Food and Agriculture Organization of the United Nations

NIGERIA

NATIONAL FOREST (CARBON) INVENTORY

WITH TECHNICAL SUPPORT OF:

FOREST CARBON PARTNERSHIP FACILITY

NIGERIA

NATIONAL FOREST (CARBON) INVENTORY

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Abuja, 2020

REQUIRED CITATION

FAO. 2020. *Nigeria - National forest (carbon) inventory*. Abuja. https://doi.org/10.4060/cb1328en

ISBN 978-92-5-133393-8

Contents

Figures

Tables

Acronyms and abbreviations

AFDB	African Development Bank
AGB	aboveground biomass
BA	basal area
BGB	belowground biomass
CO_2	carbon dioxide
CRS	Cross River State
DB	diameter at base
DBH	diameter at breast height
DM	diameter at middle
DST	stump diameter
DT	diameter at top
EEC	European Economic Community
FAO	Food and Agriculture Organization of the United Nations
FCPF	Forest Carbon Partnership Facility
FDF	Federal Department of Forestry
FGN	Federal Government of Nigeria
FMENV	Federal Ministry of Environment
FORMECU	Forestry Management, Evaluation and Coordinating Unit
FRELS	Forest Reference Emission Levels
FRIN	Forestry Research Institute of Nigeria
FRL	forest reference level
FRS	Forest Resources Study
FUTA	Federal University of Technology, Akure
HFMPP	High Forest Monitoring Plots Project
HT	total height
IPCC	Intergovernmental Panel on Climate Change
MRV	measurement, reporting and verification
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NMFP	Nigerian Montane Forest Project
PSPS	permanent sample plots
REDD+	Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks
SLMS	Satellite Land Monitoring Systems
TSPS	Temporary Sample Plots
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change


Richter
MADE IN GERMANY


©FAO/John Fonweban

Executive summary

The Forest Carbon Partnership Facility (FCPF) of the World Bank has been supporting the Federal Government of Nigeria (FGN) to develop its REDD+ readiness mechanism and part of the funds were allocated to undertake a "low intensity" forest carbon inventory in Nigeria within the Technical Assistance (TA) Agreement (UTF/NIR/066/NIR) which was signed between the Government and the Food and Agriculture organization of the United Nations (FAO).

An inventory design was developed, including a field operations manual, and field training was carried out to build the capacity of technical forestry staff on field data collection, database development and data analysis. The sampling design used was a stratified random cluster sampling, using the main ecological zones as strata. The sampling unit was a cluster composed of three square nested plots of 35 m x 35 m; placed in an L-shape arrangement at 100 m apart.

Modern laser equipment, including Criterion RD1000 and TruPulse 200B, was used to collect data on tree diameters at any height on the tree boles, and tree heights respectively. Other measurements were taken on dead standing trees, lying dead trees, stumps, and litter. Core samples from live trees, standing and lying deadwood were extracted and oven-dried in the laboratory for wood density determination. A sampled tree height dataset was used to develop a height-diameter model, which was used with suitable allometric equations to estimate biomass, carbon stocks and carbon dioxide equivalent (CO_2e) for the various carbon pools. Field data collection was facilitated by using the FAO Collect Mobile App, (complemented by manual field forms), to minimize errors, especially in species nomenclature.

The results indicate that the total biomass, carbon stocks and carbon dioxide equivalent were highest in montane forest ecosystems followed by mangroves, lowland rainforest, derived savanna, and guinea savanna; while the Sudan and Sahel savannas had the lowest estimates. However, in terms of species diversity, the lowland rainforest was the most diverse, followed by the montane forest, the derived savanna, and the Guinea savanna; while the Sudan and Sahel savannae were the least diverse ecosystems. The estimates of carbon dioxide equivalent (CO_2e: t/ha) by ecological zones constituted the emission factors that were used in the calculations of annual CO_2 emissions in Nigeria. Recommendations are given on further work to intensify field inventory data collection to improve the accuracy and credibility of the emission estimates.

The activities were also built on the support that the UN-REDD Programme has been providing to Nigeria over the years.


TRUPULSE
LASER TECHNOLOGY

Introduction

1

1.1 GENERAL BACKGROUND

The Federal Government of Nigeria (FGN) aims to develop a National Forest Monitoring System (NFMS) capable of measuring the status and evolution of forest resources in compliance with the requirements of the United Nations Framework Convention on Climate Change (UNFCCC); with Forest Reference Emission Levels (FRELs) to serve as a "yardstick" by which to assess the performance of REDD+ implementation activities. The Federal Department of Forestry (FDF), through the National REDD+ Coordination Unit, has the mandate to coordinate the implementation of activities needed to put in place the NFMS and FRELs. The main pillars of NFMS and FRELs are the Satellite Land Monitoring Systems (SLMS) and the National Forest Inventory (NFI).

The Forest Carbon Partnership Facility (FCPF) is supporting the Federal Government of Nigeria (FGN) to develop its REDD+ readiness process by expanding the process initiated at Cross River State (through the UN REDD Programme) to Nasarawa and Ondo States; and by upscaling the sub-National FREL initiated at CRS to the entire country. Part of the Readiness funds were allocated to undertake a low intensity forest carbon inventory in Nigeria; and was implemented through a Technical Assistance (TA) Agreement (UTF/NIR/066/NIR) signed between the Federal Government of Nigeria and FAO. One of the outputs of the TA Agreement was concerned with the design of a forest inventory methodology, capacity building on NFI field data collection, data base development and data analysis. This report presents a description and results of the entire forest inventory process from planning and implementation of the fieldwork to data compilation, analysis and reporting.

Unlike conventional forest inventories which focus on timber production and therefore often use volume of the growing stock as the key variable (Lund, 1998), and on tree species of commercial value, forest carbon inventories are concerned with biomass estimation for all tree species; and is thus more resource demanding. In response to the role of forests in climate change mitigation, there is now a growing demand for reliable information on carbon stock within the forest ecosystem. A National Forest (Carbon) Inventory is a key component of a Measurement, Reporting and Verification (MRV) system which is a requirement of the UNFCCC for forest reference emissions level (FREL) and national forest monitoring systems (NFMS) to assess anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks.

1.2 BRIEF HISTORY OF NATIONAL FOREST INVENTORY IN NIGERIA

- The first major forest assessment was carried out in the southern part of Nigeria in the 1930s. It involved a series of enumerations aimed at collecting huge volumes of data for pre-exploitation purposes (Hall, 1977). The enumerations were conducted in 27 forest reserves, during which trees with girth (circumference) at breast height (gbh) less than 61 cm (~ 19.4 cm diameter) were excluded. In most cases, a series of parallel strips of forest, each 20 m in width, at intervals of 2 km were enumerated. The assessment provided information that guided forest exploitation in southern Nigeria prior to 1960 (Akindele, 2014).
- Between 1964 and 1967, Schutz and Company Limited, Canada were commissioned to carry out a forest survey of Uwet-Odot, Ekinta River and Oban Group forest reserves in Calabar Province, south-eastern Nigeria. The purpose of the survey was to estimate volumes and distribution patterns of merchantable, or potentially merchantable species in the three forest reserves.

- The next major assessment took place between 1973 and 1977 by the Federal Department of Forestry, with the assistance of UNDP/FAO Forestry Division (FAO, 1980). The assessment was an indicative inventory of the reserved high forests in southern Nigeria and it covered 1 156 000 ha of reserved forests. The main objectives of the inventory were (I) to determine the amount and quality of merchantable tree sizes available and being utilized and those with potentials; and (II) to assess the degree of exploitation and the quantity and type of regrowth expected in the near future. The sampling design used was cluster sampling with variable area plots in most States. The diameter limit for tree enumeration was fixed at 40 cm.
- Between 1985 and 1987, the Federal Department of Forestry initiated the High Forest Monitoring Plots Project (HFMPP), which led to the establishment of 80 1-hectare Permanent Sample Plots (PSPs) within the lowland tropical rainforest ecological zone. It was funded by the European Economic Community (EEC). The distribution of PSPs is shown in Table 1.1. Each plot was remeasured two years after establishment. Unfortunately, further maintenance and monitoring of the plots was discontinued when the donor funds became exhausted, and many were encroached upon, and destroyed. According to Ojo (2004), by year 2000, only nine out of the 16 plots in one of the locations remained. Others had been converted to farmland by farmers.
- In 1995, the Federal Government of Nigeria received a grant from the African Development Bank (AfDB) to carry out a national forest inventory named "Forest Resources Study (FRS)". This inventory was aimed at enhancing industrial forestry development in Nigeria, and facilitating management of the nation's remaining forest resources in an efficient and environmentally adequate way. Beak Consultants Limited of Canada was commissioned to undertake the study in collaboration with the Federal Department of Forestry and State Forestry Departments in 28 participating States with sizeable areas of production forests. The study was undertaken between 1996 and 1999, under the supervision of the Forestry Management, Evaluation and Coordinating Unit (FORMECU). Results obtained indicated volume estimates for all tree species (with minimum dbh = 20 cm) were 140.6 million m^3 in forest reserves, and 120.7 million m^3 in areas outside forest (Akindele, 2000). Existing forest plantations within the forest reserves accounted for only 3.8 percent of the forest reserves area. Gmelina arborea and Tectona grandis were the two most prominent plantation species, occupying 59.3 percent and 25.1 percent of the total plantation area, respectively.

Since 1999 no forest inventory has been undertaken in Nigeria.

Table 1.1 Distribution of high forest monitoring plots in the lowland rainforest in Nigeria

S/No.	Location	No. of plots	Year of establishment
1	Omo (Sawmill Sector), Ogun State	10	1985
2	Omo (Abeku Sector), Ogun State	16	1985
3	Owan, Edo State	13	1986
4	Sakpoba, Edo State	21	1986
5	Oban East, Cross River State	10	1987
6	Oban West, Cross River State	10	1987
	Total	80	

Source: Ojo (2004)

1.3 OBJECTIVES OF THE NATIONAL FOREST INVENTORY IN NIGERIA

The overall objective of the present inventory was to assess the forest carbon stock in different ecological zones in Nigeria. In order to achieve the above objective, the following activities were undertaken:

- Establishment of sampling units (clusters) in the different ecological zones for field data collection;
- Enumeration of live and dead trees in the plots;
- Computation of carbon stock in the aboveground carbon pools; and
- Estimation of forest carbon stock per hectare in each ecological zone in Nigeria.

The information collected also permitted the assessment of species diversity in the different ecological zones.

1.4 SCOPE AND LIMITATIONS TO THE NATIONAL FOREST INVENTORY UNDERTAKEN

The present National Forest Inventory is a low-intensity inventory with relatively few sample units spread across the main ecological zones in Nigeria. As a result of security challenges in some parts of the country, the risk-prone states were excluded from the sampling plan/design. However, all ecological zones were captured in the sample.

According to the IPCC (2006), carbon pools in forest ecosystems comprise carbon stored in the living trees aboveground and belowground, in dead matter including standing dead trees, in fallen woody debris and litter, in non-tree understorey vegetation, and in soil organic matter. However, during the inventory, not all the carbon pools were directly measured. Field measurements were restricted to aboveground live and dead trees, lying deadwood, stumps and litter. The estimate of carbon stock in other tree components was indirectly estimated using existing ratios or allometric equations.


©FAO/John Fonweban

Litter collection.

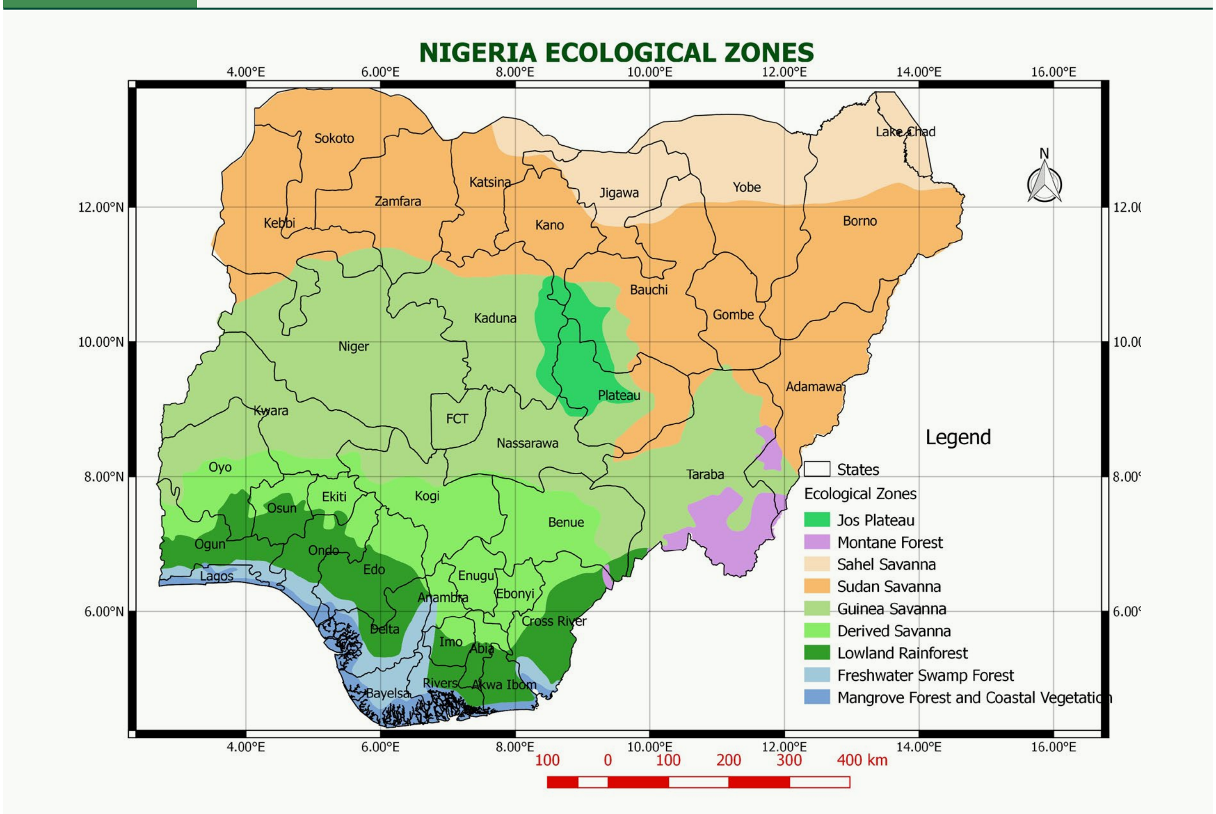
2 Sampling methodology

2.1 SAMPLING DESIGN AND DISTRIBUTION

The sampling design used is a stratified random cluster sampling, using the main ecological zones as strata. The main ecological zones are the mangrove forest and coastal vegetation, freshwater swamp forest, lowland rainforest, derived savanna, Guinea savanna, Jos plateau, montane forest, Sudan savanna, and Sahel savanna (Figure 2.1). These ecological zones cut across the administrative boundaries of the states. The sampling plan used a grid size of 10 km by 10 km in the various ecological zones, except the mangrove where grid size of 5 km by 5 km was used. At the time of carrying out this current study, the problem of insecurity in some states was prominent. These included States known as hot spots of insurgency, kidnapping, armed banditry, etc. In order to minimize potential risk to field teams, such States were masked off the plan.

