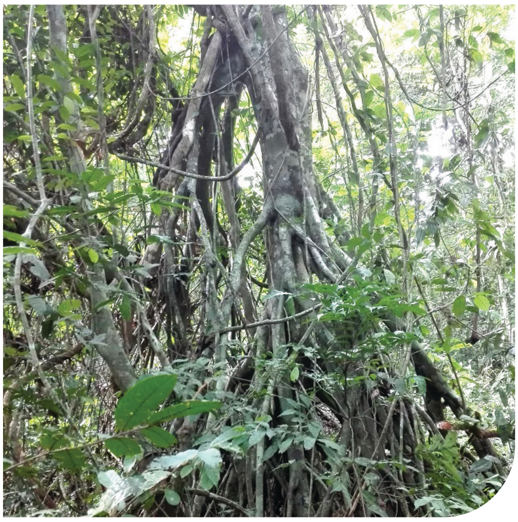
NICFI
Norway's International Climate and Forest Initiative

Liberia

National Forest Inventory 2018/2019



Food and Agriculture Organization of the United Nations

THE WORLD BANK

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Message from Forestry Development Authority Managing Director

I want to extend my heartfelt gratitude to the President of Liberia, His Excellency, President, Dr. George Mannah Weah, for his unconditional preferment to appoint and support me as Managing Director of the FDA shortly before the commencement of our National Forest Inventory (NFI). I am happy to have served the purpose leading to this forest information gathering for the forward match in sustainable forest management that will account for national development and conservation possibilities for Liberia and the world. The 1967 national forest survey under the German Forestry Mission was concerned with valuable commercial timber species which in effect is limited for sustainable forest management and conservation nowadays. Today, I am happy to preside over a nationally driven process with substantial supports from our international partners that have provided a comprehensive forest resources count encompassing major biota in the forest of Liberia.

The forests of Liberia form the backbone for major development initiatives for local people and wider society of our country. They are essential for our socioeconomic and infrastructural development, and conservation of the environmental services necessary for our survival now and in the future. Liberia's forests further serve as the largest shopping mall ever visited by the majority of its citizens due in part to its provision of traditional and localized medicines and foods. It is interesting to note that those services transcend common frontiers with our neighboring communities. The need to fully understand and account for the true values of this massive forest resource is addressed with forest accounting through the defined scientific approach called the National Forest Inventory. It is my hope that this NFI report will provide answers and at the same time serve as a recipe to our natural heritage for the essential purpose of our focus on the twin-targets (development and conservation).

Thanks to the Government of Norway, the World Bank Forest Carbon Partnership Facility (FCPF), United Nations Food and Agriculture Organization (FAO)-Liberia and Rome Offices, our REDD+ National Coordinator (NPC) and the entire REDD+ Implementation Unit (RIU) for the level of coordination and understanding in producing this astute result for our national information system. My special thanks also go to our forest technicians, especially the Supervisory, Biophysical and Socioeconomic teams, the drivers, and most importantly the local government officials and community leaders that participated and ensured field actions to produce this refined result.

Finally, it is my hope that the information produced will be useful for national forests information communication systems, policymakers, researchers, socioeconomic and infrastructural development initiatives, and attended conservation platforms.

May God bless the works of hands and save the state.

Hon. C. Mike Doryan

Message from the National REDD+ Coordinator

To the Managing Director of the FDA, and the government of Liberia, I thank you for the trust, support and various contributions made during this period of history-making. Many thanks to our national heroes of the National Forest Inventory (NFI) and the entire REDD+ Implementation Unit for a job well done to have a complete survey of our natural forests that will inform our national development agenda and form the basis for further development and conservation of the state.

Liberia conducted her first national commercial timber survey in 1967 and was led by a German Forestry Mission. Results from the survey practically led to the Act that created the FDA in 1976 as a responsible institution named and styled "The Forestry Development Authority'' with a general mandate to monitor and supervise forest resource management activities. The German-led forest inventory was not comprehensive to include other forest resources beyond timber values. The NFI of 2018/2019 is the first comprehensive and nationally driven forest resource assessment that has produced this refined result. The exercise would not have been completed without the support from our national government, local and community leaders, national institutions of higher learning, the management of FDA, our field technicians, and most importantly our international partners. I, therefore, seize this opportunity to thank the Government of Norway, the World Bank Forest Carbon Partnership Facility (FCPF), and the Food and Agriculture Organization of the United Nations (UNFAO) for their financial and technical support.

Results herein are multi-dimensional. It is my view that all (national and international) parties for commercial, conservation, and development will utilize these findings to champion desired progress.

