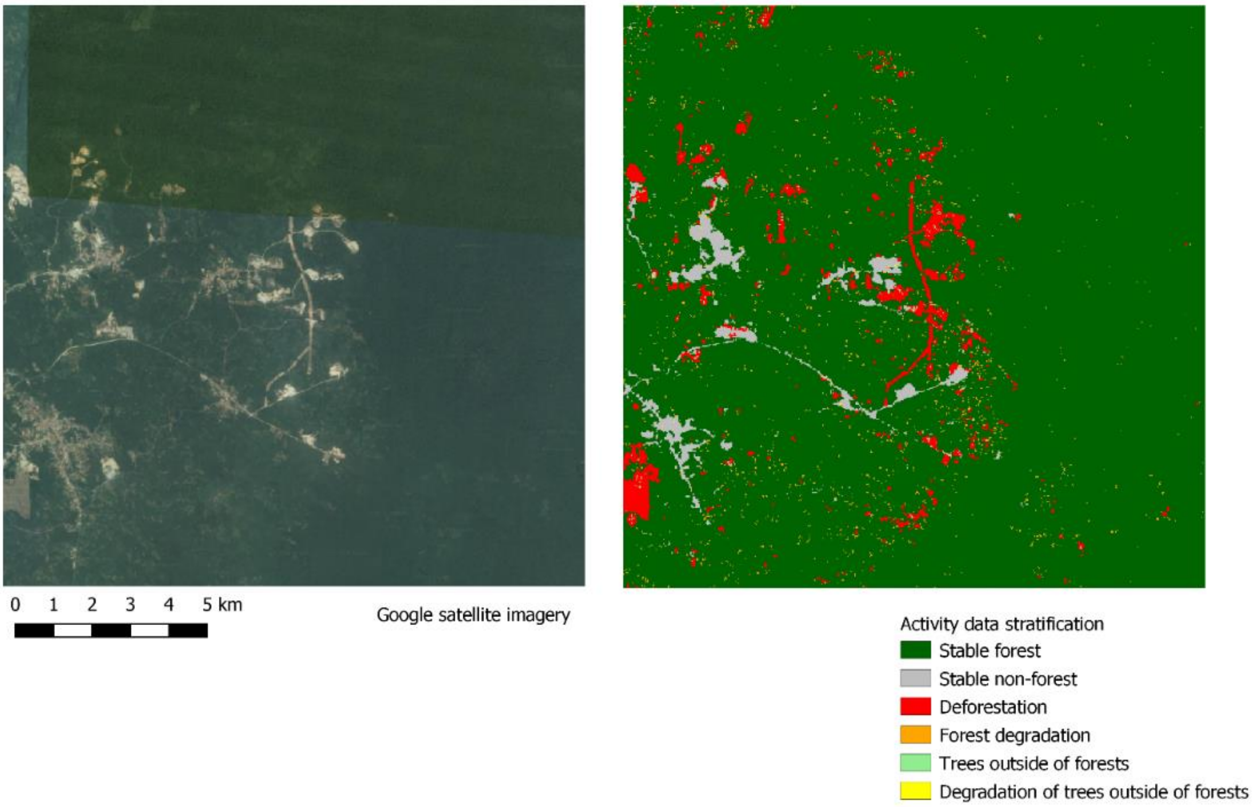


Figure 7 Detail of the forest change map created using GFC tree cover input

6.1.4 Reference data collection

GFOI (2016) suggests that for accuracy assessment and estimation to be valid for an area of interest (AOI) the reference data must be collected using a probability sampling design (McRoberts, 2014; FAO 2016). Nigeria adopted a stratified random sampling using the forest change map for stratification into three strata or classes: forest loss, stable forest and stable non-forest. Forest gain was not included as no reliable data was available for that period (GFC provides gain up to 2012 only). Gain can be added in the future when Nigeria has collected sufficient locations of known forest area increase.

The minimum number of reference data points to be collected per stratum were assessed following the formulas by Cochran (1977 in Olofsson et al 2014). This method assesses the accuracy of the map and stratified area estimates based on the reference data with associated confidence intervals. A total of 1215 samples were distributed in the 3 strata and assessed by the interpreters.

The sampling design was created using the stratified area estimator modality in SEPAL and resulted in the design shown in **Figure 8** below.

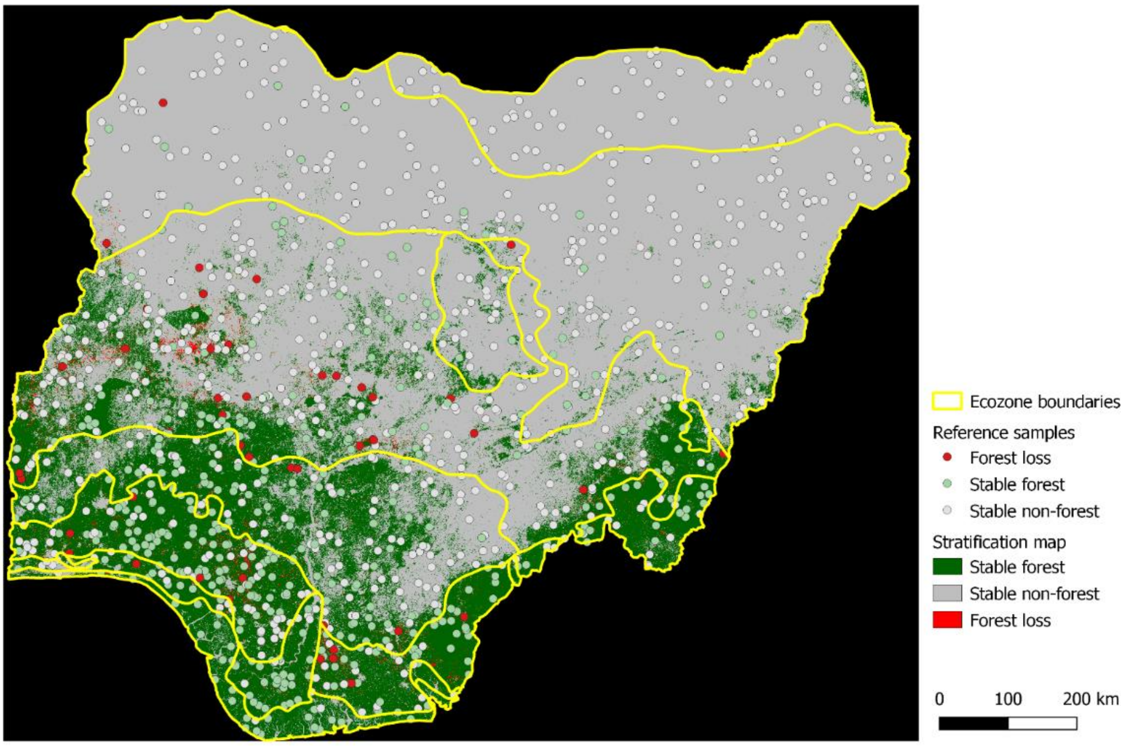


Figure 8. Sampling design based on the forest change map

The reference data was collected using Open Foris Collect Earth, a tool for collecting and storing samples collected through visual image interpretation. The reference data were generated and interpreted by 6 interpreters, providing a rigorous method for assigning the reference class labels for the samples. The interpretation between the 6 interpreters were compared and the class with the majority vote (the mode) between interpreters was used, in compliance with recommendations by McRoberts et *al*. (2018) to ensure high quality of reference data. There were 73 samples which did not have a majority vote (i.e., 3 interpreters labelled the sample as stable forest and 3 interpreters labelled the sample as stable non-forest). Those samples were reinterpreted by a panel of 4 remote sensing experts, who came to a consensus for a final interpretation of those sample points.

An example of omission of loss in the forest change map is provided below, i.e. the forest change map had classified below location as stable forest, instead the reference data interpretation suggested the reference point to concern forest loss.

Figure 9 Example of a sample from the reference data, this concerns an omission of forest loss by the forest change map. Imagery corresponds to 2005 (Left image) and 2014 (Right image**)**

Figure 8 only depicts an overlay of the changed map (created using GFOI data) and the 1,215 reference samples interpreted independently by six interpreters. Reference data are usually point data including ground truth data usually collected by direct visit to the field. Figure 9 represents the high resolution images (2005 and 2014) used to interpret the reference points as a result of changes that occurred between the two images. The reference points (samples) are disaggregated by the three change classes as can be seen in the Figure 8 legend.

Ground truthing/field checks were undertaken to identify and deduct tree crop areas forest areas by combining data obtained during the national forest carbon inventory where land use and land cover in the plots were described and their coordinates taken. Furthermore, 252 field checks were established for some unresolved classes on the images. The points were taken at random in four states where these ambiguities occurred, namely, Niger; Nasarawa in the savannah ecosystem; and Oyo and Ogun in the rainforest zones of the country.

As can be clearly observed, most part of the background (change) map in Figure 8 is grey representing stable non-forest, but by the time the reference points were overlaid on the background map, it was observed that some part of the grey areas are actually forest loss as represented by reference point in colour red. Same thing goes for the other two classes. The implementation of this correction was what was done during the stratified area estimation, a procedure that ensures that commission and omission errors are addressed.