To determine the number of clusters to be sampled in each ecological zone, preliminary results obtained from a similar exercise in Cross River State were used as input for optimal allocation (Cochran, 1977). The procedure of optimal allocation was used because it produces the smallest variance for estimating a population mean and total, for a given predetermined sample size. Table 2.1 summarizes the number of clusters estimated in each ecological zone and state (excluding Cross River State where an earlier inventory had been undertaken).

Figure 2.1 Ecological zones of Nigeria



Source: FORMECU, 1998. The Assessment of Vegetation and Landuse Changes in Nigeria. Geomatics International Inc. for Federal Department of Forestry, Abuja, Nigeria.

2.2 FIELD SAMPLE PLOT LAYOUT

The sampling unit was a cluster composed of a set of three square nested plots (or recording units) of 35 m x 35 m; two of which are positioned at right angles to the apex of a central plot, in an L-shape transect arrangement, and at 100 m apart. The plots were referred to as Elbow plot, East plot and North plot. Plot size of 35 m x 35 m was adopted in this study, for the sake of consistency with the forest carbon inventory in Cross River State. A diagram of the cluster arrangement and a nested plot is shown in Figure 2.2 and its detail specifications of a nested plot are presented in Table 2.2. The primary advantage of nested plots is that small trees can be measured on small plots which decreases costs with little loss in precision of the estimates (Tomppo *et al.* 2010). From a practical point of view circular plots are most rapidly installed wherever the visibility in the stand is good (e.g. savanna woodlands and forest plantations), and also have a lower expected number of border trees compared to square plots with same area. However, the establishment of circular plots in dense undergrowth in tropical forests, and on very steep terrain, could be very difficult. This explains why circular plots were not used in previous large-scale inventories in Nigeria.

Table 2.1 Distribution of the clusters based on ecological zones and states

State	Mangrove forest	Freshwater swamp forest	Lowland rainforest	Derived savanna	Guinea savanna	Sudan savanna	Sahel savanna	Montane forest	Jos plateau	Total
Akwa Ibom			6							6
Anambra				2						2
Bauchi						5			2	7
Ebonyi				3						3
Edo		3	9	4						16
Ekiti			1	5						6
Enugu				5						5
Imo			7							7
Jigawa							4			4
Kaduna					8				1	9
Kano						4				4
Katsina						3	2			5
Kebbi						9				9
Kwara				2	5					7
Lagos	6	3								9
Nasarawa					10					10
Niger					8					8
Ogun	3	7	13	4						27
Ondo	8	9	30	4						51
Osun			7	2						9
Oyo			4	5	3					12
Sokoto						4				4
Taraba								18		18
FCT					2					2
Total	17	22	77	36	36	25	6	18	3	240

Figure 2.2 Sketch diagram of a cluster arrangement and nested plot

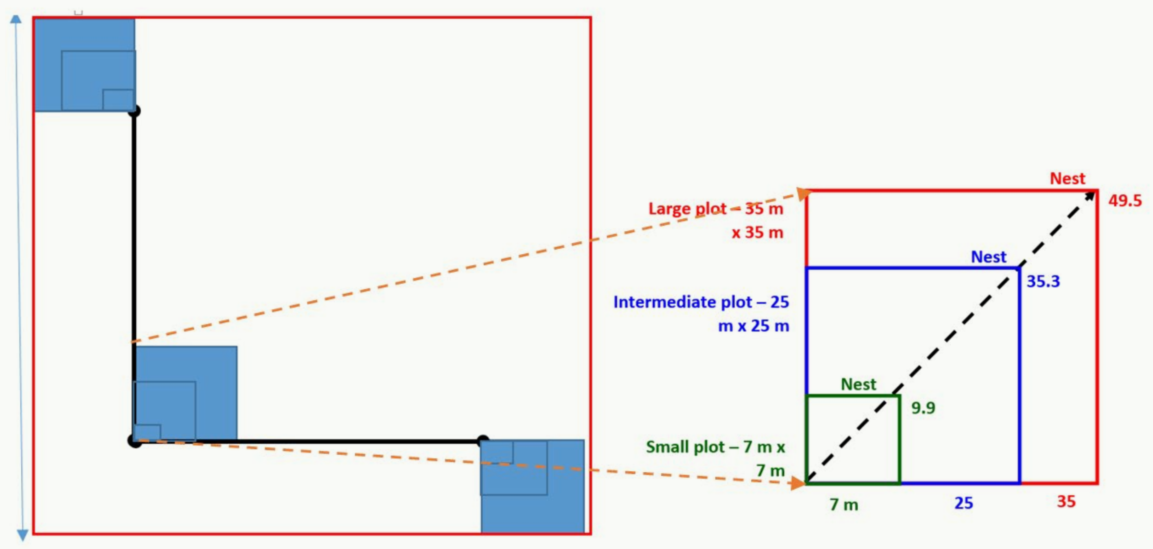


Table 2.2 Sample unit specifications

Unit	Shape	Size (Area)	Number	Tree Dbh limits
Sampling unit or tract	Square	170 m x 170 m ($28900\ m^2$)	1	N/A
Nest 1 (large plot)	Square	35 m x 35 m ($1225\ m^2$)	3	Dbh > 40 cm
Nest 2	Square	25 m x 25 m ($625\ m^2$)	1 per plot	Dbh 20 to 40 cm
Nest 3	Square	7 m x 7 m ($49\ m^2$)	1 per plot	Dbh 5 to 20 cm
Nest 4	Square	2 m x 2 m ($4\ m^2$)	1 per plot	Saplings with Dbh < 5 cm

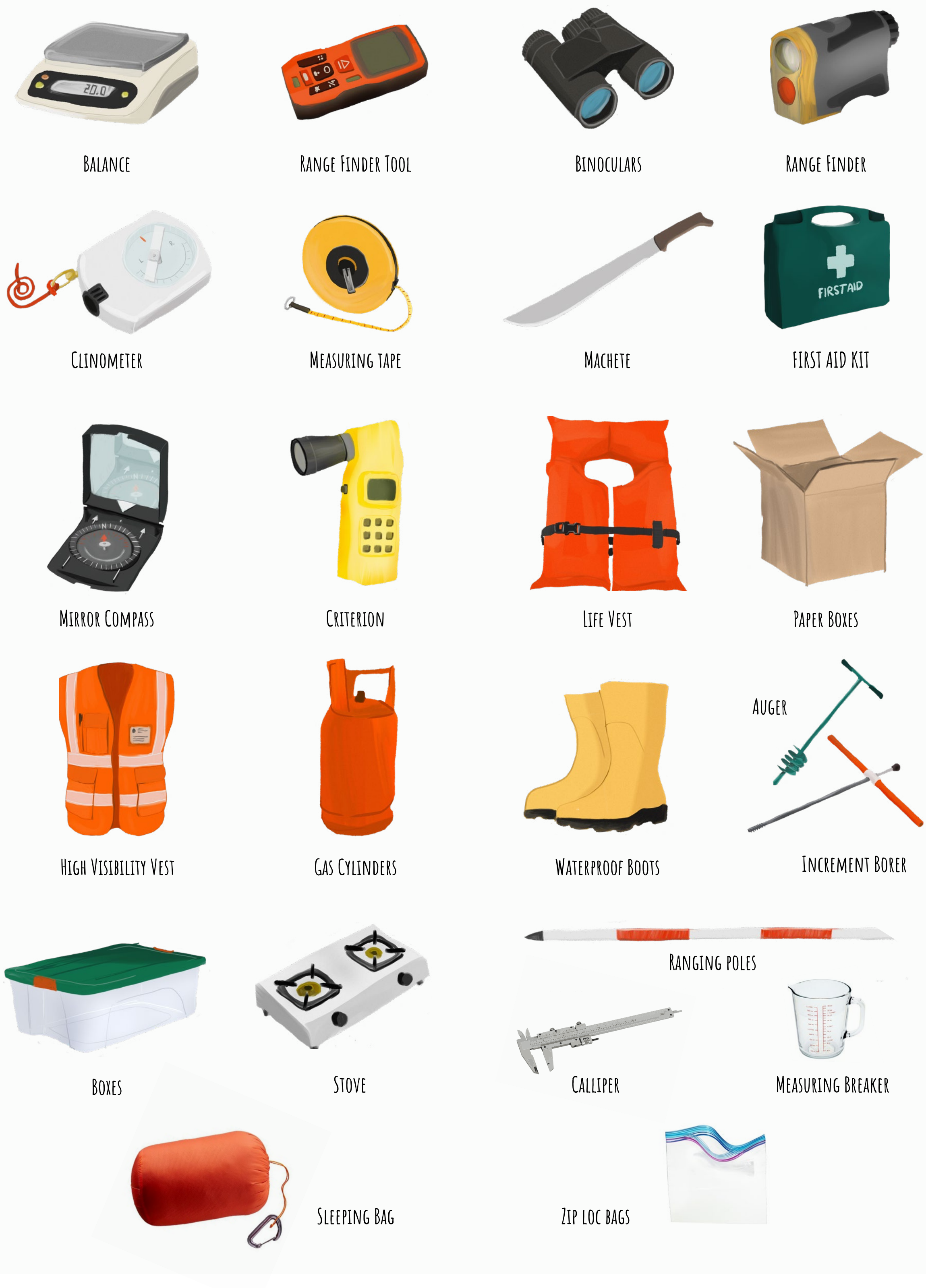
2.3 FIELD EQUIPMENT FOR THE INVENTORY

Table 2.3 presents a list of a selection of field equipment items used during the inventory, while Plate 2.1 show pictures of the main equipment.

Table 2.3 List of materials supplied to each inventory team

Equipment	Uses
Diameter tapes	For measuring tree diameter at base and diameter at breast height
Measuring tapes	For measuring distances and length of lying dead trees
Compass	For obtaining bearings of plot during demarcation
Clinometer	For measuring slope
TruPulse	For measuring horizontal distances to trees
Criterion	For measuring tree height and upper diameters
GPS	For taking coordinates of points and for cluster locations
Binoculars	For viewing tree leaves at upper canopy layer to aid in identification
Life jacket	Safety wear for use when crossing any water body (e.g. mangroves)
Camp beds	For use by the inventory teams as beds while overnighting in the forest
Vernier calliper	For measuring small diameters
Ranging poles	For aligning plot boundaries
Tablets	For field data entry on Collect Mobile
Boots	For for walking in the forest
First Aid kits	To store basic medical (first aid) items
Hand gloves	For hand protection
Raincoats	For protection during rainfall
Torch & batteries	For illumination at night
Gas/stove	For cooking by the camp caterers
Kitchen utensils	For use by the camp caterers
Camera	For taking pictures
Machetes	For cutting and slashing
Back pack	For transportation of field equipment and personal items in the field
Folders	For storage of field forms

Plate 2.1 Some of the field equipment used



2.4 TEAM COMPOSITION

For the NFI fieldwork, team members were recruited (after a series of capacity building trainings) from the National REDD+ Secretariat, Abuja, Federal Department of Forestry, Abuja; Cross River State REDD+ Secretariat; Ondo State REDD+ Secretariat; Nasarawa State REDD+ Secretariat; Forestry Research Institute of Nigeria; universities; states departments of forestry; and local communities. This composition ensured that there was a good mix of staff from diverse backgrounds and varying experiences. The selection was done after a number of capacity building trainings on forest inventory fieldwork. The NFI exercise served as an opportunity for newly recruited participants to gain hands-on field training as they learnt from the participants with prior experience. This was another means of capacity building for the country.

2.4.1 THE INVENTORY TEAM

Each inventory team was made up of one cutting crew composed of the team leader who managed the GPS, a person in charge of the compass, and one casual labourer; and an enumeration crew composed of a taxonomist, a laser instrument expert, a bookkeeper, a diameter measurer and one casual labourer. The roles of each member of the team are summarized in Table 2.5

2.4.2 THE SENSITIZATION TEAM

The sensitization team was composed of a stakeholder engagement officer from the National REDD+ Secretariat, a staff member of FAO and a staff member of the State Forestry Department (or State REDD+ Secretariat). Initially, the sensitization team was a separate entity from the inventory team, and its role was to meet and engage with and/or sensitize relevant

Table 2.5 Brief description of roles of the inventory crew members

Crew member	Brief description of roles
Team leader	• Coordinates activities of members of the team to ensure timely progress; • Recruits local labour to work with the cutting crew and the enumeration crew; • Takes stock of all field equipment and ensures their safe-keeping to ensure that none aremissing; • Leads in the location of the cluster points; • Ensures accurate completion/filling of field forms and tablets and taking notes and applying cross-checking procedures to insure reliable data is collected; • Organizes daily meetings after fieldwork in order to summarize the day's activities and plan for the next day; and • Boosts the morale of team members and maintains good team spirit.
Compass manager	• Takes bearings and makes proper alignment for demarcation of plot boundaries; • Establishes the nests within the large plot; and • Supervises the local labour in line cutting to facilitate access to sample plots.
Taxonomist	• Enumerates all the trees in the sample plot; and • Identifies each tree species and makes note of the unknown species.
Laser instruments expert	• Uses the TruPulse 200B and the Criterion RD1000 Laser instruments for distance determination and measurement of tree height and upper-stem diameters.
Diameter measurer	• Uses the girth-diameter tape to measure diameter at tree base, at breast height or above buttress.
Bookkeeper /tablet expert	• Records all measurements in the appropriate field forms; and • The tablet expert keys in the data directly into Collect Mobile installed in the Tablet.
Casual labourer	This refers to two locally hired labourers from the community in the locale of the cluster, who performed the following functions: • Guide the team in accessing the cluster points and plots; • Carry out line cutting to facilitate access to the plots and the trees to be measured; and serve as porters in carrying field equipment.

authorities in the State and local communities ahead of the inventory fieldwork and prepare the ground for the inventory team, and hence facilitate access of inventory team to cluster location for data collection in the area. However, experience after the first inventory expedition in Ondo State showed that this was not an effective approach. Subsequently, the sensitization members constituted part of the inventory team.