I thank you

Saah A. David, Jr

Message from the National Forest Inventory Coordinator

I am glad to be a part of a national endeavor that produced facts about our natural heritage: the forests of Liberia. Indeed, I am thankful to the National REDD+ Implementation Unit (RIU), Management of the Forestry Development Authority (FDA), Environmental Protection Agency and the Liberian Institute for Statistics and Geoinformation Services, the Food and Agriculture Organization of the United Nations (UNFAO), the World Bank (WB), and all other local and international organizations that assisted the NFI process.

Liberia to date is Africa's oldest independent nation and hosts West Africa's oldest and last largest remains of evergreen and semi-deciduous forest biospheres. The two main forest blocks of the state contribute enormously to the quality of our environment, socioeconomics, quality of life, and climate: all factors incredibly important for the communities of Liberia and Africa's west coast. One interesting thing to know is that the forest is a domain of excellence to the people of Liberia especially the local tribal people. Early estimation of the forests in mid to late 1960s by the German Forestry Mission was limited to valuable merchantable timber species only; unlike this present national driven exercise that has produced formidable results. These results would not have been produced without the studious efforts of Mr Saah A. David Jr, who has reinvigorated the national concept of REDD+. Many forest liberties and attended benefits we find in our country today are the direct results of the reorientation of sustainable management of forests through REDD+.

On behalf of the NFI Supervisory Team therefore, I extend thanks to Mr. Saah A. David Jr. for igniting the production of this the first concrete forest research report since German intervention in 1960s; that will serve as reference resource material in future sustainable forest management of our forest estates. I am hopeful that the report will serve as key forest instrument in teaching all fundamental and graduate levels in Liberia. Additionally, that it will serve as resource material for further monitoring and research purposes. I trust that key resource accounts provided herein especially county specific data will be disseminated to our locals in each county through means including radios using dialects.

Finally, I thank my two colleagues Mr. Isaac Nyaneyon Kannah and Mr. John Negatus Wright of the Supervisory Team, various Team Leaders and Data Entrants, our skillful and hardworking Field Technicians, the Drivers, Community Assistants, Towns and County Officials, Vendors and all who assisted us either as individual or collective support from the beginning to today.

I thank you

James Tabolokulo Kpadehyea

Acknowledgements

The Republic of Liberia recognizes the support and effort of all who have provided financial and technical support including those who participated in the National Forestry Inventory (NFI). The Country understands that the success of the inventory would not have been possible without their unwavering support and commitment carrying out the nation's first holistic Forest Inventory.

First and most importantly, The Republic of Liberia would like to thank, the World Bank's Forest Carbon Partnership Facility (FCPF) Readiness Fund and the Government of Norway for their financial support that has enabled us to complete our first National Forest Inventory, an important element towards the setting up of our national MRV system.

The Forestry Development Authority (FDA) and the REDD+ Implementation Unit merit special appreciation and most especially the Managing Director, C. Mike Doryen and the National REDD+ Coordinator, Mr. Saah A. David, Jr. Their inputs have been invaluable during the implementation of the National Forest Inventory.

NFI is a lengthy exercise requiring a lot of technical expertise. We greatly acknowledge the Food and Agricultural Organization of the United Nations for their technical support. The following experts are recognised: Mariatou Njie, FAO Liberia representative; Dr. Jonathan Wesley Roberts, Chief Technical Advisor to Liberia; Dr. Javier Garcia Perez, Forest Statistician; Mr. Stefano Ricci, Software Engineer, FAO and Cosimo Togna, Software Engineer, for their valuable inputs in terms of statistics, data management, computer programming and data analytical software. Their expert inputs and contributions have been critical to see through our NFI. We thank World Bank technical expert Marco Van der Linden for his guidance and review at various stages of the process. Additionally, Liberia appreciates the contribution of national experts who provide continuous support to the NFI for their technical and coordinating support, especially James T. Kpadehyea, National NFI coordinator, Isaac Nyaneyon Kannah, Measurement, Reporting & Verification officer (FDA) and J. Negatus Wright, Measurement, Reporting & Verification officer (LISGIS).

Most importantly, we would like to acknowledge the hard work of the NFI field crew members. They have worked under difficult terrain and harsh weather conditions risking their own lives. From the commencement of field work in June 2018 to March 2019, they have been in the field toiling under sun and rain. Their family members too deserve appreciation for continued support and for motivating them. Finally the various community members that have assisted the NFI field crew and the Country Superintendents for their leadership and support.