This then underscores the importance of reference data which tends to correct what has been wrongly classified in the change map.

Concerning the temporarily un-stocked areas, the creation of 2005 and 2014 reference points was predicated on the three mapping classes (stable forest, stable non-forest, and forest loss) and thus limiting the results of the image interpretation to those three classes. The reference points were interpreted by several experienced interpreters using the best available imagery. Often high resolution imagery is available for more recent dates, therefore the interpreters had information on the current landuse for the sample unit interpretation and this information was applied. That means that if interpreters could see there was forest in 2017 but there was a loss in 2013, this concerned temporary loss. But if such loss in 2013 is within the threshold of 15% canopy cover as enshrined in Nigeria's forest definition, the area would still be interpreted as stable forest. However, it is important to note that the change period of about ten years is involved which might make identification of a temporarily un-stocked areas challenging. Reason being that, such an area at base year might have undergone regeneration over the ten-year period which might then qualify it to be classified as stable forest or forest loss as the case may be.

Looking at intermediary images might be necessary in our future submission, to enable monitoring of changes between the base and the target years in order to actually determine the temporarily un-stocked areas.

6.1.5 Stratification

In its first sub-national FREL submission for Cross River State, Nigeria applied a single weighted emission factor to approximate carbon loss per hectare deforestation. For its national FREL submission, Nigeria intended to improve the estimates by applying a stratification according to homogenous carbon contents. For this stratification, Nigeria follows the ecological zones with the associated vegetation types as described in section 3.2. However, to allow for sufficient representation of data per stratum, i.e. a statistically representative number of sample points for both the AD and EF estimates, Nigeria has aggregated some ecological zones based on proximity and homogeneity of the carbon contents in its associated forest types in **Table 1**.

Table 1 Ecological zones used for stratification AD and EF

Ecozone	**Vegetation types**
Mangrove and swamps	Mangrove forest and Freshwater Swamp forest
Rainforest and montane	Lowland rainforest and Montane forest
Derived Savanna	Derived Savanna forest
Guinea Savanna	Guinea Savanna forest
Dry Savanna	Sudan Savanna, Jos Plateau and Sahel Savanna forest

6.1.6 <u>Deforestation area estimates</u>

The error matrix and the stratified area estimates for the three classes (Stable Forest, Stable Non-forest, Forest Loss) were calculated using the formulas as found in Olofsson et *al* (2014). **Table 2** shows the error matrix for the interpreted samples while results of the accuracy assessment are presented in **Table 3** and has been based on the agreement amongst 3 interpreters. The overall weighted accuracy is **81%** with a confidence interval for forest loss of **± 46%.** The results were also analysed by major ecological zones. The forest loss class is what constitutes deforestation. Figure 10 shows the estimated forest losses (deforestation) between 2006 and 2016 by ecological zones. While Figure 21 present activity data by ecological zones.

Table 2 Error matrix for the interpreted samples

2006-2016		Reference data			**Total samples in map class**	User's Accuracy	
		Forest Loss	Stable Forest	Stable non-forest			
Map data	Forest loss	32	35	45	112	29%	
	Stable Forest	6	335	198	539	62%	
	Stable non-Forest	10	54	500	564	89%	
Total reference samples per class		**48**	**424**	**743**	**1215**		
Producer's accuracy		67%	79%	67%	**Overall accuracy**		**71%**
Weighted Producer Accuracy		12%	71%	86%	**Weighted overall accuracy**		**81%**

Table 3 Results of Accuracy Assessment and Stratified Area Estimation for Forest Classes for one interpreter

	Results stratified area estimates for:					
Variable	**Entire Nigeria**	**Sudan & Sahel Savanna**	**Guinea Savanna**	**Derived savanna**	**Lowland Rainforest**	**(Mangrove & Freshwater Swamp)**
Stratified Area Estimate loss (ha/yr)	**163,359**	**6,807**	**95,293**	**13,613**	**40,839**	**6,807**
Standard error (ha/yr)	**38,048**	**1585**	**22194**	**3170**	**9512**	**1585**
95%Confidence Interval	**74,573**	**3,107**	**43,501**	**6,214**	**18,643**	**3,107**

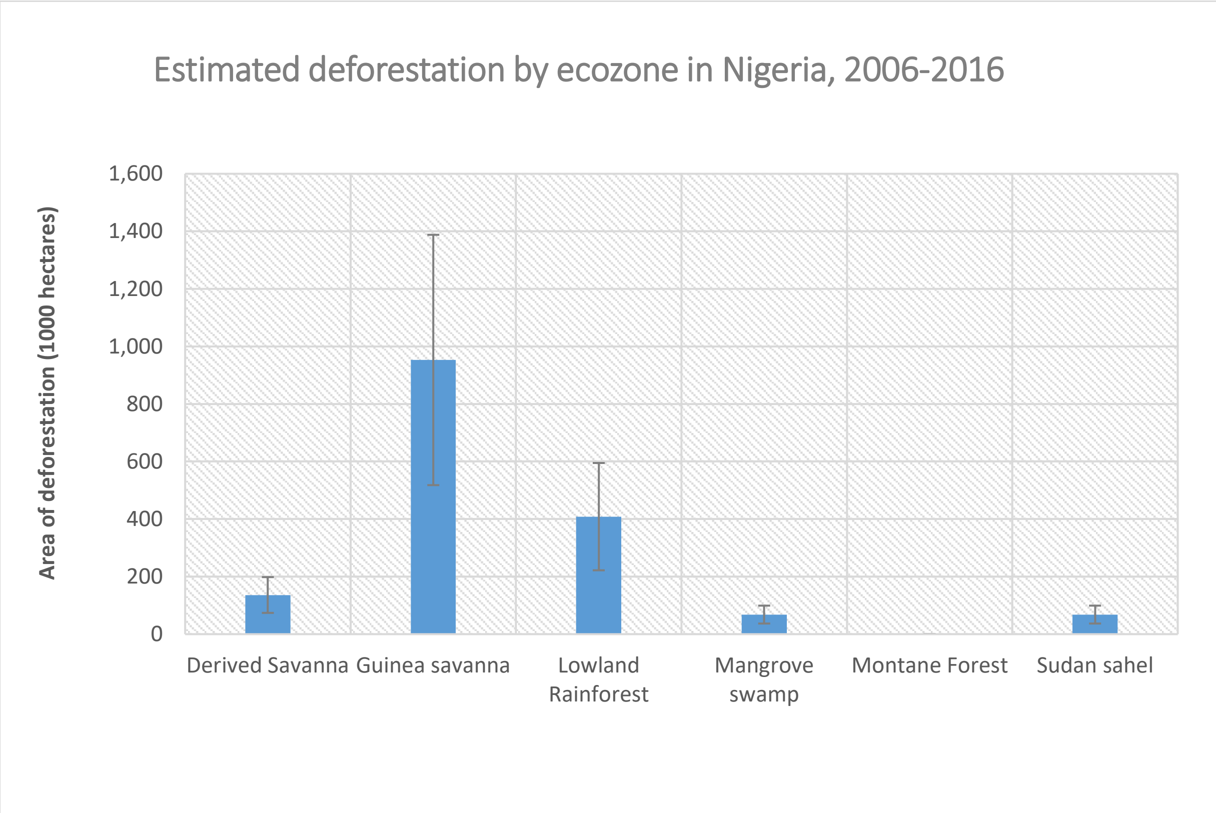


Figure 10 Estimated forest loss (deforestation) between 2006-2016 by ecological zones