There was much flexibility among members of the field team as they exchanged roles assigned by the team leader from time to time. Throughout the entire exercise, the NFI Consultant worked with the various teams to address issues as they arise and ensure that the fieldwork is implemented as planned.

2.5 FIELD DATA COLLECTION FROM THE CARBON POOLS

2.5.1 ACCESS TO CLUSTER LOCATION & PLOT DEMARCATION

Access to Cluster

After engagement and sensitization of the community closest to the cluster, the field crew proceded to the cluster location guided by the locally hired staff and also aided by the cluster description access and location. The GPS was used during the process and landmarks were noted as well. On arrival at the cluster location, the first nested (elbow) plot is established. Details on access to the cluster are found in the NFI Manual. Collect Mobile[1] was used for field data input, alongside with manual field forms.

Plot information

For each plot in the cluster, the information obtained and recorded are State, Local Government Area, Ecological Zone, Cluster ID, Plot Location (Elbow; North; East), Name of Community Nearest to the Cluster, Coordinates (Latitude (^{0}N) and Longitude (^{0}E)), Altitude (m), Aspect, Topographic Position, Canopy/Crown Cover (%), Major Land Use Categories, Description of how to locate the Cluster, Name of Bookkeeper, Phone number and Date. Even though all the plots were temporary sample plots, the detailed GPS coordinates and description of how to locate them can be used to re-locate them for future re-measurements.

2.5.2 MEASUREMENT OF STANDING LIVE TREES, STANDING DEADWOOD AND STUMP MEASUREMENTS

In the 35 m x 35 m plot, all living trees and standing deadwood 40 cm diameter and above were numbered, identified and enumerated. In the 25 m x 25 m plot, the dbh range was 20 cm to 40 cm while in the 7 m x 7 m plot, dbh range was 5 cm to 20 cm (Table 2.2). Table 2.6 presents a list of variables measured/observed for live trees, standing dead trees and stumps; while Table 2.7 contains codes used during field enumerations.

1 http://www.openforis.org/tools/collect-mobile.html

Table 2.6 Variables measured / observed in the sample plots

	Live trees	Standing deadwood	Stump
Measured variables	Diameter at base (cm) Diameter at breast height (cm) Diameter at middle (cm) Diameter at top (cm) Total height (m) Bole height (m) Species name	Diameter at base (cm) Diameter at breast height (cm) Diameter at top (cm) Total height (m	Stump diameter (cm) Stump height (m)
Observed and coded variables	Stem quality Crown condition Tree condition Damage severity Causative agent	Dead tree status Decay class	Years since cut Decay class

Table 2.7 Codes used during field enumeration

National ecological zones (NEZ)	Code
Sahel savanna	1
Sudan savanna	2
Guinea savanna	3
Derived savanna	4
Lowland rain forest	5
Freshwater swamp forest	6
Mangrove forest and coastal vegetation	7
Jos Plateau	8
Montane region	8

Stem quality	Code
Low (crooked stem)	1
Medium (bend stem)	2
High (straight stem)	3

Damage severity	Code
None	1
Slight	2
Serious	3
Very serious	4

Crown condition	Code
Healthy	1
Declining health	2
Unhealthy	3
Dying	4
Dead	5

Overall tree condition	Code
Healthy	1
Slightly affected	2
Severely affected	3
Dead/dying standing tree	4
Dead/dying fallen tree	5

Causative agents	Code
Not applicable	0
Insects	1
Disease / fungi	2
Fires	3
Animals	4
Humans	5
Climate	6
Other	99

Use(s) of tree	Code
No Use/not applicable	0
Saw logs and timber	1
Poles	2
Fuel wood / charcoal	3
Medicinal use	4
Fruits	5
Other uses	99

Year(s) since cut (for stumps only)	Code
<1 year	1
1–5 years	2
6–10 years	3
>10 years	4
Not known	90

Decay class – Determine using "Matchet" test	Code
Sound (S)	1
Intermediate (T)	2
Rotten (R)	3

Dead tree status (for standing dead trees)	Code
Bole with branches and twigs	1
Bole with small and large branches	2
Bole with large branches only	3
Vead bole only	4

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 diametertape. However, for trees with anomalies and/or multiple stems, measurements were made according to the instructions in the box below:

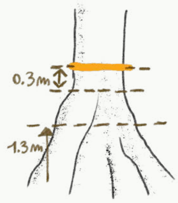
Tree height measurements

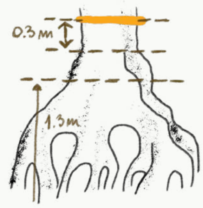
Given that height mesurements are both difficult and costly, the standard practice during inventory is to take the few height measurements as accurately as possible and then establish height-diameter relationships that can be used to compute heights of trees for which height measurement was impracticable.

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.

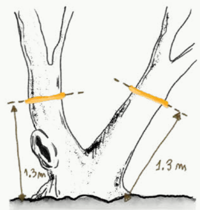
In addition to height measurements, three diameter measurements were measured with the Criterion RD1000 Laser Dendrometer: diameter at tree base (Dbase), diameter at mid-stem (Dm) and diameter below large branch (Dtop). These measurements, plus the bole height were used to compute tree bole volumes using Newton's Log Formula.

If a trunk is malformed at breast height or there is a buttress, the measurement is carried at 30 cm above the end of the deformation.

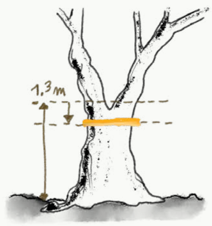




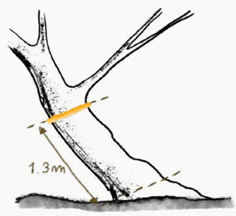
If a tree is forked below breast height of 1.3 m, then measure each fork as an individual/separete tree.



If a tree is forkes above 1.3m, measure dbh of the main stem (unless there is an unusual bulge right at 1.3m).



If the tree is on a slope, always measure on the uphill side. If the tree is leaning, the dbh tape must be wrapped to be perpendicular to the main axis of the trunk.



2.5.3 DOWNED DEADWOOD MEASUREMENT

The plot method was used to sample fallen dead wood. All lying deadwood of at least 5 cm in diameter and 1 m in length were enumerated. The data collected from these included large-end diameter (cm), small-end diameter (cm), length (m), and decay class, whichwas determined using the machete test, as described in the NFI manual entitled "Sampling Design and Field Protocol for the National Forest Inventory in Nigeria".

Three decay classes were distinguished: class 1 – sound, class 2 – intermediate, and class 3 – rotten. Samples of the lying deadwood were extracted and weighed in the field. The volume of each sample was measured using the water displacement method in laboratory. The samples were oven-dried to constant weight at 105°C.

2.5.4 LOWER VEGETATION AND SAPLINGS

All live seedlings, saplings and shrubs were counted within the 2 m x 2 m plot (Nest 4). They were identified and categorized into those below 1.3 m in height and those taller than 1.3 m. The latter category was further classified into those with less than 2 cm in diameter and those with diameters ranging from 2 cm to 4.9 cm.

2.5.5 LITTER

A 1 m x 1 m quadrat was established in an untrampled part within the 35 m x 35 m plot for litter collection. All litter within the quadrat were collected and weighed. A sub-sample of the litter was then taken and weighed. The weighed sample was bagged and labelled and taken to the laboratory for drying and litter analysis. Litter was dried in the oven at a constant temperature of 60°C. Litter sample collection was done only in a few instances and mainly in the lowland rainforest and montane forest ecosystems. In the mangrove and freshwater swamp forests, most plots were water-logged and therefore litter sample could not be collected. In the savanna ecosystems, incidence of bush fire often results in absence of litter in many parts of the ecosystems.

2.5.6 INCREMENT CORES FOR WOOD DENSITY DETERMINATION

For a sub sample of standing live trees, the increment borer was drilled into the trees at breast height position to collect core samples. Each sample was weighed and the fresh weight was recorded. In addition, the length of the core sample was also measured with a ruler and recorded in the data sheet. Each sample was then put in a small transparent nylon bag and labelled appropriately. All the core samples were then taken to the laboratory for ovendrying to determine the dry weight. The core samples were dried in the oven at a constant temperature of 70°C to constant weight.

2.6 DATA VERIFICATION AND CLEANING

Quality control (QC) is a routine practice intended to monitor and control the quality of data collected as the inventory progresses. In this study, the QC system was designed to provide routine and consistent checks to ensure data integrity, correctness, and completeness. The intent was to identify and address errors and omissions as soon as possible, and render corrective measures.

QC activities were undertaken at different stages of the study:

1. During field data collection: The NFI Consultant and Team Leaders closely followed the field teams to ensure that the NFI standard operations procedures (SOPs) were strictly followed in measuring tree variables in the field plots. Mistakes were quickly spotted and corrected. Every evening after field work, review meetings were held with the field teams to address challenges and make plans for the next day. During these meetings, completed field forms were checked for correctness and completeness. Where gaps occurred, the bookkeeper was asked to provide explanations which were then written on the form. Data directly entered into Collect Mobile in the field were also checked and necessary corrections made.

2. After downloading the data from the tablets: Once the field work was over, the tablets used for data entry on Collect Mobile were retrieved and the contents downloaded into a computer. The data sheets were saved in MS Excel spreadsheet format and examined for possible errors. This stage was very crucial as some mistakes were discovered. They were largely data input errors such as interchanging the values of latitudes for longitudes, omission or wrong placement of decimals, interchanging bole height for total height, etc. These corrections were made possible by comparing the contents of the spreadsheets with the hardcopy forms filled on the field. Though the exercise was time-consuming and laborious, it was considered crucial for QC. At this stage, data were also checked to see that the units of measurement were correctly recorded.

2.7 DATA ANALYSIS

2.7.1 CALCULATING THE PLOT AREA AND SCALING FACTOR

Given that trees were measured in nests of different sizes, a scaling factor was needed for each nest in order to standardize all measurements to a per-hectare basis. The scaling factor gives the number of each nest size that can be found in one hectare; and was obtained by dividing one hectare (10 000 m²) by the area of each nest. Table 2.8 gives the scaling factors computed for each nest.

2.7.2 WOOD DENSITY DETERMINATION FOR LIVE TREES

Wood density is one of the key variables required for the estimation of aboveground tree biomass and forest carbon stock. A non-destructive sampling approach was used, through extraction of 235 increment cores at tree breast height from 54 species. These are oven-dried to constant weight at 70ºC and the ratio of their dry weight to their wet volume is taken as the wood density (in g/cm³). If, L_c = length of the core sample (cm), d_c = diameter of the core sample (cm), V_c = volume of the core sample (cm³), DWTc = oven-dry weight of the core sample (g), and ϱ = wood density (g/cm³). The diameter of the core samples was 0.45cm then:
In addition to the wood densities obtained through core sampling, a wood density database of all the species

$$V_c = \frac{\pi (d_c)^2}{4} \times L_c \quad \text{.......................................(3)}$$

$$\rho = \frac{DWT_c}{V_c} \quad \text{..(4)}$$

encountered in the study was compiled from existing literature and from research scientists (Prof. Shadrach Akindele, Dr Chenge, Dr Aghimien) who had worked on wood densities in Nigeria. A table showing the tree species list and their wood densities is presented in the Appendix 1.

Table 2.8 Area of each nest and the corresponding scaling factor

Nest	Dimension	Area (m²)	Area of 1 ha (m²)	Scaling factor
1	35m x 35m	1225	10 000	8.16
2	25m x 25m	625	10 000	16.00
3	7m x 7m	49	10 000	204.08

2.7.3 WOOD DENSITY DETERMINATION FOR STANDING AND DOWNED DEADWOOD

Deadwood densities for each category of Deadwood (sound, intermediate and rotten) were estimated using the following equation:

$$\rho_{DW} = \frac{\text{Mass}}{\text{Volume}} \quad \text{..(5)}$$

where ρ_{DW} = Deadwood density (g/cm^3),
Mass = oven-dried weight (g) of sample,
and Volume is the fresh volume of the sample obtained through the water displacement method. The average wood densities for each category was then calculated and used for deadwood biomass estimation.

2.7.4 MODELLING HEIGHT-DIAMETER RELATIONSHIP

Apart from diameter and wood density, another important variable in biomass estimation is the tree height. However, the nature of the tropical rainforest makes height measurement difficult due to canopy closure and interlocking crowns, which impair clear visibility of the tree top as well as dense undergrowth. Consequently, height measurements were only done for a sample of trees where visibility of the tree top and base was not impaired; and tree bole was clearly visible. The height-diameter data collected from sample trees were used to develop a height-diameter model. Scatterplots of the data were produced to observe the pattern of the relationship between tree total height and diameter at breast height. A number of height-diameter models were fitted to the data using R-Development package (https://www.R-project.org/). The models were compared and the best selected and was used to compute heights for those trees that were for which height was not measured during the inventory. The equation for the final model selected is as follows:

$$H_{est} = 1.3 + 30.441065 \left[1 - \exp\left(- 0.40144 \times dbh^{0.8239} \right) \right]$$

2.7.5 ESTIMATION OF ABOVEGROUND BIOMASS

The conversion of field data collected to forest biomass and carbon stocks requires the use of biomass allometric equations. The equations use tree variables like dbh, height and, sometimes, wood density of the species to estimate tree biomass. In the absence of country-specific allometric equations pantropical biomass equations were assessed for their appropriateness for estimation of tree biomass from the NFI data collected. Amongst the equations, the following pan-tropical allometric equation by Chave *et al* (2014) was used to estimate above ground biomass for all ecological zones, except mangroves:

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

$$(\sigma = 0.357, \text{AIC} = 3130, \text{df} = 4002)$$

where:

AGB_{est} = above ground biomass (kg)

ρ = species dry wood density (g/cm^3)

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, as described in section 2.7.4 above. Wood density estimates were obtained from core samples collected during the inventory (as described above), and additional data from a number of studies undertaken in Nigeria (Chenge, 2017; Aghimien, 2018; Akindele (unpublished)), and from a global database (Zanne *et al.* 2009), for species without local wood density values.