The FDA and RIU would also like to acknowledge the valuable contribution made by two international independent forest professionals who undertook a technical review of a draft version of this report. The inputs from Charles "Chip" Scott (USFS SilvaCarbon) and Kari Korhonen (Natural Resources Institute Finland (Luke)) were invaluable in the preparation of the final version of this report.

Therefore, all aforementioned donors, experts including NFI field crew and coordinating team are acknowledged sincerely for their support. Their contributions in terms of technical, financial and hard work are recorded deep in the hearts of many. They have been part of history and another milestone achieved.

Acronyms and abbreviations

AGB	Above-Ground Biomass
BA	Basal Area
BGB	Below-Ground Biomass
CI	Confidence Interval
CO^2	Carbon Dioxide
CWD	Coarse Woody Debris
DBH	Diameter at Breast Height
DW	Dead wood
FAO	Food and Agricultural Organization of the United Nations
FCPF	Forest Carbon Partnership Facility
FDA	Forestry Development Authority
FRA	Global Forest Resource Assessment
FWD	Fine Woody Debris
GPS	Global Positioning System
ha	hectare
m	meter
NFI	National Forest Inventory
NFRL	National Forestry Reform Law
NTFP	Non-Timber Forest Products
PL	Priority Landscape
PSU	Primary Sampling Unit
REDD+	Reducing emissions from deforestation and forest degradation
RIU	REDD+ implementation unit
RS	Remote Sensing
SOC	Soil Organic Carbon
SFM	Sustainable Forest Management
SSU	Secondary Sampling Unit
SU	Sampling Unit
t	Metric tonnes
UN	United Nations
WB	World Bank

Executive Summary

In June 2018, as Liberia embarked on its first National Forest Inventory, six (later eight) teams entered into the field in Voinjama, Lofa county. The field teams undertook a national inventory of forest resources using a field inventory survey designed to aid the Liberian REDD+ program and the Forestry Development Authority to understand the state of forest resources in Liberia. After seven campaigns and almost 10 months, the teams completed the inventory in Grand Bassa County having successfully enumerated 257 of the planned 285 clusters.

Field inventory teams made use of digital data collection tools running customized surveys designed for the Liberian forest inventory. A data manager who assisted with data collection as well as quality control and data management supported each field team. Field inventory data was initially cleaned using a dedicated data cleaning workflow while a custom data analysis workflow derived a number of forest inventory metrics relevant for the REDD+ program as well as sustainable forest management. Data analysis was undertaken using Open Foris Calc, a robust, modular, browser-based software for analysis and reporting of results from sample-based natural resource assessments.

Results from the NFI are presented at three separate scales, national, Priority Landscape and finally for all counties. Liberia's REDD+ program has identified two Priority Landscapes, which contain the largest blocks of primary deciduous (Northwest Priority Landscape) and evergreen (Southeast Priority Landscape) forest. These areas have been identified as Priority Landscapes for the implementation of REDD+ activities and as such results are generated for these areas to facilitate informed decision-making regarding REDD+.

In 2018 Liberia established a formal country-specific definition of forest which was developed and validated by the Forestry Development Authority. For the purposes of the inventory and all forest related activities to follow, forest is defined as an area of land that:

- Has a canopy cover of minimum 30%;
- Contains trees with a minimum of 5 m height or the capacity to reach 5 m; and
- Covers a minimum of 1 hectare of land.

This includes shifting cultivation in its fallow phase (in so far as the threshold values are met) but does not include land with predominant agricultural use (oil palm, rubber, cocoa etc). This forest definition and the data collected in the inventory mean that Liberia can for the first time in its history report a forest cover estimate based on data collected in a single national inventory. All results presented in this report are accompanied by a ratio based 90% confidence interval. Forest cover in Liberia is estimated to be 6.6 million ha (CI 5%) which is approximately 69% of the total landmass. The Northwest Priority Landscape contains approximately 1.93 million ha (CI 8%) of forest while the Southeast Priority Landscape contains 2.56 million ha (CI 5%) of forest. Gbarpolu and Sinoe counties contain the highest per-county forest cover with 794,390 ha (CI 8%) and 891,806 ha (CI 3%) of forest respectively. Domain confidence intervals reported reflect the forested nature of both Gbarpolu (85% of clusters fall in forest) and Sinoe (95% of clusters fall in forest). Combined these two counties contain just over 25% or one quarter of the country's forest cover.