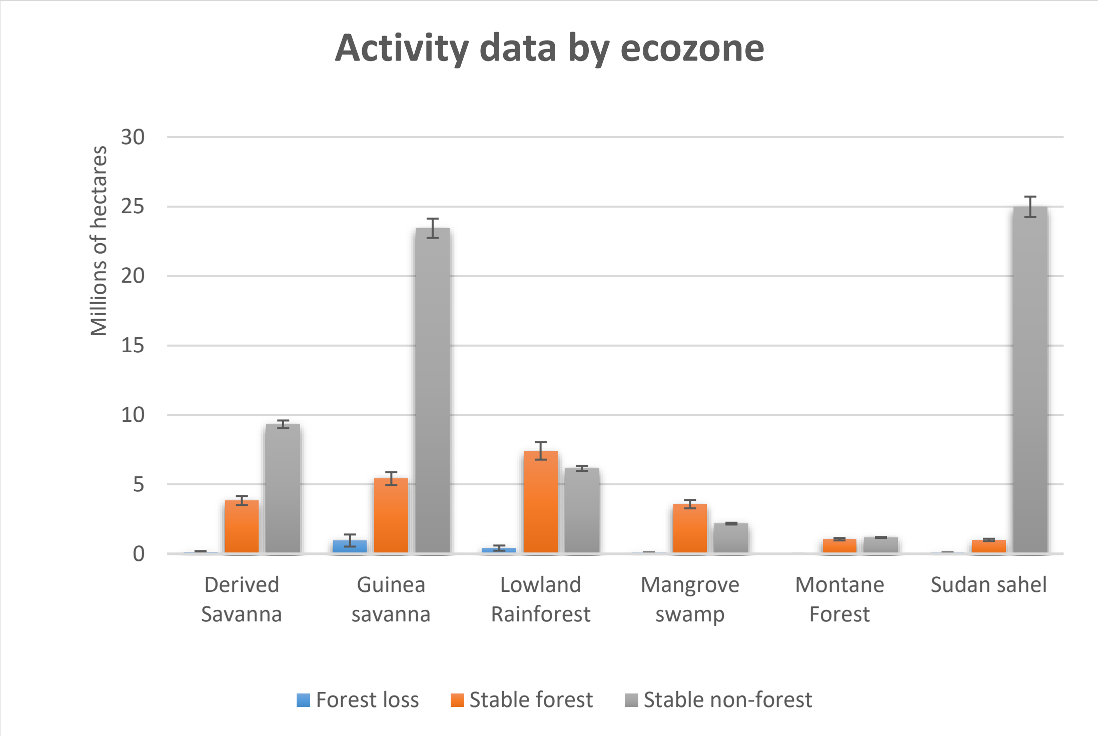


Figure 3 Estimated Forest loss, Stable Forest and Stable Non Forest within ecological zones

6.2 Emission factor estimation

Emission factors are derived from forest inventory data. A review of historical inventories in Nigeria revealed a lot of limitations in their usage for forest biomass estimation, and carbon stocks determination; and hence, their use for estimating emission factors for REDD+ purposes. The inventories were originally designed for timber volume estimation for commercial tree species and not for all tree species, and estimations were limited to bole volume, and not for all carbon pools. Furthermore, results for forest inventory for Cross River State which were used for the sub-national FREL were limited to CRS and did not capture all land use/land cover types in Nigeria. In order to circumvent this situation a national forest carbon inventory was designed and (partially) implemented to sample all main ecological zones and land use land cover types in Nigeria.

6.2.1 Sampling design for Nigeria Forest Carbon Inventory

The sampling design consisted of nested sample plots that were randomly distributed across all ecological zones. A **stratified random sampling design** was used in order to capture spatial variability of land-use/land cover types and forest carbon stocks. The design was consistent with the one previously used for Cross River State. The stratification was based on main ecological zones as defined in FORMECU (1998): the Mangrove forest and coastal vegetation, Freshwater swamp forest, Lowland rainforest, Derived savanna, Guinea savanna, Montane forest, Sudan savanna, and Sahel savanna. However, due to various risks levels associated with some States the sampling was further constrained by eliminating high risks States.

6.2.2 Cluster Design and Characteristics

Each cluster covered an area of 205 m x 205 m, and consisted of three plots of 35 m x 35 m arranged in an L-shaped configuration (**Figure 12**) : the Elbow or central plot, the Northern and the Eastern plots distant at 100 m from the central plot, and arranged in an alternate manner. Each plot has three nested sub-plots of 25 m x 25 m, 7 m x 7 m and 2 m x 2 m.

All trees with diameters greater than 40 cm were measured within the 35 m x 35 m plot; those between 20 cm and 40 cm were measured in the 25 m x 25 m nest and those between 5 cm and 20 cm were measured in the 7 m x 7 m nest. Regeneration was tallied in the 2 m x 2m nest. Standing dead trees were measured in the corresponding nests using the same diameter cut-off points as for life trees. Fallen dead trees with diameter greater than 10 cm were measured in the entire plot; while those below 10 cm were measured in the 7 m x 7 m sub-plot.

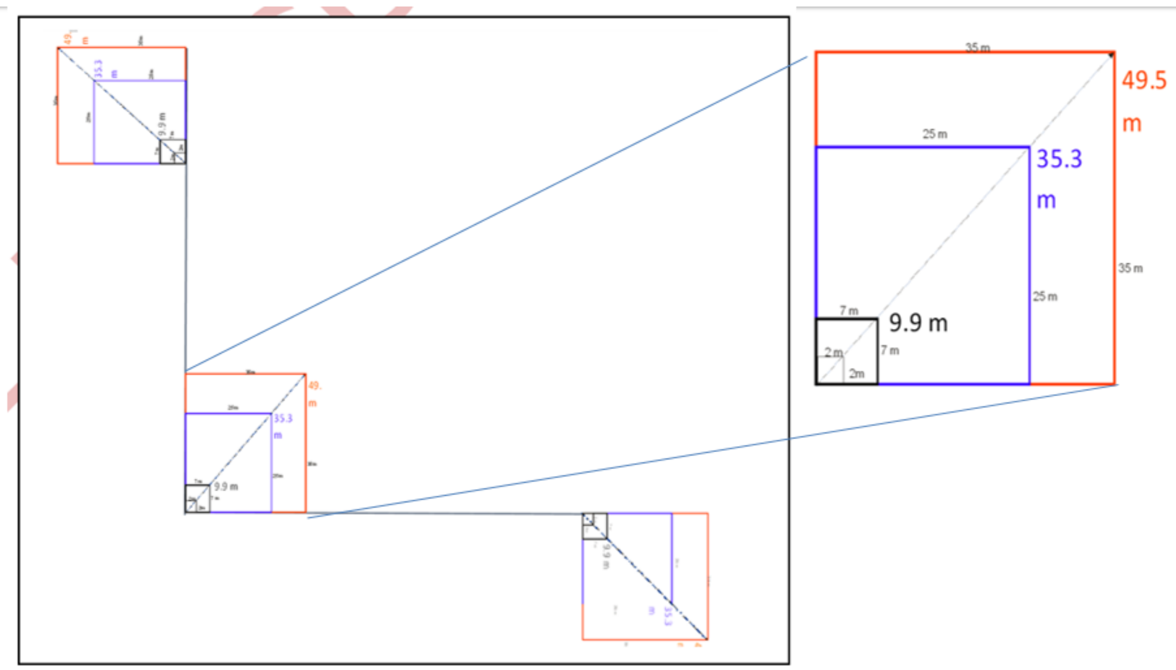


Figure 12 Cluster design used for the inventory

6.2.3 Sample Plot Design: Mangroves and Freshwater swamp (FWS)

An initial attempt to sample mangroves and fresh water swamps using the above design failed due to the conditions of these ecosystems. Hence, we resorted to use a design similar to the one used for Cross River State Inventory as described in Ajonia (2008). The design uses three- 10m x 20 m rectangular plots laid along a transect at intervals of 10 m; with 5 m x 5 m sub-plots nested within them, and in an alternate manner shown below (**Figure 13**).

All trees with diameter > 10 cm were measured in the entire plot (for trees with stilt/roots, measure diameter at 0.3 m (30 cm) above stilt. On the 5 m x 5 m sub-plot, all trees with diameter < 10 cm and height > 1.3 m were measured in the 5 m x 5 m subplot. Stilts were sampled in a 1 m x 1 m randomly located quadrat; soil samples were collected for soil organic carbon estimation.

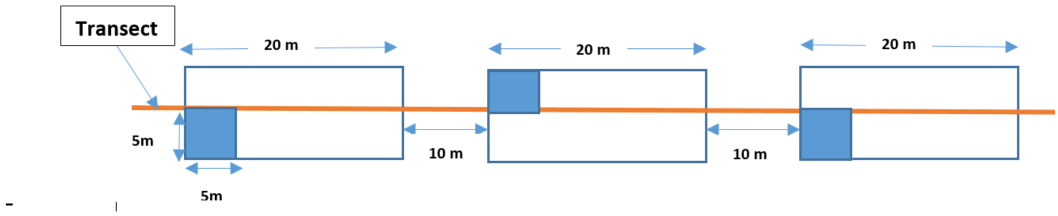


Figure 13 Sketch diagram of sample Transect sampling design for Mangroves and Fresh Water Swamp Forest.