2.7.6 ESTIMATION OF BELOWGROUND BIOMASS

Field data collection for estimation of belowground biomass is both laborious, expensive and destructive. It requires uprooting the sample trees and excavating the roots. In tropical forests with very large trees and deep tap roots it is impractical to undertake such studies, hence, most studies resort to the use of root-shoot ratios, in order to obtain root biomass from aboveground biomass. 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:

$$BGB = \begin{cases} 0.235 \times AGB \text{ if } AGB > 62.5t\ C/ha \\ 0.205 \times AGB \text{ if } AGB > 62.5t\ C/ha \end{cases}$$

2.7.7 ESTIMATION OF BIOMASS FOR MANGROVE FORESTS

For the mangrove ecosystem, the following common allometric equations by Komiyama *et al.* (2005) were used for the computation of aboveground and belowground biomass:

For aboveground biomass:

$$W_{top} = 0.251\rho D^{2.46} \qquad (r^2 = 0.98,\ n = 104,\ D_{max} = 49cm)$$

For belowground biomass:

$$W_R = 0.199\rho^{0.899}D^{2.22} \qquad (r^2 = 0.98,\ n = 26,\ D_{max} = 45cm)$$

where W_{top} = Aboveground biomass (kg), WR = Belowground biomass (kg), ρ = wood density (g/cm^3), and D = Diameter at breast height (cm). From these, total biomass of trees in the mangrove forest is as follows:

$$W_{total} = 0.251\rho D^{2.46} + 0.199\rho^{0.899}D^{2.22}$$

2.7.8 ESTIMATION OF BIOMASS FOR STANDING AND LYING DEADWOOD

Using field data recorded for the standing and lying deadwood, the volume of each deadwood was calculated. The Smalian formula (Husch, *et al.*, 2003) was used for the calculation.

The formula is expressed as:

$$V = \frac{\pi H}{8}(D_b^2 + D_t^2)$$

where V = Volume (m^3), H = height (m), π = 3.141592654, D_b = Diameter at the base (m) and D_t = Diameter at the top (m).

From the volumes obtained, biomass was estimated by multiplying the volume obtained by the deadwood density for the appropriate decay category. The deadwood density for each decay category were obtained from lab analysis of the deadwood samples. Results based on the analysis of the samples collected, for sound, intermediate and rotten deadwood are as shown in Table 2.9.

2.7.9 ESTIMATION OF BIOMASS FOR STUMPS

The first step in the estimation of stump biomass was to calculate the volume of each stump, using the following formula:

$$V_{st} = \frac{\pi D_{st}^2}{4} \times H_{st}$$

where V_{st} = Stump Volume (m^3), Dst = Stump Diameter (m), and H_{st} = Stump Height (m). Each volume was then multiplied by the appropriate wood density of the species.

Table 2.9 Density values for deadwood

Decay class	Standing deadwood	Lying deadwood
	Density (g/cm3)	Density (g/cm3)
Sound	0.46	0.262
Intermediate	0.36	0.192
Rotten	Not applicable	0.186

2.7.10 ESTIMATION OF BIOMASS FOR LITTER

The dry mass of each sub-sample obtained after oven-drying to constant weight in the laboratory was divided by the fresh weight of the sub-sample. This was then multiplied by the fresh weight of the entire litter in the 1 m x 1 m quadrat from which the sub-sample was taken. The result was then upscaled to per-hectare basis by multiplying it by a scaling factor of 10 000. The values were averaged for each ecological zone.

2.7.11 ESTIMATION OF CARBON STOCKS IN DIFFERENT ECOLOGICAL ZONES

The steps adopted for computing estimates of carbon and CO_2 equivalent stocks were as follows:

1. Within each plot, the biomass computed for each carbon pool in a nest was summed up and upscaled to per hectare basis. The results for the various nests were added together to obtain the biomass per ha for the plot.
2. Plot biomass expressed in kg/ha was converted into tons/ha by dividing by 1000.
3. For each ecological zone, the mean plot biomass and the standard error were computed.
4. The mean plot biomass (in tons/ha) was converted into carbon stock estimates by multiplying it by the IPCC default value of 0.47.
5. The CO_2 equivalent was obtained by multiplying it with the ratio of the molecular weight of carbon to that of oxygen (i.e. 44/12) or 3.6667.

Field team perfoming NFI activities.

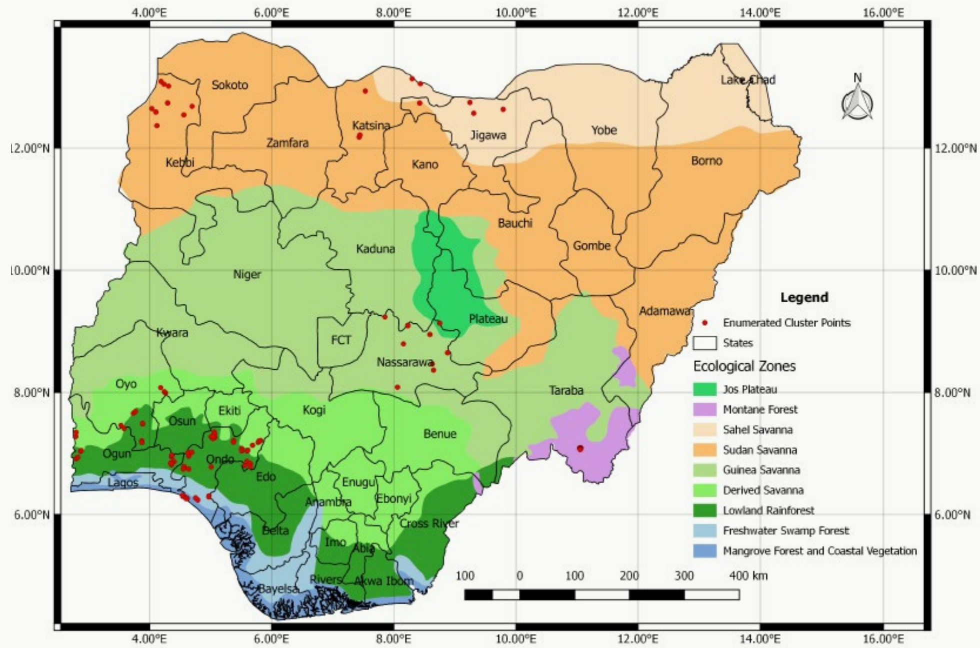
3 Results

The number of clusters enumerated in the various ecological zones is presented in Table 3.1; while the spatial distribution of the clusters is presented in Figure 3.1.

Table 3.1 Number of clusters enumerated in each ecological zone.

Row labels	Jigawa	Katsina	Kebbi	Nasarawa	Ogun	Ondo	Oyo	Taraba	Grand total
Derived savanna					4	4	3		**11**
Freshwater swamp forest						3			**3**
Guinea savanna				10					**10**
Lowland rainforest					13	24	8		**45**
Mangrove forest						9			**9**
Montane forest								18	**18**
Sahel savanna	4	2							**6**
Sudan savanna		3	9						**12**
Grand total	**4**	**5**	**9**	**10**	**17**	**40**	**11**	**18**	**114**

Figure 3.1 Spatial distribution of sample clusters visited and measured in different ecological zones



Source: FORMECU, 1998. The Assessment of Vegetation and Landuse Changes in Nigeria. Geomatics International Inc. for Federal Department of Forestry, Abuja, Nigeria.

3.1 SUMMARY OF FIELD DATA

A total of 3,978 individual trees were enumerated during the NFI field work. Of this, 574 individuals (i.e. 14.4%) could not be identified, while the remaining 3,404 belonged to 280 different species. The diversity of species is very typical of the tropical forests as reported earlier by Turner (2001) and Akindele and LeMay (2006).

3.2 TREE SIZE DISTRIBUTION BY ECOLOGICAL ZONES

All trees enumerated during this National Forest Inventory had diameters at breast height or above buttress ranging from 5 cm to 236 cm in diameter. The dbh frequency distribution is presented in Table 3.2. The table indicates that most of the trees are in the lower diameter classes. The graphical illustration of the diameter distribution across all ecological zones is presented as Figure 3.2. The figure shows that 77.5% of the trees have dbh ≤ 40 cm. The diameter distribution curve has an inverted J-shape typical of uneven-aged distributions in tropical forests.

3.3 TREE SPECIES DIVERSITY AND RELATIVE ABUNDANCE

Figure 3.3. shows the number of live tree species enumerated in each ecological zone. A total of 280 species were enumerated. The lowland rainforest has the highest number of tree species (153), and hence the most diverse ecological zone; followed by the montane forest, with 97 species, derived savanna, with 52 species and Guinea savanna, with 38 species. The Mangrove Forest, Sahel and Sudan savannas had the least number of species, and hence the least diverse.

Figure 3.4 shows the frequency distribution of species found in the Fresh Water Swamp ecological zone in Nigeria. The predominant species in the Fresh water swamp are Ficus sp (26.6%), Sterculia oblongata (13.7%), Nauclea diderrichii (13.7%), Mitragyna ciliate (12.9%), Musanga cecropioides (10.5%) and Alchornea cordifera (8.9%), making up more than 85% of the species composition.

Figure 3.5. Presents the frequency distribution of species found in the Lowland Rainforest in Nigeria. The graph indicates that the predominant species are tree crop plantation species (Theobroma cacao (8.8%) Elaeis guineensis (5.8%) and forest plantation species (Gmelina arborea (19.6%) and Tectona grandis (3.7%). The abundance of pioneer species like Albizia zygia (3.0%) and Musanga cercropoides (1.7%) is evidence that the ecosystem has undergone degradation and may be in the recovery phase. The tropical rainforest has been under pressures from industrial plantations like Cocoa (Theobroma cacao) and Oil palm (Elaeis guineensis), and plantation silviculture in the tropical high forest in Nigeria has been undertaken mostly with two exotic species: Gmelina arborea and Tectona grandis. Hence while the forest cover (e. g. on satellite imagery) still reflects a lot of rainforest, the land use (as observed in the field during inventory) indicates the presence of industrial crop plantations and forest plantations with exotic species.

The least represented species found during the inventory include the following:

Albizia lebbeck, Albizia sp., Allophylus africanus, Anthocleista djalonensis, Anthocleista sp., Anthonotha macrophylla, Antiaris toxicaria, Bambusa arundinacea, Berliana sp., Berlinia coriacea, Bombax sp., Brachystegia leonensis, Bridelia bipidensis, Buchholzia coriacea, Canthium subcordatum, Celtis sp., Cocos nucifera, Cordia sp., Dacryodes edulis, Desplatsia dewevrei, Diospyros cinnabarina, Diospyros mespiliformis, Diospyros sp., Dracaena mannii, Enladosia angolensis, Erythrophleum suaveolens, Fagara loprietus, Fagara sp., Garcinia mannii, Gliciridia sepium, Khaya sp., Lannea acida, Lannea sp., Milletia excelsa, Millettia thonningii, Musanga sp., Nauclea poseguini, Neoboutonia sp., Parkia bicolor, Pexlapia sp., Psydrax aeutiflora, Pterocarpus osun, Ricinodendron sp., Scottellia coriacea,Spathodea campanulate, Sterculia oblonga, Syzygium guineense, Terminalia sp., Trichilia megalantha,Zanthoxylum leprieurii.

These species could be threatened by extinction if proper measures are not taken to regenerate their populations.

Figure 3.6 presents frequency distribution of species found in the Mangrove Ecosystem in Nigeria. The Mangrove ecosystem has only a few species predominated by Rhizophora racemosa (49.4%), and Avicennia africana (45.0%) occupying 95% of the species abundance. The remaining 5% is composed of Ficus sp. (4.1%) and Rhizophora mangue (1%).

Table 3.2 **Distribution of enumerated live trees into DBH classes in the various ecological zones**

Dbh class (cm)	Mangrove forest	Freshwater swamp	Lowland rainforest	Montane forest	Derived savanna	Guinea savanna	Sudan savanna	Sahel savanna	Total	Percent
05-10	206	27	520	161	124	125	21	2	1 186	36,5%
20 - 40	39	41	674	306	113	139	2	18	1 332	41,0%
40 - 60	1	5	292	188	12	12	3	10	523	16,1%
60 - 80	1	0	44	82	1	0	0	0	128	3,9%
80 - 100	0	0	13	26	1	0	0	1	41	1,3%
100 - 120	0	0	4	11	0	0	0	0	15	0,5%
120 - 140	0	0	3	6	1	0	0	0	10	0,3%
140 - 160	0	0	1	6	0	0	0	0	7	0,2%
160 - 180	0	0	3	1	0	0	0	0	4	0,1%
180 - 200	0	0	0	0	0	0	0	0	0	0,0%
200 - 220	0	0	0	0	0	0	0	0	0	0,0%
220 - 240	0	0	1	0	0	0	0	0	1	0,0%
Total	247	73	1 555	787	252	276	26	31	3 247	100,0%
Percent	7,6%	2,2%	47,9%	24,2%	7,8%	8,5%	0,8%	1,0%	100,0%	

Figure 3.2 **Percentage frequency distribution for the enumerated trees**

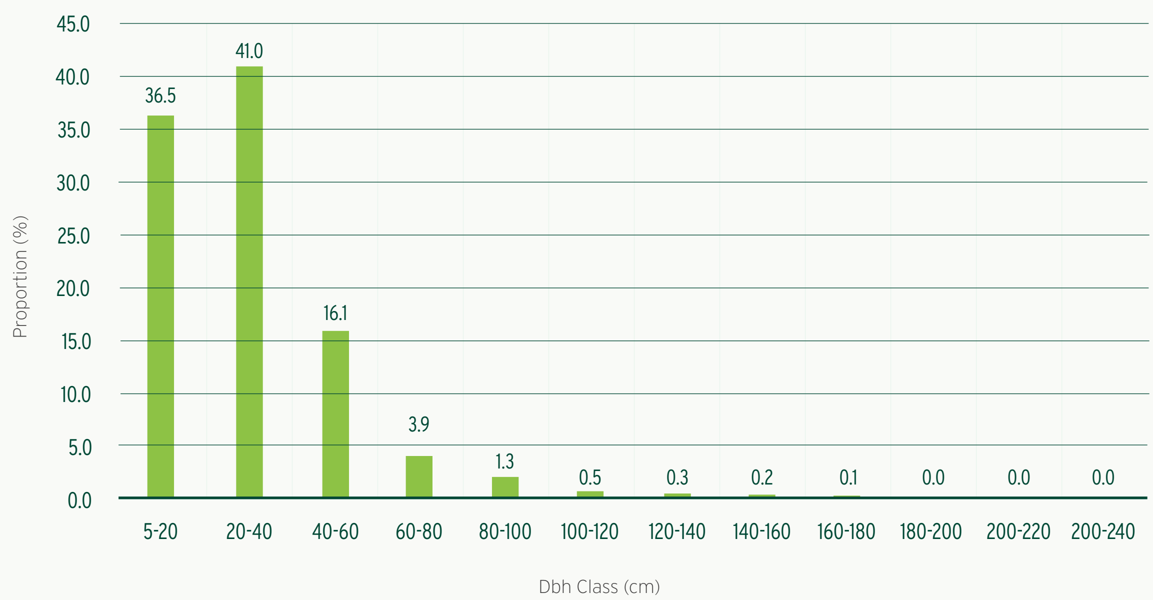


Figure 3.3 Frequency distribution of species by ecological zones

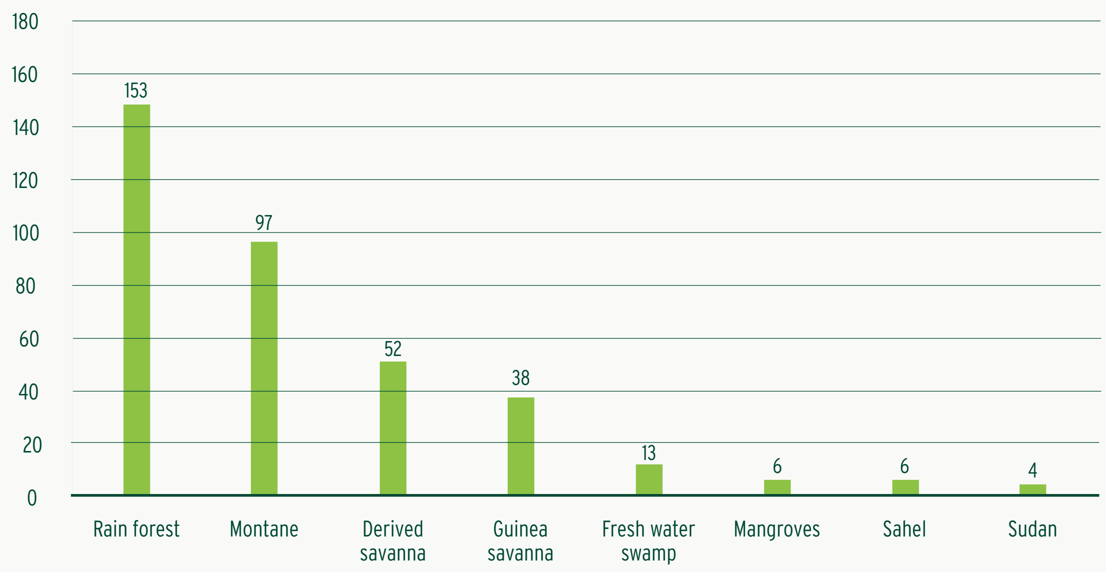


Figure 3.4 Frequency distribution of species found in the fresh water swamp in Nigeria

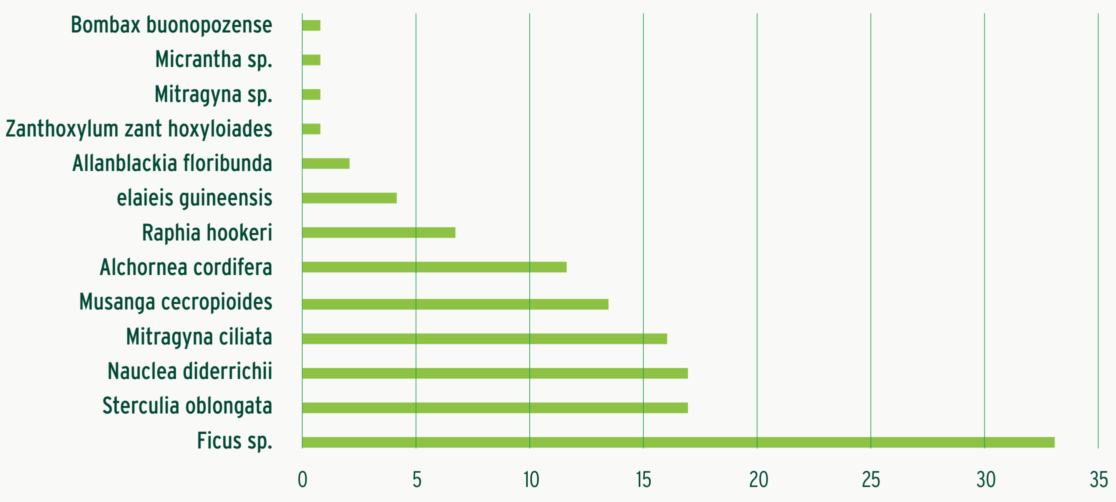


Figure 3.5 **Frequency distribution of the most abundant species in the lowland rainforest in Nigeria**

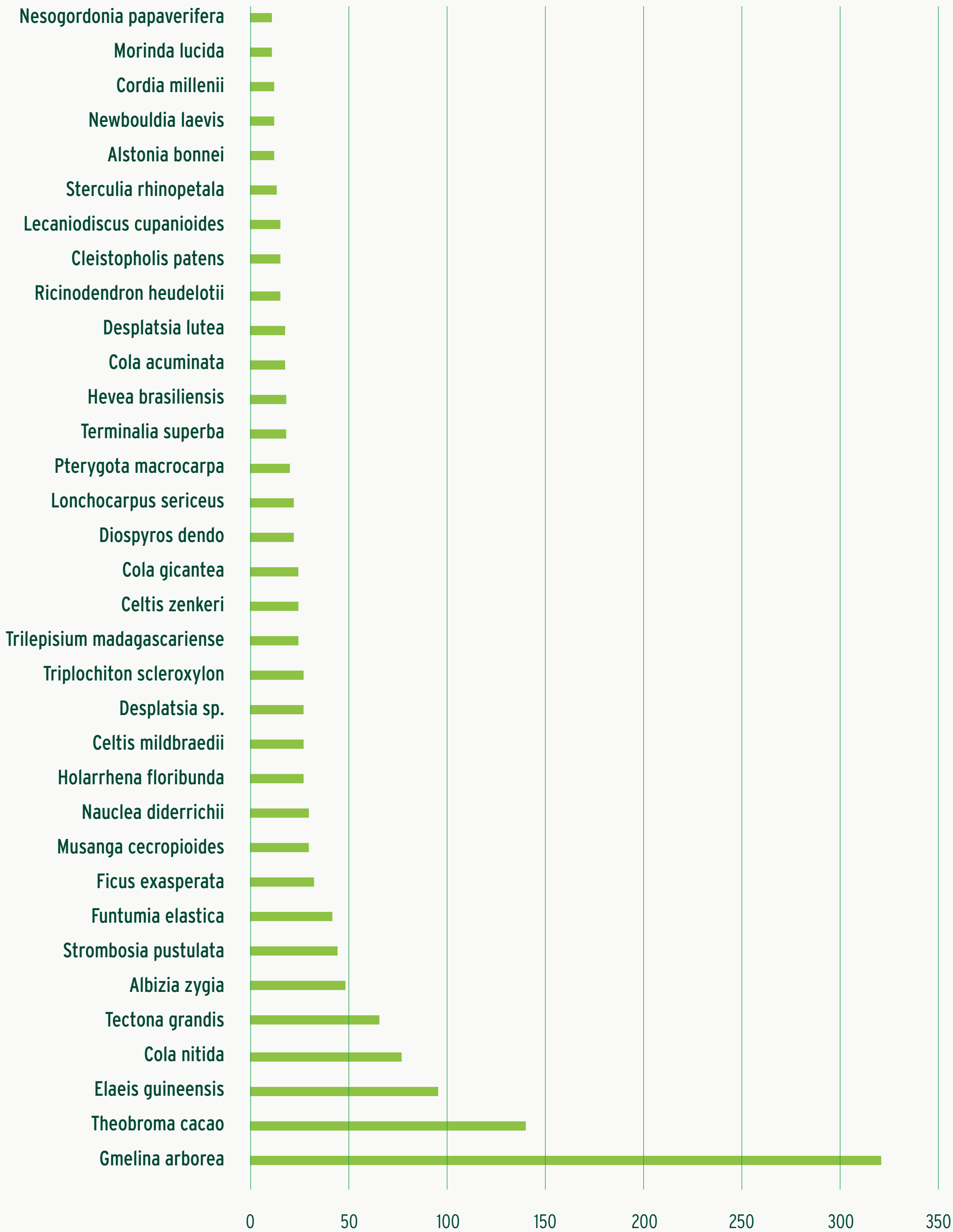


Figure 3.7 present the species distribution in the derived savanna ecosystem.

The predominant species in the derived savanna are two exotic species: Tectona grandis (43.5%) and Gmelina arborea (6.5%); while predominant non exotic species are Piptadeniastrum africanum (2.8%), Sterculia tragacantha (2.4%), Gliciridia sepium (2.4%), Albizia zygia (2.4%), and Terminalia glaucescens (2.0%).

The least represented species in the derived savanna include: *Vitex doniana, Terminalia ivorensis, Spondias mombin, Pterygota macrocarpa, Parkia biglobosa, Newbouldia laevis, Musanga cecropioides, Millettia thonningii, Lecaniodiscus cupanioides, Khaya ivorensis, Ficus sur, Entandrophragma angolense, Elaeis guineensis, Chrysophyllum albidum, Celtis zenkeri, Celtis integrifolia, Brachystegia eurycoma, Borassus aethiopum, Bombax buonopozense, Antiaris africana, Anthocleista sp., Afzelia Africana, and Adansonia digitata.*

Figure 3.8 present the frequency distribution of species found in the Guinea Savanna in Nigeria. The predominant species in the Guinea savanna include: Vitellaria paradoxa (20.0%), Tectona grandis (17.0%) and Daniellia oliveri (14.0%) making up 50 percent of the species composition in terms of relative abundance.

Figure 3.6 **Frequency distribution of species found in the mangrove ecosystem in Nigeria**

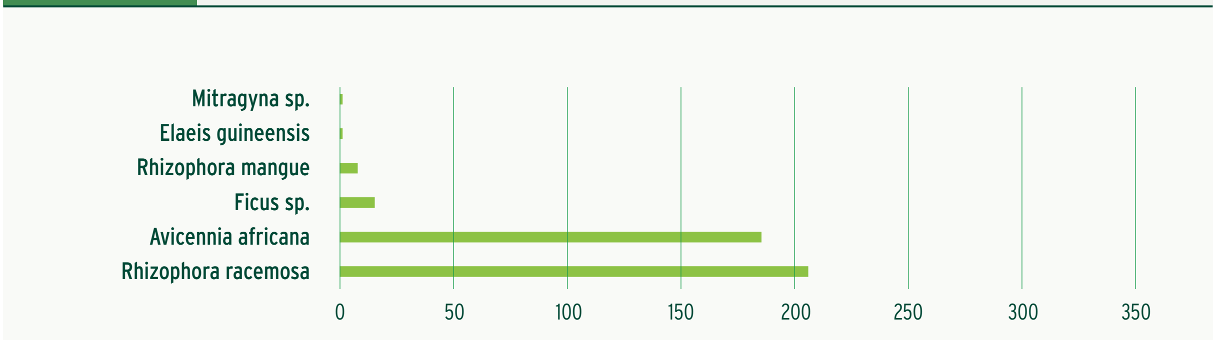


Figure 3.7 **Frequency distribution of species found in the derived savanna in Nigeria**

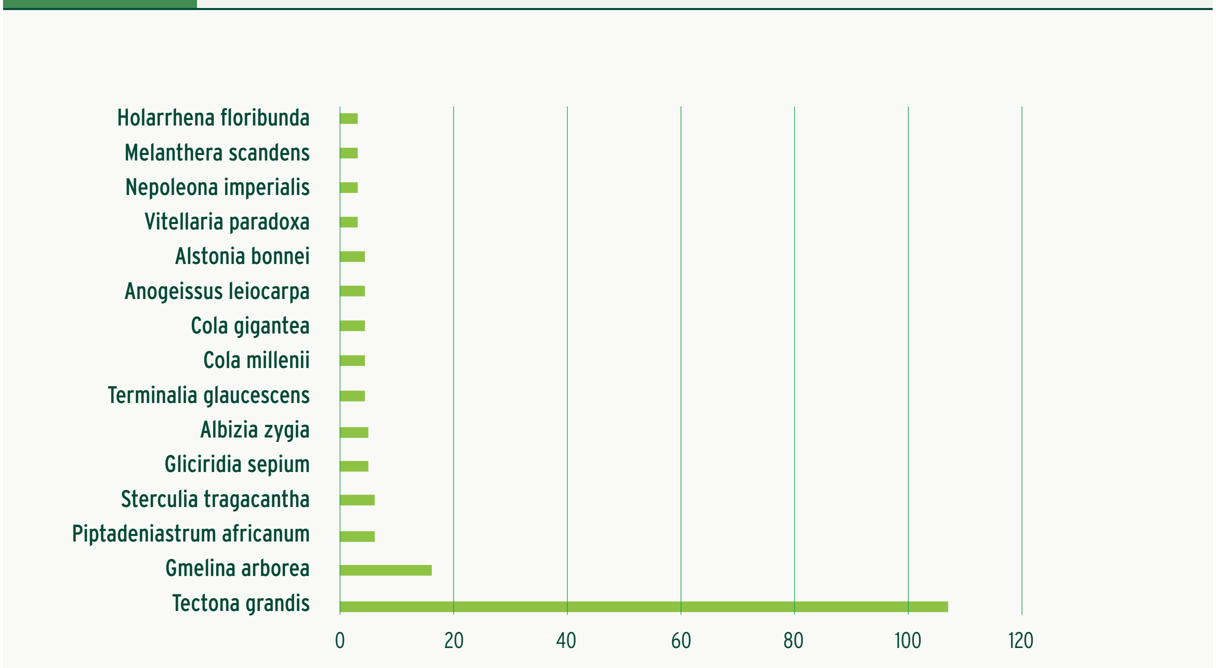
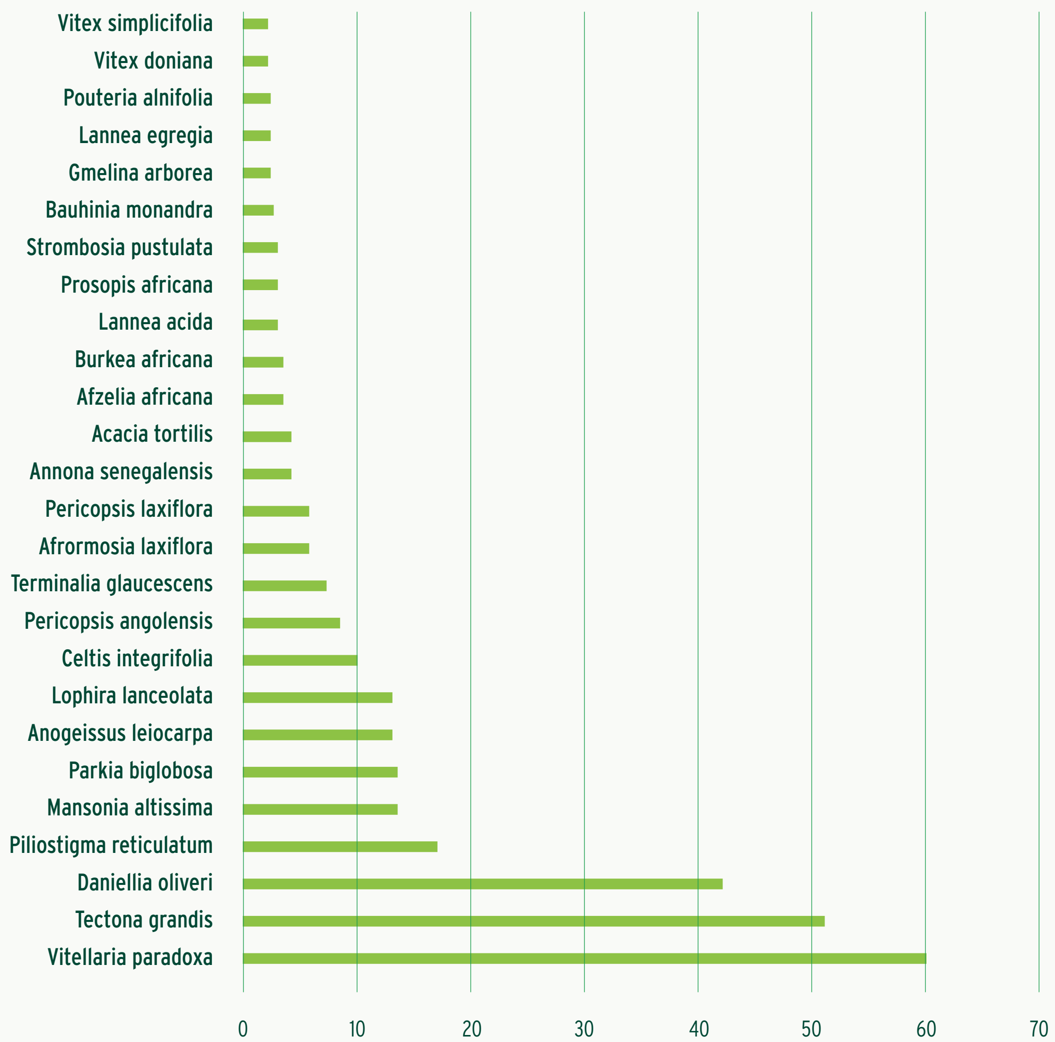