Table 4 shows the number clusters by State and ecological zone, while **Figure 14** shows the spatial location of the clusters sampled in various ecological zones, while

Table 4 Number of Clusters enumerated in different ecological zones in Nigeria

State	Mangrove Forest	Freshwater Swamp Forest	Lowland Rainforest	Derived Savanna	Guinea Savanna	Sudan Savanna	Sahel Savanna	Montane Forest	TOTAL
Jigawa	0	0	0	0	0	0	3	0	3
Katsina	0	0	0	0	0	1	2	0	3
Kebbi	0	0	0	0	0	3	0	0	3
Nasarawa	0	0	0	0	10	0	0	0	10
Ogun	3	7	13	4	0	0	0	0	27
Ondo	9	3	24	4	0	0	0	0	40
Oyo	0	0	4	5	3	0	0	0	12
Taraba	0	0	0	0	0	0	0	18	18
TOTAL	12	10	41	13	13	4	5	18	116

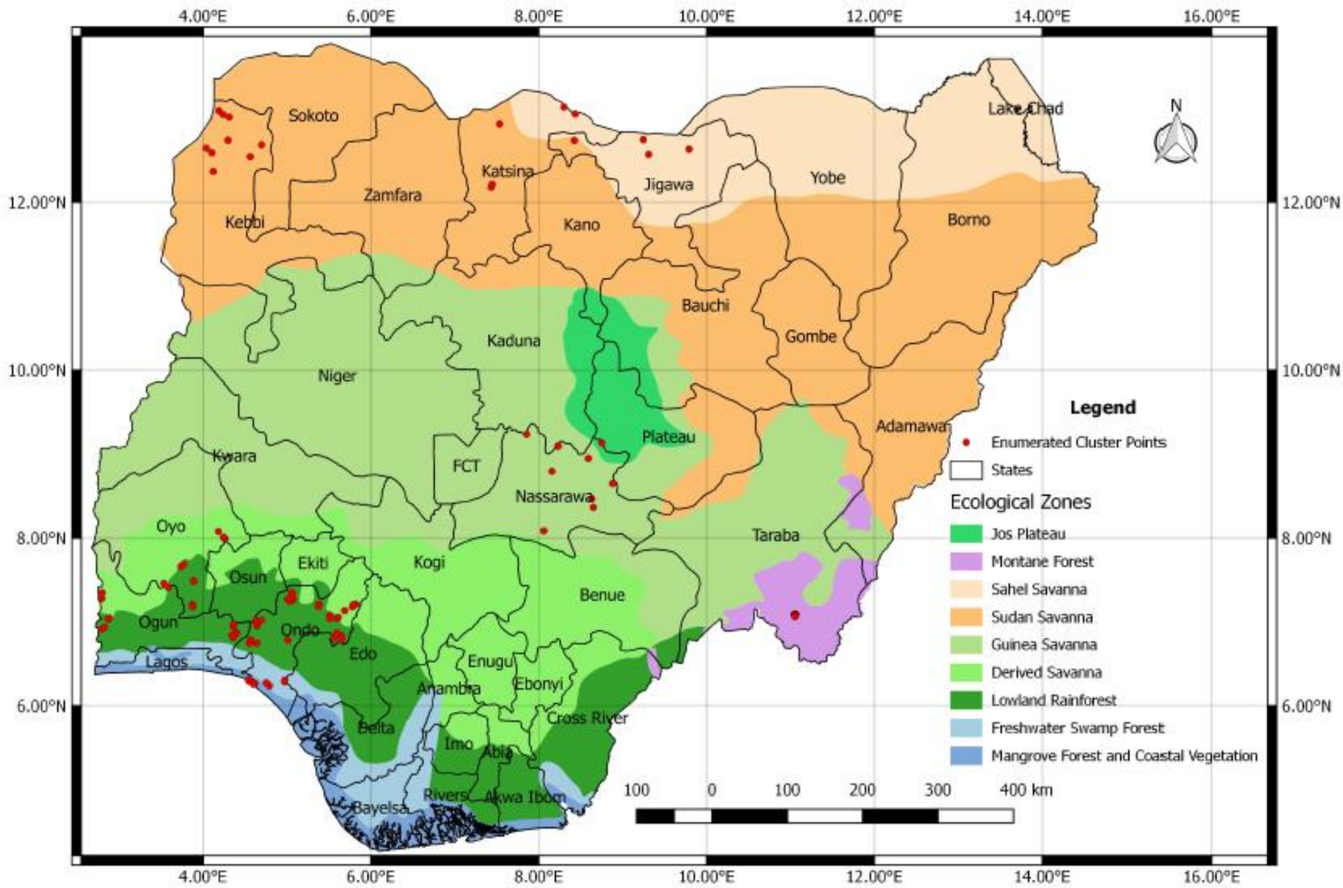


Figure 4 Spatial Distribution of Sample Clusters visited and measured in different Ecological Zones[2].

6.2.4 Data Collection: Above Ground Biomass

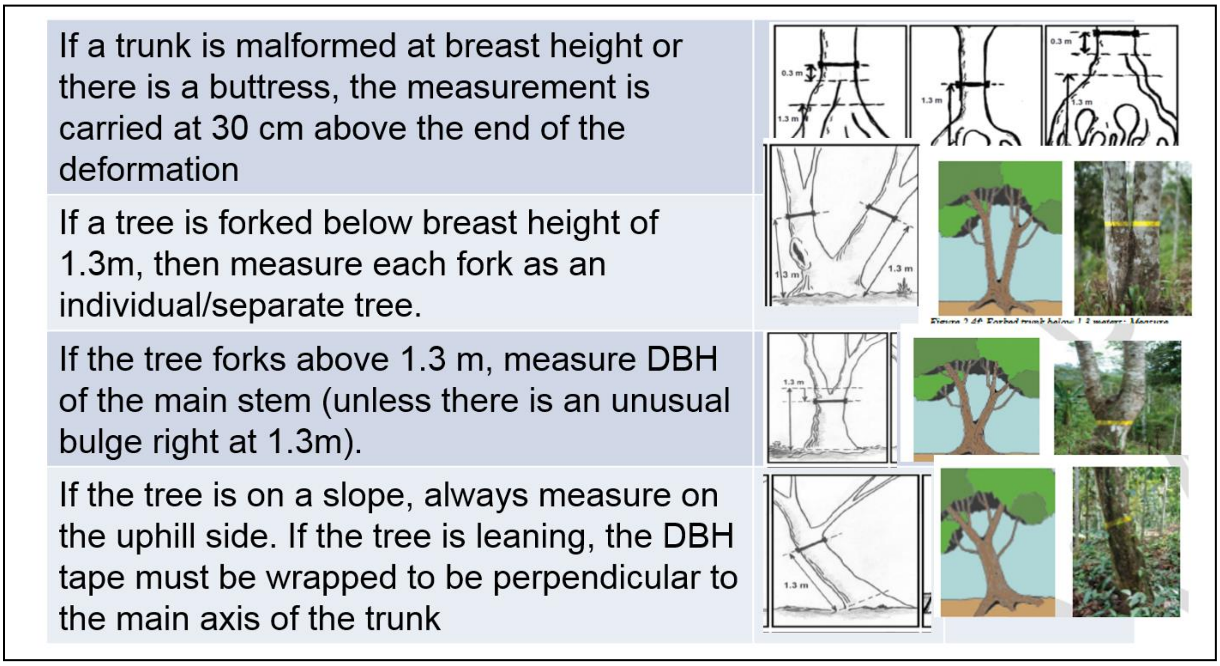
i. ***Stem Diameter Measurements.***

All trees in the plot above 5 cm diameter at breast height (dbh) were identified as much as possible to species level and measured at 1.3 m from the ground, with diameter-tape. However, for trees with anomalies and/or multiple stems, measurements were made according to the instructions in the box below:

[2] The distribution presented here refers to the actual clusters visited in the field, which is a sub-set of the sampling frame that consisted of 240 clusters. Due to budgetary constraints and time limitation, barely 50% of the clusters in the design were visited and data collected.

ii. Tree Height Measurements

The TruPulse 200B Laser Rangefinder was used to measure tree heights (bole and total heights) on a sample of trees whose boles were clearly visible from base to top. Specific crew members were assigned the task of height measurements based on their good mastery of the laser equipment following training received prior to the field work. In addition to height measurements, three diameter measurements were measured with the Criterion RD1000 Laser Dendrometer: diameter at tree base (D_{base}), diameter at mid-stem (D_m) and diameter below large branch (D_{top}). These measurements, plus the bole height were used to compute tree bole volumes using Newton's Log Formula.



iii. Standing Deadwood and Stumps

Standing dead trees were measured for diameters and heights concurrently with live trees, and in the corresponding nests, according to tree sizes. Three diameter measurements were taken using the Criterion RD1000 laser dendrometer: diameter at the base of the dead tree (**D**$_{base}$); diameter at breast height (dbh), and diameter at top of dead tree (**D**$_{top}$) (**Figure 15**). Deadwood bole height (H) was measured with the TruPulse 200B Ranger finder.

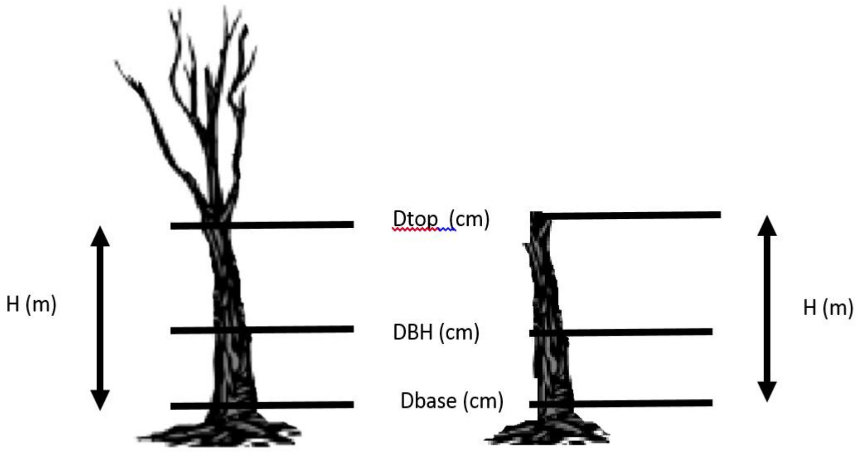


Figure 5 Standing deadwood parameters assessment

Two deadwood status were distinguished:
Category 1, included trees with branches and twigs that resembled live trees (except for the absence of leaves);
Category 2 - Tree without twigs and branches, and already showing signs of decomposition or decay.
The decay categories were determined using a "*Matchete Test*" which assigns deadwood (standing or lying) into one of three density categories: sound (S), intermediate (I) or rotten (R), by striking the wood with a matchete. If on striking the deadwood the matchete:

1. bounces back, then the piece is classified as sound (S)
2. partly sinks into the wood then it is classified as intermediate (I)
3. sinks into the wood and the wood crumbles then the wood is categorized as rotten (R).