Figure 3.8 **Frequency distribution of major species found in the Guinea savanna in Nigeria**



The least abundant species include: *Antidesma venofum, Bridelia ferruginea, Detarium microcarpum, Erythrina senegalensis, Parinari curatellifolia, Parinari polyandra, Piliostigma thonningii, Piptostigma pilosum, Pterocarpus erinaceus, Sterculia setigera, Strychnos spinosa, and Terminalia sp.*

Figure 3.9 shows the frequency distribution of species found in the Sudan and Sahel Savanna in Nigeria. The Sudan and Sahel savannahs are predominated by Azadirachta indica with 75% of species abundance, while the remaining 25% is composed on Piliostigma reticulatum (9.6%), Lannea barteri (5.8%), Balanites aegyptiaca (3.8%), Annona senegalensis (1.9%), Hyphaene thebaica (1.9%), Tamarindus indica (1.9%).

Figure 3.10 shows the distribution of the most abundant species in the Montane ecosystem in Nigeria. The predominant species in the Montane ecosystem is Anthonotha noldeae (13.2%), Isolona sp. (5.9%), Carapa procera (4.9%), Polyscias fulva (4.8%), Strombosia schefflera (3.6%), Deinbollia sp.(3.3%), Vitex doniana (2.9%), Ficus sp. (2.8%),

Figure 3.9 **Frequency distribution of species found in the Sudan and Sahel savanna in Nigeria**

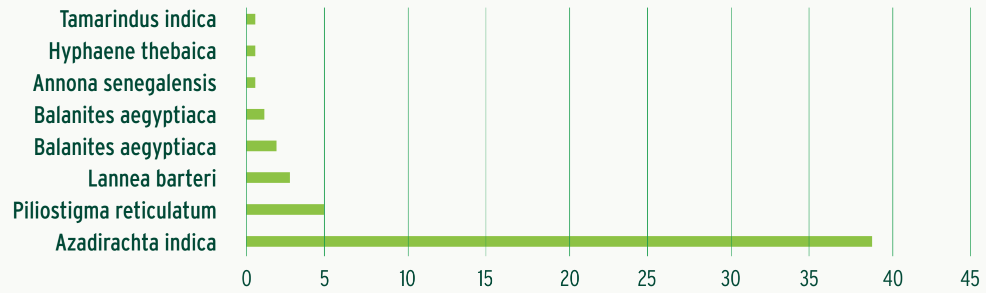
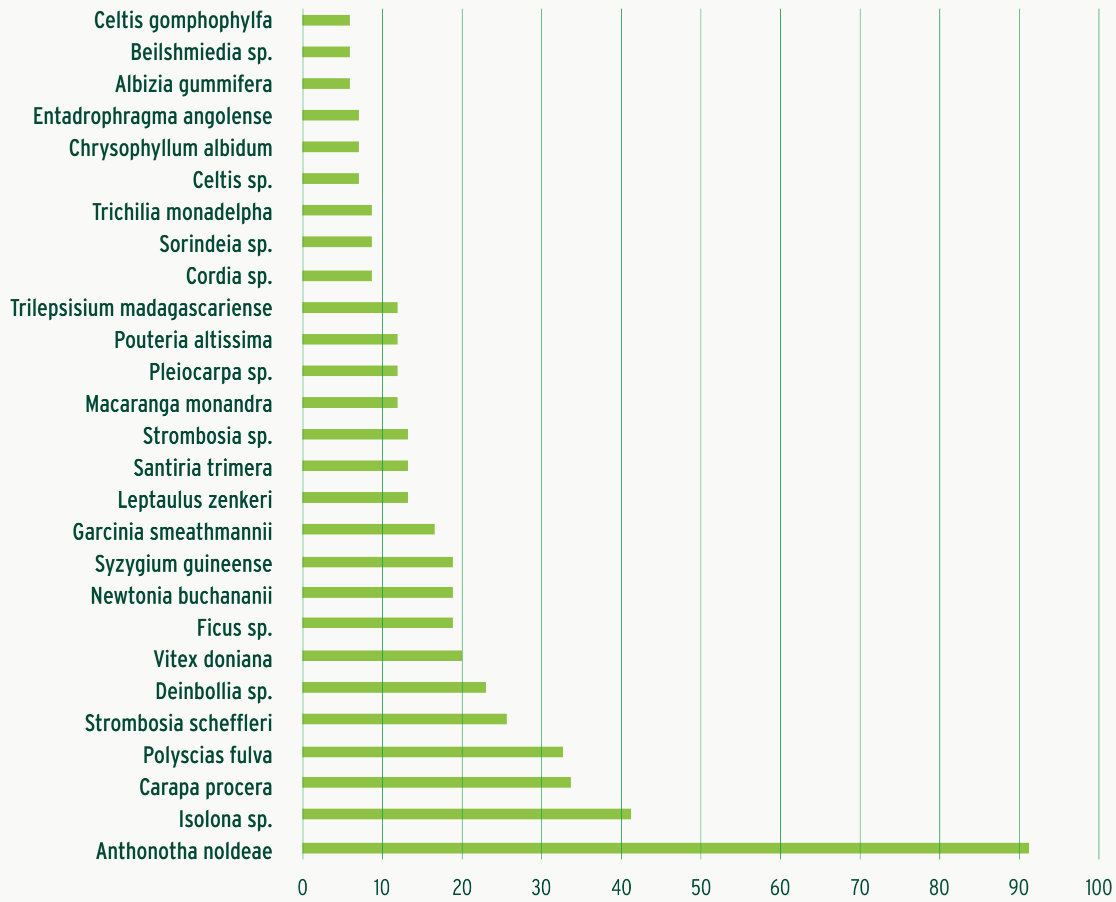


Figure 3.10 **Frequency distribution of species found in the montane forest in Nigeria**



Newtonia buchananii (2.8%), Syzygium guineense (2.8%), Garcinia smeathmannii (2.5%), and Leptaulus zenkeri (2.0%). These are characteristic of montane forests. The least represented species found during the Montane Forest inventory include: *Albizia glaberrima, Antidesma venofum, Beilschmedia sp., Beilschmiedia mannii, Bombax sp., Chrysophyllum sp., Clausena anisate, Combretum mole, Combretum sp., Croton macrostachyus, Croton sp., Dasylepis racemose, Diospyros monbuttensis, Donbea ladamania, Eugenia gilgiana, Ficus thonningii, Grewia sp., Isotonia onic, Macaranga sp., Milicia sp., Millettia rhodantha, Newboutonia sp., Newtonia sp., Olax subscorpioidea, Parkia bicolor, Parkia sp., Pterocarpus santalinoides, Rothmannia sp., Rothmannia urcelliformis, Sterculia sp., Tabernaemontana contota, Trichilia emetica, Warneckia sp.*

Table 3.3 **Biomass estimates for live trees in the different ecological zones in Nigeria**

Ecological zone	Total (ABG & BGB) biomass (mean±StdError)	Total (ABG & BGB) carbon stock (mean±StdError)	Total (ABG & BGB) CO_2 equivalent (mean±StdError)	95% confidence intervals for CO_2 equivalent	
	(t/ha)	(tC/ha)	(tCO_2/ha)	CI	CI%
Mangrove and fresh water swamp	186.28±38.62	87.55±18.15	321.02±66.57	130.47	40.6%
Lowland rainforest	165.51±29.87	77.79±14.04	285.25±51.48	100.90	35.4%
Montane forest	249.43±21.98	117.23±10.33	429.84±37.89	74.27	17.3%
Derived savanna	147.32±57.94	69.24±27.23	253.88±99.84	195.68	77.1%
Guinea savanna	57.30±10.87	26.93±5.11	98.76±18.72	36.69	37.2%
Sudan & Sahel savanna	11.70±2.40	5.50±1.13	20.18±4.16	8.15	40.4%

*:Se=Standard Error

3.4 BIOMASS AND CARBON STOCK ESTIMATES

3.4.1 TOTAL (ABOVE AND BELOWGROUND) LIVE BIOMASS

The aboveground and belowground biomass estimates for live trees are presented in Table 3.3. From the estimates, the montane forest has the highest biomass (249.43±21.98 t/ha), carbon stocks (117.23±10.33 tC/ha) and Carbon Dioxide Equivalent (429.84±37.89 tCO_2e), followed by the mangrove and Fresh Water Swamp and Lowland Rainforest.

As would be expected, the Sudan and Sahel savanna have the lowest values (see Table 3.3 for details). This is because the Sahel savanna zone has the smallest tree population in the country.

The few available trees and shrubs there are sparsely distributed.

3.4.2 STANDING AND LYING DEADWOOD AND LITTER BIOMASS

Table 3.4. shows standing and lying deadwood and stump biomass. The lowland rainforest has the highest biomass for standing deadwood (9.76±2.60t/ha) followed by Derived savanna (4.15±0.85 t/ha), and montane forest (2.97±0.58t/ha); while the Guinea savanna, Sudan and Sahel savannas had no standing deadwood. This could be attributed to the scarcity in fuelwood in the savanna region and also to charcoal production. The same trends are noticeable for lying deadwood with lowland rainforest having the highest (10.72±1.93t/ha), followed by the Derived savanna (5.70±2.88 t/ha) and the montane (3.16±0.50 t/ha).

For stumps, the mangrove and forested freshwater swamps have the highest biomass value (6.44±1.32 t/ha), followed by the lowland rainforest (3.01±0.64 t/ha), and the Sudan and Sahel savannas.

Table 3.4 Biomass estimates for standing deadwood and lying deadwood in Nigeria

Ecozone	Standing deadwood (mean±Se*)	Lying deadwood (mean±Se)	Stumps (mean±Se)	Total deadwood biomass (mean±Se)	Total deadwood carbon stock (mean±Se)	Total deadwood CO_2 equivalent (mean±Se)	Confidence intervals for CCO_2 equivalent	
	t/ha	t/ha	t/ha	t/ha	tC/ha	tCO_2/ha	CI	CI%
Mangrove forest & fresh water swamp	0.51±0.00	2.20±1.52	6.44±1.32	9.15±2.02	4.30±0.95	15.76±3.47	6.81	43.2%
Lowland rainforest	9.76±2.60	10.72±1.93	3.01±0.64	23.49±3.30	11.04±1.55	40.48±5.69	11.14	27.5%
Montane forest	2.97±0.58	3.16±0.50	0.36±0.15	6.49±0.78	3.05±0.37	11.18±1.34	2.63	23.5%
Derived savanna	4.15±0.85	5.70±2.88	1.58±0.70	11.44±3.08	5.37±1.45	19.71±5.31	10.41	52.8%
Guinea savanna	0.00±0.00	1.25±0.00	1.02±0.38	2.28±0.38	1.07±0.18	3.93±0.65	1.27	32.3%
Sudan & Sahel savanna	0.00±0.00	0.00±0.00	2.19±0.00	2.19±0.00	1.03±0.00	3.77±0.00	0.00	0.0%

*:Se=Standard Error

Table 3.5 Biomass estimates for litter in three ecological zones in Nigeria

Ecozone	Litter biomass (mean±Se)	Litter carbon stock (mean±Se)	Total litter CO_2 equivalent (mean±Se)	95% confidence interval (CI)	
	(t/ha)	(tC/ha)	(tCO_2/ha)	CI	CI%
Lowland rainforest	4.39 ± 0.46	2.07±0.22	7.58±0.79	1.5484	20.4%
Montane forest	18.41 ± 1.70	8.65±0.80	31.71±2.93	5.7428	18.1%
Derived savanna	3.43 ± 0.34	1.60±0.16	5.86±0.59	1.1564	19.7%

Table 3.6 Total live and dead biomass and carbon stocks for different ecological zones in Nigeria

Ecozone	Total live CO_2 stock (tCO_2/ha)	[95% CI]	Total deadwood CO_2 stock (tCO_2/ha)	[95% CI]	Total live & dead CO_2 stock (tCO_2e/ha	95% confidence interval (CI)	
	(t/ha)	CI%		(tC/ha)	(tCO_2/ha)	CI	CI%
Mangrove and fresh water swamp	321.02±66.57	40.6%	15.76±2.83	35.1%	354.53±70.81	138.78	39.1%
Lowland rainforest	285.25±51.48	35.4%	40.48±5.69	27.5%	325.73±51.79	101.51	31.2%
Montane forest	429.84±37.89	17.3%	11.18±1.34	23.5%	441.02±37.91	74.32	16.9%
Derived savanna	253.88±99.84	77.1%	19.71±5.31	52.8%	273.59±99.98	195.95	71.6%
Guinea savanna	98.76±18.72	37.2%	3.93±0.65	32.3%	102.69±18.73	36.71	35.8%
Sudan & Sahel savanna	20.18±4.16	40.4%	3.77±??	----	23.95±4.16	8.15	34.0%

The high stump biomass in the mangroves is due to the harvesting of the main mangrove species (Rhizophora racemosa) for drying of fish, while the stump biomass in the savanna zones is due to harvesting for charcoal production. Total deadwood biomass and carbon is highest in the Lowland rainforest (23.49±3.30t/ha) followed by Derived Savanna (11.44±3.08 t/ha), mangrove forest and freshwater swamp (9.15±2.02 t/ha), and montane (6.49±0.78 t/ha); while the the Guinea, Sudan and Sahel savannas have the lowest biomass.