Stumps were measured for diameter and height in corresponding subplots based on their sizes.

iv. Lying (down) Deadwood or Coarse Woody Debris

Only lying deadwood (and dead branches) that had a minimum diameter of 10 cm diameter and at least 1 m long were measured. Where a dead lying tree contained the stump part with some roots; the stump data is recorded in the stumps section on the field form. The "*matchete test*" was used to determine the decay category as (described above). Deadwood with diameter>10 cm and greater than 1 m long were measured in the entire plot; while fine woody debris (FWD) (diameter between 2 cm to 10 cm, and deadwood with diameter > 10 cm but with length < 1m) were measured only within the 7m x 7 m nest. All sections of the deadwood falling outside the plot boundaries were excluded (see illustration below).

Measurements taken included a diameter at tree base ($\mathbf{D}_{base}$), diameter at top ($\mathbf{D}_{top}$) and deadwood length (L) (Figure 16). These measurements were used to compute deadwood volumes using Smalian formula.

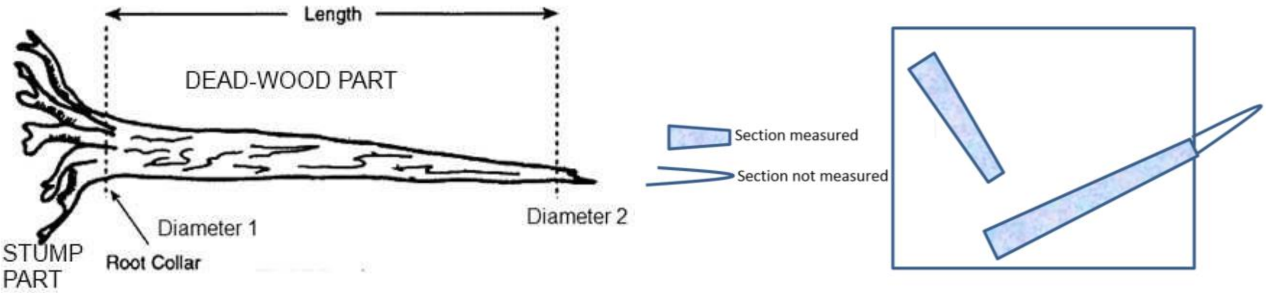


Figure 6 Lying deadwood parameters assessment

v. Extraction of Core Samples for Wood Density Determination.

Wood core samples were extracted from tree species using an increment borer for wood density determination. Trees were cored from bark towards the pith, where possible, at breast height with a 5.15 mm diameter increment borer. The bark was removed from the cores, and the samples weighed (fresh weight) on an electronic balance, labelled and placed in increment core holders. The fresh volume of each sample was calculated using the diameter of the borer (d) and the length of the core (L) as follows:

$$V = [\pi d^2 L]/4$$

where V is volume, d is mean diameter, L is length, π=3.14.

The samples were oven-dried to constant weight, and weighed with an electronic balance. The dry weight divided by the fresh volume for each sample gave the wood density. Wood density of a species was computed as the arithmetic average value of all samples of that species.

6.2.5 Data Analysis

i. Above Ground Biomass

The conversion of field data collected to forest biomass and carbon stocks requires the use of biomass allometric equations. The following steps were used to estimate above ground biomass for each land use/land cover type:

1. For each tree in the plot/nest the above ground dry biomass was estimates using the selected allometric equation.

2. Its biomass was then multiplied by the correct scaling factor based on the sub-plot size in which the tree was measured to get the biomass in Kg/ha.

3. The biomass in kilograms was converted to biomass in tons per hectare.

4. Biomass per hectare of all trees in each plot were summed to get an estimate of total biomass per hectare.

In the absence of country-specific allometric equations, a pan-tropical allometric equation by Chave *et al* (2014) below was used to estimate above ground biomass from field measurements.

$$AGB_{est} = (0.0673\rho D^2 H)^{0.976}$$

(σ =0.357, AIC=3130, df=4002).

where:

AGB_{est} = above ground biomass (kg)

ρ =species wood density (g/cm3)

D=diameter at breast height (cm)

H=tree height (m)

The equation also requires an estimate of tree height, and wood density. Given that tree heights were not measured on all trees during the inventory, we developed a height-diameter equation using the height-diameter measurements made during the inventory. The equation is as follows:

$$H_{est} = 1.3 + 30.441065[1 - \exp(-0.040144 * dbh^{0.8239})]$$

Wood density estimates were obtained from core samples collected during inventory (as described above), and additional data from a number studies undertaken in Nigeria (Chenge, 2017; Aghimien, 2018; Akindele (unpublished)), and from global database (Zanne *et al*. 2009), for species without local wood density values.

Above ground biomass (including stilt roots) for trees sampled in mangroves was estimated using the following equations for all mangrove species developed by Komiyama *et a*l (2005), and which has been widely used (cf. Komiyama et *al*. 2008; Kauffman and Donato, 2012; Allemayehu et *al*. 2014.):

$$W_{top} = 0.251.\rho.D^{2.46} : \ R^2{=}0.98,\ n{=}104$$

ii. Standing Dead Wood

Standing deadwood measurements included diameter at tree base (D_{base}), diameter at top of tree bole (D_{top}), bole height (H), and determination of decomposition status of the deadwood. The volume of each deadwood was then calculated assuming the tree is a frustum of truncated cone. Depending on whether or not the diameter at bole top is available, the following formulae was used to estimate standing deadwood volume.

$$\boldsymbol{Volume} = \begin{cases} \left(\dfrac{\boldsymbol{\pi * H}}{\mathbf{12}}\right)\left(\boldsymbol{D_{base}^2} + (\boldsymbol{D_{base}.D_{top}}) + \boldsymbol{D_{top}^2}\right), & \boldsymbol{if\ tree\ is\ assumed\ frustum\ of\ truncated\ cone} \\ \left(\dfrac{\boldsymbol{\pi * H}}{\mathbf{3}}\right).\left(\dfrac{\boldsymbol{D_{base}^2}}{\mathbf{2}}\right)^2 & \boldsymbol{if\ tree\ is\ assumed\ frustum\ of\ a\ cone\ (D_{top} = 0)} \end{cases}$$

Deadwood volumes were converted to dry biomass using deadwood density values based on deadwood density values obtained during the inventory and also from a study by Akindele (*unpublished*). The values used are 0.46 for sound standing deadwood, and 0.36 for Intermediate standing deadwood.

iii. Lying Dead Wood

Lying (down) deadwood volume is computed using Smalian's formula, assuming frustum of a paraboloid:

$$Volume = \frac{\pi.L}{8}\left(D_{base}^2 + D_{top}^2\right)$$

Biomass of lying deadwood was then estimated as Volume x Density.

The value for sound dead wood density used were based on a study by Akindele (*unpublished*), which provided the following density estimates: 0.31 for sound lying deadwood, 0.26 for intermediate lying deadwood and 0.21 for rotten deadwood.

iv. Stump biomass

The volume of the stump was estimated using the formula below:

$$Volume = \frac{\pi.Hstump * D_{stump}^2}{4}$$

Biomass of stump was then estimated as Volume x Density.

v. Below Ground Biomass

The estimation of below ground biomass (BGB) is difficult and expensive to undertake in most tropical high forest, and few country-specific allometric equations exist for BGB. Most projects or studies therefore resort to the use of a proxy root-to-shoot (R/S) ratios (Kauffman and Donato, 2012). In the present study we used a ratio equation for moist tropical forests developed by Mokany *et al*. (2006; also reported in the IPCC 2006 AFOLU), which predicts below ground biomass (BGB) based on above ground biomass (AGB) as follows:

$$\boldsymbol{BGB} = \begin{cases} \mathbf{0.235} * \boldsymbol{AGB\ if\ AGB} > 62.5\boldsymbol{t\ C/ha} \\ \mathbf{0.205} * \boldsymbol{AGB\ if\ AGB} \leq \mathbf{62.5}\ \boldsymbol{t\ C/ha} \end{cases}$$

Belowground biomass for **mangroves** (excluding stilt roots) was estimated using the following equation by Komiyama *et al* (2005) :

$$W_{root} = 0.199.\rho^{0.899}D^{2.22} \qquad R^2=0.95;\ n=26.$$

vi. Estimation of Carbon content

The carbon content of biomass was estimated by applying a conversion factor of **0.47** to total biomass, 0.47 is default carbon fraction or conversion factor applicable for tropical and sub-tropical species (range 0.44 - 0.49) (see Table 4.3 Chap. 4. IPCC 2006), while the carbon dioxide equivalent (CO_2e) was computed by multiplying the carbon content by **3.67** (44/12) (IPCC, 2006). **Table 7** present summary results for the total live carbon stock estimates (for above and below ground biomass) and total deadwood carbon stocks (sum total for standing deadwood, lying deadwood and stumps) for different for major ecological zones. Detailed tables for intermediate calculations have been left out, and can be found in the forest carbon inventory report. The estimates retained are those to serve as emission factors for FREL calculations.