Litter was collected in three of the ecological zones, namely lowland rainforest (60 samples), montane forest (47 samples) and Derived savanna (8 Samples) zones. The results in Table 3.5 indicate that the montane forest has the highest litter biomass (18.41 ±1.69t/ha), litter carbon stock (8.65±0.80 tC/ha) and Carbon dioxide equivalent (31.71±2.93 tCO_2/ha), while the Lowland rainforest and Derived Savanna had relatively low litter biomass, litter carbon stocks and carbon dioxide equivalents. The high litter biomass for the montane is probably due to the slower rate of litter decomposition caused by the lower temperature associated with the ecosystem.

3.4.3 TOTAL LIVE AND DEADWOOD BIOMASS AND CARBON STOCKS

When biomass estimates from all the carbon pools (live and dead wood) were pooled together, the montane forest has the highest total live and dead CO_2 equivalent (441.02tCO_2e) followed by Mangrove and Swamps (354.53 tCO_2e) lowland rainforest (325.73 tCO_2e), and Derived Savanna (273.59 tCO_2e), while the Sudan and Sahel savanna have the least value (23.95 tCO_2e).


©FAO/John Fonweban

Summary, conclusions and recommendations 4

4.1 SUMMARY AND CONCLUSION

The National Forest Inventory in Nigeria was completed by in-country staff with technical assistance from the Food and Agriculture Organization of the United Nations (FAO). An inventory design was developed, including a field operations manual, and field training undertaken to build the capacity of technical forestry staff in relation to field data collection, data base development and data analysis.

Modern laser equipment, including Criterion RD1000 and TruPulse 200B, were used to collect data on tree diameters at any heights on the tree boles and tree heights respectively. Other measurements were undertaken on dead standing trees, lying dead trees, stumps, and litter. Core samples from live trees, standing and lying deadwood were extracted and oven-dried in the laboratory for wood density determination. A sampled tree height dataset was used to develop a height-diameter model, which was used with suitable allometric equations to estimate biomass, carbon stocks and carbon dioxide equivalent (CO_2e) for the various carbon pools. Field data collection was facilitated by using the FAO Collect Mobile App, (complemented by manual field forms), to minimize errors, especially in species nomenclature.

The results indicate that the total biomass, carbon stocks and carbon dioxide equivalent were highest in montane forest ecosystems followed by mangroves, lowland rainforest, derived savanna, and guinea savanna; while the sudan and sahel savannas had the lowest estimates. However, in terms of species diversity, the lowland rainforest was the most diversed, followed by the montane forest, the derived savanna, and the guinea savanna; while the Sudan and Sahel savannae were the least diversed ecosystems. The estimates of carbon dioxide equivalent (CO_2e: t/ha) by ecological zones constituted the emission factors that were used in the calculations of annual CO_2 emissions in Nigeria. A national forest inventory database has been developed, initially populated with the data collected in this inventory.

The initial sampling plan envisaged data collection from 240 clusters across the various ecological zones in the country. However, due to the constraints of time, funds and security issues, only 114 clusters were enumerated. These were however spread across the various ecological zones in order to capture biomass variation.

The implementation of the fieldwork faced a number of challenges, among which :

- Delays in procurement and clearance (at Lagos Port) of major field equipment, some of which didn't arrive until after completion of the field campaigns;
- Absence of designated field vehicles which necessitated reliance on hired commercial vehicles which are not well adapted for the rough and/or wet terrain in many forest areas; and
- Implementation of the fieldwork during rainy season, which made many areas in the mangrove and freshwater swamp completely flooded and inaccessible.

In spite of these and other challenges, the field teams put in a great deal of effort to ensure the success of the field exercise.

4.2 RECOMMENDATIONS

Based on the NFI experience, the following recommendations are made:

1. There is an urgent need to develop site-specific and country-specific allometric equations for biomass assessment in Nigeria. The National Secretariat of REDD+ should commission forest measurement specialists to conduct studies in this regard.
2. The clusters enumerated during the inventory were all geo-referenced (see Appendix 3) and can be easily re-located during subsequent field visits. Some of them should be selected to serve as Permanent Sample Plots (PSPs) for the purpose of monitoring emissions from the forest.
3. Subsequent fieldwork should be designed to take place in the dry season to facilitate accessibility to the sample plots, especially in the mangroves, fresh water swamp and tropical rain forest.
4. There is need to intensify and complete the sampling plan which was initially designed with 240 clusters. Additional data collected should be used to update the NFI database developed during this study.

References

Aghimien E.V. 2018. *Above-Ground Bole Carbon Stock Estimation using Forest Inventory and Remote Sensing of Secondary Forest Ecosystem in Ibadan Nigeria*. University of Ibadan. (PhD dissertation)

Chave, J., Réjou-Méchain, M., Búrquez, A., Chidumayo, E., Colgan, M.S., Delitti, W.B.C., Duque, A., Eid, T., Fearnside, P.M., Goodman, R.C., Henry, M., Martínez-Yrízar, A., Mugasha, W.A., Muller-Landau, H.C., Mencuccini, M., Nelson, B.W., Ngomanda, A., Nogueira, E.M., Ortiz-Malavassi, E., Pélissier, R., Ploton, P., Ryan, C.M., Saldarriaga, J.G. and Vieilledent, G. 2014. *Improved pantropical allometric models to estimate the aboveground biomass of tropical forests*. Global Change Biology 20: 3177–3190.

Chenge I.B. 2017. *Estimation of tree aboveground biomass and carbon stocks in Omo Biosphere Reserve, Nigeria*. Univesity of Ibadan. (PhD dissertation).

Cochran W.G. 1977. *Sampling Techniques*. 3rd ed N.Y. Wiley.

IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories,* Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K. , Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

Komiyama, A., Poungparn, S., Kato, S. 2005. *Common allometric equations for estimating the tree weight of mangroves*. J. Trop. Ecol. 21, 471–477.

Lund H. 1998. *IUFRO Guidelines for Designing Multipurpose Resource Inventories: A Project of IUFRO Research Group 4*, (IUFRO World Series, vol. 8). IUFRO, Vienna.

Mokany K., Raison R.J., Prokushkini A.S. 2006. *Critical analysis of root:shoot ratios in terrestrial biomes*. Global Change Biology 12:84–96.

Ojo, L. O. 2004. *The fate of a tropical rainforest in Nigeria: Abeku Sector of Omo Forest Reserve*. Global Nest: the International Journal, Vol. 6, No. 2: 116-130.

R Core Team (2016). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna.

Appendices

Appendix 1: Wood density data based on increment cores collected during inventory.

Species scientific name	wood density (g/cm^3)
Albizia gummifera	0.48
Albizia sp.	0.52
Anthonotha noldeae	0.54
Beilschmiedia sp.	0.41
Carapa oriophylla	0.63
Carapa procera	0.91
Carapa spp	0.43
Celtis sp.	0.47
Chrysophyllum albidum	0.55
Combretum molle	0.58
Copaitera spp	0.60
Cordia sp.	0.42
Croton macrostachyus	0.53
Dasylepis racemosa	0.73
Deinbollia sp.	0.51
Entandrophragma angolense	0.65
Ficus lutea	0.58
Ficus sp.	0.51
Ficus sur	0.35
Garcinia smeathmannii	0.61
Harungana madagascariensis	0.50
Isolona campanulata	0.39
Isolona sp.	0.36
Leptaulus daphnoides	0.45
Lovoa trichilioides	0.37
Macaranga monandra	0.52
Macaranga occidentalis	0.87
Newtonia buchananii	0.59
Newtonia sp.	0.53
Oxyanthus sp.	0.46
Parkia bicolor	0.50
Pleicarp pycnantha	0.66
Polyscias fulva	0.48
Pouteria altissima	0.35
Ritchiea albersii	0.55
Rothmannia sp.	0.68
Santiria trimera	0.49
Sorindeia sp.	0.75
Strombosia scheffleri	0.96
Strombosia sp.	0.61
Symphonia globulifera	0.58
Sytheria altissima	0.71
Syzygium guineense	0.76
Syzygium sp.	0.58
Tabernaemontana sp.	0.45
Trema orientalis	0.34
Trichilia monadelpha	0.80
Trichilia sp.	0.44
Trilepisium madagascariense	0.54
Unknown species	0.50
Vitex doniana	0.50
Voacanga sp.	0.45
Warneckia spp	0.80

Appendix 2: Compiled wood density data for tree species in Nigeria (based on increment cores and literature)

Species scientific name (continued)	wood density (g/cm³)
Acacia tortilis	0.68
Adansonia digitata	0.28
Afrormosia laxiflora	0.83
Afzelia africana	0.65
Albizia ferruginea	0.43
Albizia glaberrima	0.55
Albizia gummifera	0.50
Albizia lebbeck	0.60
Albizia sp.	0.54
Albizia zygia	0.64
Alchornea cordifera	0.49
Allanblackia floribunda	0.74
Allophylus africanus	0.45
Alstonia bonnei	0.41
Alstonia boonei	0.41
Amphimas pterocarpoides	0.59
Anacardium occidentale	0.45
Annona senegalensis	0.52
Anogeissus leiocarpa	0.76
Anthocleista djalonensis	0.50
Anthocleista nobilis	0.58
Anthocleista sp.	0.51
Anthonotha macrophylla	0.60
Anthonotha noldeae	0.68
Anthonotha sp.	0.57
Antiaris africana	0.38
Antiaris toxicaria	0.42
Antidesma sp.	0.81

Species scientific name (continued)	wood density (g/cm³)
Antidesma venofum	0.81
Avicennia africana	0.77
Azadirachta indica	0.76
Balanites aegyptiaca	0.77
Bambusa arundinacea	0.79
Baphia nitida	0.60
Bauhinia monandra	0.67
Beilschmedia sp.	0.64
Beilschmiedia mannii	0.57
Beilschmiedia sp.	0.57
Berliana grandifolia	0.76
Berliana sp.	0.67
Berlinia sp.	0.67
Blighia sapida	0.72
Blighia welwitschii	0.79
Bombax buonopozense	0.39
Bombax sp.	0.41
Borassus aethiopum	0.96
Boscia angustifolia	0.59
Brachystegia eurycoma	0.57
Brachystegia leonensis	0.57
Brachystegia sp.	0.57
Bridelia sp.	0.49
Bridelia speciosa	0.49
Buchholzia coriacea	0.50
Burkea africana	0.65
Canthium subcordatum	0.60
Carapa procera	0.60

Species scientific name (continued)	wood density (g/cm³)
Cedrela odorata	0.38
Ceiba pentandra	0.27
Celtis gomphophylfa	0.62
Celtis integrifolia	0.62
Celtis mildbraedii	0.53
Celtis sp.	0.62
Celtis zenkeri	0.66
Chrysophyllum albidum	0.67
Chrysophyllum sp.	0.61
Citrus paradise	0.59
Clausena anisata	0.48
Cleistopholis patens	0.32
Cocos nucifera	0.50
Cola acuminata	0.53
Cola gigantea	0.50
Cola millenii	0.88
Cola nigerica	0.60
Cola nitida	0.56
Combretum molle	0.81
Combretum sp.	0.81
Copaifera mildbraedii	0.66
Cordia millenii	0.63
Cordia sp.	0.63
Croton macrostachyus	0.48
Croton sp.	0.48
Dacryodes edulis	0.52
Dambolea pignanta	0.59
Daniellia ogea	0.57
Daniellia oliveri	0.51
Dasylepis racemosa	0.59
Deinbollia sp.	0.59

Species scientific name (continued)	wood density (g/cm³)
Desplatsia dewevrei	0.58
Desplatsia lutea	0.59
Desplatsia sp.	0.59
Detarium microcarpum	0.58
Dialium guineense	0.80
Diospyros canaliculata	0.67
Diospyros cinnabarina	0.67
Diospyros dendo	0.71
Diospyros mespiliformis	0.62
Diospyros sp.	0.67
Donbea ladamania	0.59
Dracaena mannii	0.59
Drypetes gossweileri	0.67
Drypetes sp.	0.70
Elaeis guineensis	0.50
Enladosia angolensis	0.58
Entandrophragma angolense	0.58
Entandrophragma cylindricum	0.59
Erythrina senegalensis	0.28
Erythrophleum sp.	0.69
Erythrophleum suaveolens	0.76
Eugenia gilgiana	0.92
Fagara loprietus	0.49
Ficus capensis	0.39
Ficus exasperata	0.40
Ficus lutea	0.36
Ficus mucoso	0.36
Ficus mucuso	0.36
Ficus sp.	0.35
Ficus sur	0.45
Ficus thonningii	0.43

Species scientific name (continued)	wood density (g/cm³)
Funtumia elastica	0.51
Garcinia kola	0.73
Garcinia mannii	0.82
Garcinia smeathmannii	0.71
Garcinia sp.	0.71
Gliciridia sepium	0.56
Gmelina arborea	0.41
Gombea	0.58
Grewia sp.	0.45
Hannoa klaineana	0.58
Harungana madagascariensis	0.47
Hevea brasiliensis	0.47
Holarrhena floribunda	0.55
Holoptelea grandis	0.59
Hyphaene thebaica	0.59
Irvingia gabonensis	0.77
Isolona sp.	0.59
Isotonia onic	0.58
Khaya ivorensis	0.49
Khaya sp.	0.51
Lannea acida	0.56
Lannea barteri	0.41
Lannea egregia	0.56
Lannea sp.	0.56
Lecaniodiscus cupanioides	0.57
Leptaulus daphnoides	0.59
Leptaulus zenkeri	0.59
Lonchocarpus sericeus	0.78
Lophira lanceolata	0.90
Lovoa trichilioides	0.46
Macaranga barteri	0.36

Species scientific name (continued)	wood density (g/cm³)
Macaranga monandra	0.36
Macaranga occidentalis	0.36
Macaranga sp.	0.40
Magarteria sp.	0.40
Magnistipula tessmannii	0.59
Malacantha alnifolia	0.67
Mangifera indica	0.54
Mansonia altissima	0.54
Maranthes glabra	0.92
Margariataria discordea	0.72
Margaritaria discoidea	0.72
Melanthera scandens	0.58
Milicia excelsa	0.58
Milicia sp.	0.58
Milletia excelsa	0.58
Millettia rhodantha	0.58
Millettia thonningii	0.56
Mitragyna ciliata	0.53
Morinda lucida	0.56
Musanga cecropioides	0.30
Muxinda lucida	0.58
Myrianthus arboreus	0.54
Nauclea diderrichii	0.63
Nauclea poseguini	0.58
Neoboutonia sp.	0.59
Nepoleona imperialis	0.58
Nesogordonia papaverifera	0.68
Newbouldia laevis	0.56
Newboutonia sp.	0.58
Newtonia buchananii	0.51
Newtonia sp.	0.73

Species scientific name (continued)	wood density (g/cm³)
Olax subscorpioidea	0.77
Oxyanthus sp.	0.53
Pachystela brevipes	0.59
Parinari curatellifolia	0.63
Parkia bicolor	0.40
Parkia biglobosa	0.39
Parkia sp.	0.64
Pentadesma butyracea	0.81
Pericopsis angolensis	0.72
Pericopsis elata	0.69
Pericopsis laxiflora	0.64
Persea americana	0.52
Persia americana	0.52
Physalis micrantha	0.58
Picralima nitida	0.72
Piliostigma reticulatum	0.66
Piliostigma thonningii	0.62
Pinus caribaea	0.48
Piptadeniastrum africanum	0.62
Piptostigma pilosum	0.59
Pleiocarpa pycnantha	0.58
Pleiocarpa sp.	0.64
Polyscias fulva	0.24
Pouteria alnifolia	0.59
Pouteria altissima	0.44
Prosopis africana	1.02
Psydrax aeutiflora	0.48
Psynfonia sp.	0.59
Pterocarpus osun	0.60
Pterocarpus santalinoides	0.71
Pterygota macrocarpa	0.50

Species scientific name (continued)	wood density (g/cm³)
Pterygota sp.	0.52
Pycnanthus angolensis	0.51
Raphia hookeri	0.21
Rauvolfia vomitoria	0.46
Rhizophora mangue	0.89
Rhizophora racemosa	0.90
Ricinodendron africanum	0.36
Ricinodendron heudelotii	0.36
Ricinodendron sp.	0.36
Ritchiea albersii	0.59
Rothmannia sp.	0.54
Rothmannia urcelliformis	0.54
Santiria trimera	0.55
Scottellia coriacea	0.58
Sorindeia sp.	0.56
Spathodea campanulata	0.26
Spondias mombin	0.49
Sterculia oblonga	0.73
Sterculia oblongata	0.73
Sterculia rhinopetala	0.65
Sterculia setigera	0.64
Sterculia sp.	0.62
Sterculia tragacantha	0.56
Strombosia pustulata	0.77
Strombosia scheffleri	0.58
Strombosia sp.	0.80
Strychnos spinosa	0.65
Symphonia globulifera	0.59
Symphonia sp.	0.59
Synsepalum sp.	0.82
Syzygium cumini	0.61

Species scientific name (continued)	wood density (g/cm³)
Syzygium guineense	0.61
Syzygium sp.	0.61
Tabernaemontana contota	0.58
Tabernaemontana sp.	0.57
Tamarindus indica	0.80
Tectona grandis	0.70
Terminalia avicennioides	0.56
Terminalia glaucescens	0.73
Terminalia ivorensis	0.51
Terminalia sp.	0.56
Terminalia superba	0.49
Tetrapleura tetraptera	0.60
Theobroma cacao	0.42
Treculia africana	0.62
Trema orientalis	0.37
Trichilia dregeana	0.48
Trichilia emetica	0.54

Species scientific name (continued)	wood density (g/cm³)
Trichilia megalantha	0.58
Trichilia monadelpha	0.48
Trichilia prieuriana	0.66
Trichilia sp.	0.59
Trilepisium madagascariense	0.61
Triplochiton scleroxylon	0.39
Vitellaria paradoxa	0.56
Vitex doniana	0.40
Vitex simplicifolia	0.41
Voacanga sp.	0.58
Warneckia sp.	0.58
Xylopia aethiopica	0.47
Xymalos monospora	0.59
Zanthoxylum leprieurii	0.33
Zanthoxylum zanthoxyloides	0.84
Unknown species	0.58

Appendix 3: Location of Cluster Points sampled across various ecological zones

S/No.	Enumerated Cluster ID	State	Ecological_Zone	Longitude E	Latitude N
1	JG1	Jigawa	Sahel Savanna	9.789800	12.633890
2	JG2	Jigawa	Sahel Savanna	9.307710	12.571320
3	JG3	Jigawa	Sahel Savanna	9.245340	12.748220
4	JG4	Jigawa	Sahel Savanna	8.422390	12.739410
5	KT1	Katsina	Sahel Savanna	8.299630	13.134780
6	KT2	Katsina	Sahel Savanna	8.432650	13.053170
7	KT3	Katsina	Sudan Savanna	7.432830	12.180170
8	KT4	Katsina	Sudan Savanna	7.443430	12.215720
9	KT5	Katsina	Sudan Savanna	7.532200	12.934270
10	KB1	Kebbi	Sudan Savanna	4.187440	13.091000
11	KB2	Kebbi	Sudan Savanna	4.236700	13.046450
12	KB3	Kebbi	Sudan Savanna	4.294620	12.740520
13	KB4	Kebbi	Sudan Savanna	4.036390	12.647020
14	KB5	Kebbi	Sudan Savanna	4.102440	12.591260
15	KB6	Kebbi	Sudan Savanna	4.561740	12.544010
16	KB7	Kebbi	Sudan Savanna	4.695030	12.684520
17	KB8	Kebbi	Sudan Savanna	4.120060	12.367800
18	KB9	Kebbi	Sudan Savanna	4.310490	13.015210
19	NS1	Nasarawa	Guinea Savanna	8.750220	9.135220
20	NS2	Nasarawa	Guinea Savanna	8.228977	9.099970
21	NS3	Nasarawa	Guinea Savanna	8.589100	8.950230
22	NS4	Nasarawa	Guinea Savanna	8.879130	8.650640
23	NS5	Nasarawa	Guinea Savanna	8.629790	8.468170
24	NS6	Nasarawa	Guinea Savanna	8.228990	9.091710
25	NS7	Nasarawa	Guinea Savanna	8.648800	8.366330
26	NS8	Nasarawa	Guinea Savanna	7.853470	9.236790
27	NS9	Nasarawa	Guinea Savanna	8.059900	8.086640
28	NS10	Nasarawa	Guinea Savanna	8.156590	8.795710
29	OG1	Ogun	Lowland Rainforest	2.796170	6.914800

S/No.	Enumerated Cluster ID	State	Ecological_Zone	Longitude E	Latitude N
30	OG2	Ogun	Lowland Rainforest	2.823050	6.938730
31	OG3	Ogun	Lowland Rainforest	2.869650	7.037850
32	OG4	Ogun	Lowland Rainforest	2.880340	7.048240
33	OG5	Ogun	Derived Savanna	2.792240	7.278570
34	OG6	Ogun	Derived Savanna	2.796510	7.348420
35	OG7	Ogun	Derived Savanna	3.531340	7.462062
36	OG8	Ogun	Derived Savanna	3.581380	7.411630
37	OG9	Ogun	Lowland Rainforest	4.356710	6.814720
38	OG10	Ogun	Lowland Rainforest	4.400040	6.868480
39	OG11	Ogun	Lowland Rainforest	4.366970	6.835690
40	OG12	Ogun	Lowland Rainforest	4.341240	6.843150
41	OG13	Ogun	Lowland Rainforest	4.357010	6.945880
42	OG14	Ogun	Lowland Rainforest	4.357700	6.942780
43	OG15	Ogun	Lowland Rainforest	4.361080	6.973980
44	OG16	Ogun	Lowland Rainforest	4.367190	6.973400
45	OG17	Ogun	Lowland Rainforest	4.362600	6.973140
46	OY10	Oyo	Derived Savanna	4.260220	7.993290
47	OY11	Oyo	Derived Savanna	4.181220	8.079190
48	OY9	Oyo	Derived Savanna	4.243480	8.010140
49	OY1	Oyo	Lowland Rainforest	3.870639	7.205526
50	OY2	Oyo	Lowland Rainforest	3.872410	7.207804
51	OY3	Oyo	Lowland Rainforest	3.886790	7.485090
52	OY4	Oyo	Lowland Rainforest	3.884820	7.495070
53	OY5	Oyo	Lowland Rainforest	3.733010	7.660860
54	OY6	Oyo	Lowland Rainforest	3.767130	7.686910
55	OY7	Oyo	Lowland Rainforest	3.875030	7.180480
56	OY8	Oyo	Lowland Rainforest	3.872400	7.183020
57	TR1	Taraba	Montane Forest	11.038330	7.088330
58	TR2	Taraba	Montane Forest	11.059820	7.093110
59	TR3	Taraba	Montane Forest	11.054320	7.089930
60	TR4	Taraba	Montane Forest	11.062900	7.089470
61	TR5	Taraba	Montane Forest	11.046100	7.088690
62	TR6	Taraba	Montane Forest	11.050810	7.083230

S/No.	Enumerated Cluster ID	State	Ecological_Zone	Longitude E	Latitude N
63	TR7	Taraba	Montane Forest	11.057070	7.086260
64	TR8	Taraba	Montane Forest	11.046140	7.082000
65	TR9	Taraba	Montane Forest	11.055460	7.081450
66	TR10	Taraba	Montane Forest	11.049050	7.078520
67	TR11	Taraba	Montane Forest	11.045810	7.077190
68	TR12	Taraba	Montane Forest	11.056050	7.074890
69	TR13	Taraba	Montane Forest	11.046540	7.071950
70	TR14	Taraba	Montane Forest	11.054330	7.073460
71	TR15	Taraba	Montane Forest	11.050460	7.067080
72	TR16	Taraba	Montane Forest	11.056670	7.070600
73	TR17	Taraba	Montane Forest	11.053280	7.068130
74	TR18	Taraba	Montane Forest	11.050460	7.065370
75	OD1	Ondo	Mangrove Forest	4.590750	6.276180
76	OD2	Ondo	Mangrove Forest	4.576540	6.288810
77	OD3	Ondo	Mangrove Forest	4.543570	6.298910
78	OD4	Ondo	Mangrove Forest	4.788990	6.239690
79	OD5	Ondo	Mangrove Forest	4.612960	6.264880
80	OD6	Ondo	Mangrove Forest	4.602770	6.270320
81	OD7	Ondo	Mangrove Forest	4.598780	6.261090
82	OD8	Ondo	Mangrove Forest	4.362600	6.973140
83	OD9	Ondo	Mangrove Forest	4.541040	6.316300
84	OD10	Ondo	Freshwater Swamp Forest	4.973030	6.308500
85	OD11	Ondo	Freshwater Swamp Forest	4.752790	6.273340
86	OD12	Ondo	Freshwater Swamp Forest	4.969200	6.289730
87	OD13	Ondo	Lowland Rainforest	5.070100	7.263760
88	OD14	Ondo	Lowland Rainforest	5.055220	7.353130
89	OD15	Ondo	Lowland Rainforest	5.039460	7.247340
90	OD16	Ondo	Lowland Rainforest	5.003150	7.275170
91	OD17	Ondo	Lowland Rainforest	5.064760	7.321400
92	OD18	Ondo	Lowland Rainforest	5.031500	7.279590
93	OD19	Ondo	Lowland Rainforest	5.377190	7.212040
94	OD20	Ondo	Lowland Rainforest	5.374180	7.186760
95	OD21	Ondo	Lowland Rainforest	5.507490	7.080300

S/No.	Enumerated Cluster ID	State	Ecological_Zone	Longitude E	Latitude N
96	OD22	Ondo	Lowland Rainforest	5.597560	7.044130
97	OD23	Ondo	Lowland Rainforest	5.509750	7.045170
98	OD24	Ondo	Lowland Rainforest	4.639230	6.955080
99	OD25	Ondo	Lowland Rainforest	4.644260	6.984210
100	OD26	Ondo	Lowland Rainforest	5.610220	7.054880
101	OD27	Ondo	Lowland Rainforest	4.563330	6.789290
102	OD28	Ondo	Lowland Rainforest	4.628610	7.016160
103	OD29	Ondo	Lowland Rainforest	5.593280	6.870980
104	OD30	Ondo	Lowland Rainforest	5.651520	6.836730
105	OD31	Ondo	Lowland Rainforest	4.692910	7.022290
106	OD32	Ondo	Lowland Rainforest	5.558320	6.805110
107	OD33	Ondo	Lowland Rainforest	4.639550	6.747280
108	OD34	Ondo	Lowland Rainforest	5.651110	6.783600
109	OD35	Ondo	Lowland Rainforest	5.007460	6.782330
110	OD36	Ondo	Lowland Rainforest	4.554070	6.746570
111	OD37	Ondo	Derived Savanna	5.817900	7.211880
112	OD38	Ondo	Derived Savanna	5.777500	7.181820
113	OD39	Ondo	Derived Savanna	5.686450	7.135440
114	OD40	Ondo	Derived Savanna	5.786390	7.204680

NIGERIA

NATIONAL FOREST (CARBON) INVENTORY

Contacts:

Forestry - Natural Resources and Sustainable Production
E-mail: NFM@fao.org
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla
00153 Rome, Italy

FAO Representation in Nigeria
Wing 'C' First Floor UN House, Plot 617/618 Diplomatic Drive, Central Business District (CBD), Abuja
FAO-NG@fao.org

ISBN 978-92-5-133393-8

9 789251 333938

CB1328EN/1/11.20