Table 5 Total live and Dead Biomass and Carbon Stocks for different ecological zones in Nigeria

Ecological Zone	Total Live Carbon stock (tCO2/ha)	[95% CI]	Total Deadwood Carbon stock (tCO2/ha)	[95% CI]	Total Live & Dead Carbon stock (tCO2e/ha)	95% Confidence Interval (CI)	
	Mean ± StdError	CI%	Mean ± StdError	CI%	Mean ± StdError	CI (tCO2e/ha)	CI%
Derived Savanna	253.88±99.84	77.1%	19.71±5.31	52.8%	273.59±99.98	195.95	71.6%
Sahel, Sudan & Jos Plateau	20.18±4.16	40.4%	3.77±??	----	23.95±4.16	8.15	34.0%
Guinea Savanna	98.76±18.72	37.2%	3.93±0.65	32.3%	102.69±18.73	36.71	35.8%
Lowland Rainforest & Montane	368.59±31.65	16.8%	30.79±3.87	24.7%	399.39±31.88	62.49	15.6%
Mangrove & FWS	321.02±66.57	40.6%	15.76±2.83	35.1%	354.53±70.81	138.78	39.1%

7. Transparent, complete, consistent and accurate information

7.1 Transparent information

During the development of the FREL document, all processes followed and methodologies used for the estimation of activity data and emission factors were documented in a transparent manner. Some information is provided in the appendices to this document. All maps used for estimating activity data have been referenced, and both metadata and spatial datasets are available in a spatial database. Also for the estimation of emission factors, based on forest inventory data, all calculations have been done in a transparent manner. The spreadsheets are available, and some detail results have been included in the Appendices to this document.

7.2 Complete information

Annex I in Decision 12/CP.17 indicates that complete information means information provided that allows for the reconstruction of forest reference emission levels and/or forest reference levels. All information used in the context of the construction of the present FREL has been developed by Nigeria, and allows for the reconstruction of the FREL and is publicly available. Nigeria also ascertains that all information used for the construction of Nigeria's FREL will be uploaded to the website and is available for download.

7.3 Consistent information

Consistency with the national greenhouse gas inventory paragraph 8 in Decision 12/CP.17 establishes that FRELs and/or FRLs shall maintain consistency with anthropogenic forest related greenhouse gas emissions by sources and removals by sinks as contained in the country's national greenhouse gas inventory. Compared to the second National GHG Inventory (NGHGI) submitted by Nigeria in its Second National Communication, there was no clear forest definition used. The second NGHGI did not include a forest definition and was using data available at the time which concerning forests is likely to have been focussed on tropical high forest only.

7.4 Accurate information

7.4.1 Accuracy of the estimated activity data

Same process was repeated for Hansen maps for the purpose of comparison. The results of the comparative analysis informed the decision to opt for Hansen datasets for the creation of new change layer through direct change assessment using FAO-SEPAL platform at FAO Rome. Reference data were generated for the accuracy assessment using land use/land cover maps in **section 5.1.3** for Nigeria and Hansen maps stratifications.

7.4.2 Uncertainty of the activity data

Error matrix of the standard error was computed for the reference data representing stable forest, stable non-forest and forest loss. Uncertainties were then calculated for the standard error at 95% confidence interval as shown in Table 6 below. Uncertainty for forest loss is 46% while stable and stable non-forest have 9% and 3% respectively as uncertainties.

Table 6. Uncertainty estimates (95% confidence intervals) for forest loss, stable forest and stable non-forest

Error matrix of standard error		Reference data		
		Forest loss	Stable forest	Stable non-forest
	Forest loss	1.061E-07	1.1169E-07	1.24957E-07
Map data	Stable forest	1.60004E-06	3.4192E-05	3.37809E-05
	Stable non-forest	1.57155E-05	7.8124E-05	9.07756E-05
	Total	**1.74217E-05**	**0.00011243**	**0.000124681**
	Standard error	380,476	966,538	1,017,849
	95% Confidence Interval	745,733	1,894,414	1,994,984
	95% Confidence Interval as percent of adjusted area	46%	9%	3%

7.4.3 Uncertainty of the estimated emission factor

The estimation of emission factors is associated to many sources of uncertainty, including the use of default values, sampling errors and bias from field measurements, etc. All biomass estimates (**Tables 7)** from the inventory were reported with 95% uncertainty values associated with them. Also, **Table 8** gives 95% uncertainty estimates for above and below biomass carbon pools for different land use types. The uncertainties are all below 100%; with those for deadwood.

Table 7. Uncertainty estimates (95% confidence intervals) for total live and deadwood carbon stocks by ecological zones

	Uncertainty Estimates (% of mean values) for:		
Ecological Zone	Total (ABG & BGB) Live Carbon Stock (tCO2/ha)	Total Deadwood Carbon Stocks (tCO2/ha)	Total Live and Dead wood Carbon Stocks (tCO2/ha)
Derived Savanna	±77.1%	±52.8%	±71.6%
Guinea Savanna	±37.2%	±32.3%	±35.8%
Lowland Rainforest & Montane	±16.8%	±27.5%	±15.6%
Mangrove Forest & FWS	±40.6%	±35.1%	±39.1%
Sahel, Sudan & Jos Plateau	±40.4%	-	±34.0%

8. FREL/FRL Construction

8.1 Historical average of emissions

Emission Factors and Activity Data have been estimated by ecological zones and are shown in Tables 8 below. The annual emissions for the period 2006-2016 was estimated as the product of the average annual deforestation (Activity Data: AD) and the estimated CO_2 e per hectare (Emission Factor) by ecological zone, then summed up to provide the average annual emissions (Table 8) . Average values for emissions and their confidence intervals were also computed in order to determine the upper and lower limits of the estimates.

Table 8: Total Emissions for Ten Years [2006-2016] (tCO2e)

Agregated Ecozone	Activity Data [AD]		Emission Factors[EF]		Emissions [2006-2016: tCO2e]		
	Forest loss_AD[ha]	CI_Forest loss	EF	CI_EF	Emissions=EF*AD	CI(EF*AD)	CI%
Derived Savanna	136132.5	62144.4	273.59	195.95	37244490.68	31632819.71	84.93%
Guinea savanna	952927.8	435010.8	102.69	36.71	97856155.78	56738525.52	57.98%
Lowland Rainforest	408397.6	186433.2	399.39	63.02	163109917.5	78782166.56	48.30%
Mangrove swamp	68066.3	31072.2	354.53	138.78	24131545.34	14511523.82	60.14%
Sudan sahel	68066.3	31072.2	23.95	8.15	1630187.885	928191.5305	56.94%
Total Emissions (tCO2e)					323972297.1	103140541	31.84%

Table 9: Summary computations for Annual Emissions

	Activity Data [AD]		Emission Factors[EF]		Annual Emissions [2006-2016: tCO2e]		
Agregated Ecozone	Forest loss [ha/yr]	StdError (ha/yr)	EF (tCO2e/ha)	StdError (tCO2e/ha)	Emissions=EF*AD	CI(EF*AD)	CI%
Derived Savanna	13,613	3,171	273.59	99.97	3,724,449	3,163,180	84.93%
Guinea savanna	95,293	22,194	102.69	18.73	9,785,616	5,673,900	57.98%
Lowland Rainforest & Montane	40,840	9,512	399.39	31.88	16,310,992	7,871,105	48.26%
Mangrove swamp	6,807	1,585	354.53	70.81	2,413,155	1,451,188	60.14%
Sudan sahel	6,807	1,585	23.95	4.16	163,019	92,834	56.95%
Annual Emissions (tCO2e/yr)					32,397,230	10,308,623	31.82%

9. Changes from previous submission

The following changes occurred between the 2019 national FREL submission and the 2018 FREL submission for the Cross River State:

(a) The previous submission was subnational and covered only one State (Cross River) of the country while the current one covers the entire country;

(b) The previous submission focused only on annual emissions (a single weighted EF as the approximate value of carbon loss per hectare of deforestation) for the entire state and not based on ecological zones, while the latest submission provides estimates on the basis of ecological zones and then on the national aggregate;

(c) Emission estimates from the deadwood pool were not included in the previous submission but they are included in the current submission;

(d) The sample design for the previous FREL was different from that used for the current submission. Previously, sample plots were randomly selected, while in the national FREL, sample clusters of three plots each were randomly selected for enumeration;

(e) Owing to a lack of modern tree height measurement tools, trees were only counted without height measurements, which made it necessary to use a diameter-height equation in the previously submitted FREL, while for the national FREL submission, TruPulse 200B Laser Rangefinder was used to measure tree heights (bole and total heights) on a sample of trees whose boles were clearly visible from base to top;

(f) In the previous submission, ground truthing/checks for areas of agricultural tree crops were not undertaken to facilitate accurate delineation but such checks were carried out for the current submission;

(g) Information on emissions from soil organic carbon and non-CO_2 emissions from fires that justifies their omission has been provided in the current submission;

(h) Information on forest degradation was assessed and included in an appendix to the current submission to justify the omission of this activity.

10. Areas for future improvements

FREL/FRL development is a stepwise process and Parties are encouraged to improve and update it as soon as more accurate information becomes readily available. The present FREL constitutes an up-scaled version of the Sub-National FREL developed for Cross River State and submitted for technical assessment in January 2018. A number of improvements highlighted in the sub-national FRELs, including data collection for deadwood carbon pool, tree height measurements and providing justification for omissions have been captured in the national FRELs. Furthermore, core samples were extracted from live trees for wood density determination, as well as deadwood density determination; and a litter sampling was done in a small sample of plots in some ecological zones. The activity data has also been stratified by main ecological zones.

Never-the-less, there are still several avenues for further improvement to the present national FREL document. Some important areas for improvement are as follows:

1. **On the Scope of activities:** Deforestation is the main emission activity addressed in the present FREL. Further improvement will require the inclusion of **forest degradation** which also leads to a lot of emissions through timber harvesting, fuelwood harvesting, and forest fires. The estimation of emissions from forest degradation is more challenging than for deforestation. However, as part of our future improvement plan, Nigeria intends to take some measures such as sub-categorisation of forest class to enable tracking of transition of in-situ natural forest to another (disturbed) forest class. We hope to leverage on the emerging partnership between Nigeria and British High Commission to mobilise the United Kingdom's 2050 calculator tool, which was an easy-to-use energy and emissions model to probably track data and information on wood fuels while efforts are made to obtain data on other indices like

timber extraction, forest fires, etc. from available sources to enrich data on degradation. Our future plan would also include specific data and technical capacity needs assessment to enable identifying and addressing possible gaps inclusion of reliable emission estimate resulting from forest degradation. **Afforestation (enhancement)** could be one of the areas of improvement given the long history of plantation silviculture in Nigeria; during which parts of forest reserves were replanted. Field inventory revealed this, especially in the lowland rainforest.

2. As regards **emission factors (EF)** determination, the inventory design attempted to sample all major ecological zones from coastal mangroves and Fresh Water Swamps to Sudan and Sahel savanna ecosystems; and EFs have been computed per major ecological zones. However, from the confidence intervals obtained, the level of uncertainty is still high for some ecological zones, and it will be important (subject to availability of funds), that additional and intensive inventories be undertaken to improve on the precision and accuracy of the estimates. The estimates used in the present FREL can serve in the optimization of a future inventory sampling design.
3. Regarding the **activity data** (**AD**), work was undertaken to produce land use/land cover maps, change detection analysis and accuracy assessment. However, considering the large size of the country, and problems with “pixel-based” change analysis, the use of Hansen GFC data was recommended for AD estimation. Further improvements could be made on the land use land cover maps.

11. Appendices

Appendix 1: Summary results for above ground biomass (AGB), below ground biomass (BGB) and carbon stocks for different forest types at Cross River State (First submission)

Land use Type	ABG (t/ha)	ABG (tC/ha)	BGB (tC/ha)	ABG (tCO2/ha)	BGB (tCO2/ha)	Total Biomass (tCO2/ha)	REMARKS
Derived Savanna (4)	99.65±132.6	46.84±62.30	20.91±28.4	171.73±228.5	76.67±104.20	248.0±332.6	Emission factor was estimated for each of the land use types at subnational scale but only emissions from **Forestland** was considered in the submission since the emission factor was only considered for deforestation only. At the end of the day, Nigeria applied a single weighted emission factor to approximate carbon loss per hectare deforestation i.e. the emission factor for the forested land was estimated as a weighted average of the mean values estimated for different forest types (open forest, tropical high forest, montane forest, mangrove forest, etc.
Farmland(9)	80.58±56.8	37.87±26.69	16.52±11.64	138.86±97.87	60.57±42.69	199.4±140.5	
Gmelina	162.85±54.3	76.54±25.56	34.11±8.98	280.64±93.71	125.08±32.92	405.72±126.00	
Montane (5)	**528.46**±240.91	**248.37**±113.23	**112.10**±53.32	**910.70**±415.18	**411.04**±195.52	**1321.74**±610.49	
Open Forest (14)	311.41±119.72	146.36±56.27	67.57±27.45	536.67±206.32	247.76±100.66	784.43±306.92	
Swamp (7)	76.42±51.94	35.92±24.41	15.67±10.65	131.70±89.51	57.44±39.04	189.15±128.55	
Tropical High Forest (15)	531.71±190.17	249.90±89.38	115.82±43.66	916.32±327.73	424.68±160.10	1341.00±487.78	
Mangroves (7)	380.57±210.64	178.87±99.00	163.15±72.24	655.85±363.00	598.23±264.89	1254.08±626.59	
Forest Land*	373.48±68.16	175.53±31.39	89.65±16.05	643.63±115.11	328.74±58.86	972.37±173.9	

Appendix 2: Total live and Dead Biomass and Carbon Stocks for different ecological zones in Nigeria (Second submission)

	Activity Data [AD]		Emission Factors[EF]		Annual Emissions [2006-2016: tCO2e]			
Agregated Ecozone	**Forest loss [ha/yr]**	**StdError (ha/yr)**	**EF (tCO2e/ha)**	**StdError (tCO2e/ha)**	**Emissions=EF*AD**	**CI(EF*AD)**	**CI%**	**REMARKS**
Derived Savanna	**13,613**	**3,171**	**273.59**	**99.97**	**3,724,449**	**3,163,180**	**84.93%**	Emission factor was rather estimated at national scale for each ecological zone as against land use type in the first submission. This is actually an improvement in the overall emission factor as aggregate annual emissions also include estimates for savanna zones.
Guinea savanna	**95,293**	**22,194**	**102.69**	**18.73**	**9,785,616**	**5,673,900**	**57.98%**	
Lowland Rainforest & Montane	**40,840**	**9,512**	**399.39**	**31.88**	**16,310,992**	**7,871,105**	**48.26%**	
Mangrove swamp	**6,807**	**1,585**	**354.53**	**70.81**	**2,413,155**	**1,451,188**	**60.14%**	
Sudan sahel	**6,807**	**1,585**	**23.95**	**4.16**	**163,019**	**92,834**	**56.95%**	
Annual Emissions (tCO2e/yr)					**32,397,230**	**10,308,623**	**31.82%**	

Appendix 3: Sample Referference Data use for Accuracy assessment and Area Estimation

id	YCoordinate	XCoordinate	elevation	slope	aspect	region	country	geometry	area	map_class	fin_ref_class	ecozone	gfc_tc	gfc_l
1	8.8047923	5.8196008	65	0.0035427	2.5725347	Niger	Nigeria	points	1	2	4	Guinea savanna	36	5

2	6.0244167	5.4892005	17	0.0014596	5.0933043	Edo	Nigeria	points	1	1	2	Mangrove swamp	55	0
3	10.911971	13.245524	407	0.0074548	4.6029903	Borno	Nigeria	points	1	2	2	Sudan sahel	12	0
4	5.4479678	7.550295	155	0.0029302	5.3014042	Abia	Nigeria	points	1	1	1	Lowland Rainforest	27	0
5	8.447173	3.398731	309	0.0037927	4.3466159	Oyo	Nigeria	points	1	2	2	Guinea savanna	12	0
6	7.2207032	11.635024	582	0.0305409	0.7420219	Taraba	Nigeria	points	1	1	1	Montane Forest	52	0
8	8.5767999	9.4650541	170	0.0082854	5.5651952	Plateau	Nigeria	points	1	1	1	Guinea savanna	16	0
10	8.0370023	5.4522797	437	0.0118398	6.2026459	Ekiti	Nigeria	points	1	1	2	Derived Savanna	16	0
11	9.7278113	7.2069589	468	0.0094186	5.3088232	Niger	Nigeria	points	1	2	2	Guinea savanna	12	0
12	12.301754	5.364155	279	0.0056087	3.6557352	Sokoto	Nigeria	points	1	2	2	Sudan sahel	1	0
13	11.374693	13.387548	352	0.0005498	1.5707963	Borno	Nigeria	points	1	2	2	Sudan sahel	12	0
14	9.4790678	11.284951	255	0.1349341	2.7579087	Taraba	Nigeria	points	1	2	2	Sudan sahel	5	0
15	11.060732	6.1882694	495	0.0010437	1.1702456	Zamfara	Nigeria	points	1	2	1	Guinea savanna	12	0
16	9.5114071	8.4213015	535	0.0109893	3.4576308	Kaduna	Nigeria	points	1	2	2	Guinea savanna	8	0
17	5.387062	6.8568855	52	0.0003833	3.925846	Imo	Nigeria	points	1	4	1	Lowland Rainforest	29	13
18	9.8738774	10.590733	267	0.0174792	4.1195328	Bauchi	Nigeria	points	1	2	2	Sudan sahel	12	0
19	7.2605884	11.826635	NA	NA	NA	Taraba	Nigeria	points	1	1	2	Montane Forest	29	0
20	5.9279376	7.2266321	132	0.0238561	4.4477877	Anambra	Nigeria	points	1	2	2	Derived Savanna	12	0
22	8.6339328	8.6015934	199	0.0079162	2.0325707	Nassarawa	Nigeria	points	1	2	2	Guinea savanna	12	0

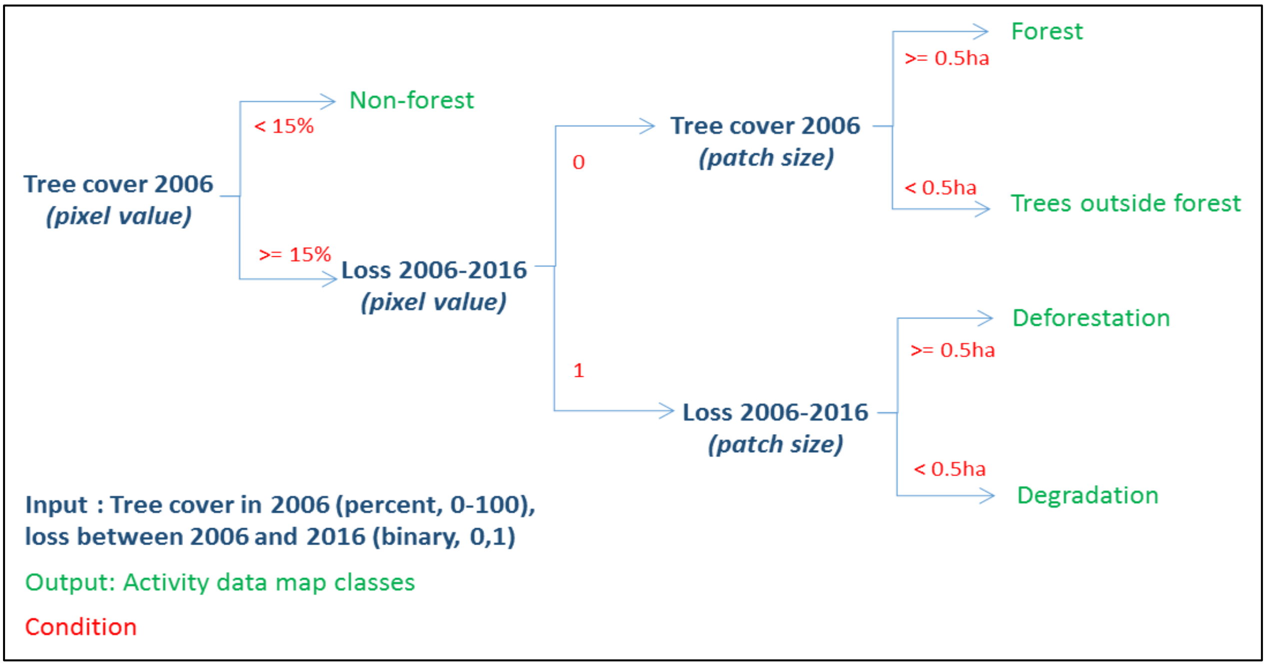
Appendix 4: Computation of Error Matrix for the Stratified Area Estimation Samples

Matrix of samples					
		Reference data			**Total samples in map class**
		Forest loss	Stable forest	Stable non-forest	
Map data	Forest loss	32	35	45	**112**
	Stable forest	6	335	198	**539**
	Stable non-forest	10	54	500	**564**
Total reference samples per class		**48**	**424**	**743**	**1215**
Proportional error matrix					
		Reference data			**Map area (ha)**

		Forest loss	Stable forest	Stable non-forest	
Map data	Forest loss	0.0022	0.0024	0.0031	692,467
	Stable forest	0.0031	0.1738	0.1027	25,491,086
	Stable non-forest	0.0126	0.0682	0.6319	64,971,846
	Marginal total	0.0179	0.2444	0.7377	**91,155,399**
Weighed proportional error matrix in ha					
		Reference data			**Map area (ha)**
		Forest loss	Stable Forest	Stable non-forest	
Map data	Forest loss	197,848	216,396	278,223	**692,467**
	Stable forest	283,760	15,843,254	9,364,072	**25,491,086**
	Stable non-forest	1,151,983	6,220,709	57,599,154	**64,971,846**
	Stratified area estimation	**1,633,591**	**22,280,358**	**67,241,450**	
		Reference data			
Error matrix of standard error					
		Forest loss	Stable forest	Stable non-forest	
	Forest loss	1.061E-07	1.11695E-07	1.24957E-07	
Map data	Stable forest	1.60004E-06	3.41922E-05	3.37809E-05	
	Stable non-forest	1.57155E-05	7.81237E-05	9.07756E-05	
	Total	**1.74217E-05**	**0.000112428**	**0.000124681**	

	Standard error	380,476	966,538	1,017,849	
	95%Confidence Interval	745,733	1,894,414	1,994,984	
	95%Confidence Interval as percent of adjusted area	46%	9%	3%	

Appendix 5: Decision tree for the creation of the forest change map



Nigeria did perform a preliminary assessment to approximate its significance (see section 6). Nigeria assessed pixel count of tree cover loss in patches corresponding to the minimum area in the forest definition (0.5 ha), which retain a cover >15% to estimate the area of degradation. Of the overall map area of tree cover loss in forest area (deforestation and degradation) assessed in the forest change map described in section 6, 72% of the loss concerned deforestation while 28% concerned degradation. In addition, the EF for degradation will be smaller than the EF for deforestation since only part of the forest carbon stock is lost with degradation. In the NFI, the average carbon contents for intact and disturbed forest has been assessed. The difference between the average stocks currently suggests a 61% lower carbon contents in disturbed forest sites as opposed to intact ones. If we would use this value to approximate the EF for degradation this would suggest degradation to consist of 17% of total emissions from both deforestation and degradation.

In addition to the process in Section 6.1.3, loss patches with less than 6 pixels were overlaid with the forest and trees outside of forest in 2006 to identify “degradation” and “degradation of trees outside forests”.

These filtered layers were further combined into one single change map with the following classes:

1: Stable Forest

2: Stable Non Forest

4: Deforestation

5: Degradation

6: Trees outside forest

7: Degradation of trees outside forest

The combination was done through a decision tree that is illustrated in a simplified version in Appendix 5 above

Appendix 6: Matrix of Reference Data per Ecological Zones (sample count)

Row Labels	Forest loss	Stable forest	Stable non-forest	Grand Total
Derived Savanna	4	73	103	180
Guinea savanna	28	103	259	390
Lowland Rainforest	12	141	68	221
Mangrove swamp	2	68	24	94
Montane Forest		20	13	33
Sudan sahel	2	19	276	297
Grand Total	**48**	**424**	**743**	**1215**

Matrix of reference data per ecozone (% of reference data class)

Count of ref_class_label	**Column Labels**			
Row Labels	**Forest loss**	**Stable forest**	**Stable non-forest**	**Grand Total**
Derived Savanna	8.33%	17.22%	13.86%	14.81%
Guinea savanna	58.33%	24.29%	34.86%	32.10%
Lowland Rainforest	25.00%	33.25%	9.15%	18.19%
Mangrove swamp	4.17%	16.04%	3.23%	7.74%
Montane Forest	0.00%	4.72%	1.75%	2.72%
Sudan sahel	4.17%	4.48%	37.15%	24.44%
Grand Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Area in hectares

Eco zones	Forest loss	Stable forest	Stable non-forest
Derived Savanna	136,133	3,836,005	9,321,493
Guinea savanna	952,928	5,412,446	23,439,483
Lowland Rainforest	408,398	7,409,270	6,153,995
Mangrove swamp	68,066	3,573,265	2,171,998
Montane Forest	0	1,050,960	1,176,499
Sudan sahel	68,066	998,412	24,977,981
Total	1,633,591	22,280,358	67,241,450

Confidence interval in hectares

	Forest loss	Stable forest	Stable non-forest
Derived Savanna	62,144	326,161	276,559
Guinea savanna	435,011	460,200	695,425
Lowland Rainforest	186,433	629,982	182,583
Mangrove swamp	31,072	303,821	64,441
Montane Forest	0	89,359	34,906
Sudan sahel	31,072	84,891	741,071

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