In terms of stocking density, results generated by the field inventory indicate that across the country there are 2,856 trees per hectare (CI 7%) and approximately 18 billion (CI 9%) trees in forests only. Stocking rates vary only slightly across the country with Gbarpolu returning the highest stocking rate of 2,842 trees per hectare (CI 20%) while Margibi returns the lowest with only 1,393 trees per hectare (CI 37%).

Growing stock in Liberia is reported as meters cubed for both whole tree and tree bole metrics on a per hectare basis. At the national scale tree volume is reported to be 386 m^3/ha (CI 15%) while bole volume is 235 m^3/ha (CI 15%). At the Priority Landscape scale the Southeast landscape returns the highest tree volume of 601 m^3/ha (CI 22%) and a bole volume of 369 m^3/ha (CI 23%) followed by the Northwest landscape which returns tree volume per ha of 405 m^3 (CI 24%) and bole volume of 245 m^3 (CI 24%). At the county level Rivercess returns the highest tree and bole volumes with 899 m^3/ha (CI 37%) and 561 m^3/ha (CI 38%) respectively.

Tree biomass and carbon results are presented as combined above and below ground biomass and carbon. At the national scale the inventory reports 313.15 t/ha of biomass and 153.45 t/ha of carbon (both have CI 16%). The Southeast once again returns the highest biomass and carbon estimates with 514.92 t/ha and 252.31 t/ha (CI 23%) followed by the Northwest with 324.34 t/ha and 158.93 t/ha (CI 23%) of biomass and carbon. Rivercess, with 753.99 t/ha and 369.46 t/ha (CI 38%) returns the highest county level estimates of biomass and carbon followed by Gbarpolu with 559.29 t/ha and 274.05 t/ha (CI 30%). Margibi returns the lowest estimates of biomass and carbon with 52.25 t/ha and 25.60 t/ha (CI 30%).

Additional metrics reported include dead wood for both fine and coarse woody debris, biodiversity estimates, non-timber forest products, forest regeneration, forest health, forest disturbance, litter, land use and finally land ownership.

The report concludes with a number of recommendations related to technical improvements in the inventory work as well as recommendations aligned to the three C's of forestry development of the FDA which stand for Community, Commercial, Conservation and the final fourth unofficial C, Carbon. Concerning technical improvements, the report recommends that the FDA maintain a core group of the NFI teams to undertake annual MRV inventory activities as well as support commercial operations within the FDA. In addition, the inventory did not plan to enumerate mangrove forests and a request for a dedicated mangrove inventory is made. Recommendations for commercial include suitable monitoring of logging activities making use of the inventory methodology and tools. Communities in Liberia stand to benefit from the data collected and reported here; recommendations include additional research on the potential benefits non-timber forest products have for communities as well as the use of the methods and tools for community forest management planning purposes. In terms of conservation, the data within the report highlights the importance of Liberia's forests and calls for increased protection of resources particularly in the Northwest and Southeast landscapes. Finally, concerning carbon, the inventory report documents the vast biomass and carbon resources in Liberia and reiterates the potential Liberia has in mitigating global climate change.

1 Introduction

1.1 Scope of National Forest Inventory of Liberia

Liberia contains approximately 43 percent of the remaining Upper Guinea forests of West Africa, which extend from neighbouring Guinea to Togo (CILSS, 2016). While the overall extent of the Upper Guinea Forest has dwindled to an estimated 14.3 percent of its original extent (Bayol & Chevalier, 2004), Liberia still has two massifs of forest including evergreen lowland forests in the southeast and the semi-deciduous mountain forests in the northwest. The forests of Liberia are extremely rich in biodiversity, being a recognized global hotspot and Priority Landscape for conservation (Junker et al, 2015). The forests' biological diversity encompasses the last long-term viable populations of several endemic animal species and over 2000 flowering plants (FFI & PROFOREST, 2012), playing a role in ecosystem service provisioning, and with potential to contribute to the country's development goals (PAPD, 2019).

Liberia's forest cover provides direct benefits that include wildlife habitat, ecotourism opportunities, soil conservation and sustainable agriculture, protection of water resources, and availability of non-timber forest products to local communities. Most of Liberia's rural population (roughly one-third of the national population) is dependent on forests and their various products and ecosystem services for their livelihoods. Forests also play an important role as a safety net for vulnerable and marginalized people, especially those living around forest areas, and for the broader community during times of hardship.

Forests in Liberia also have a potential to contribute to the reduction of extreme poverty. Over the past decade the country has made notable progress in reducing poverty and transitioning from post-conflict to stabilizing and growing its economy. However, challenges remain, as poverty and social development needs remain high, while natural resources are being depleted. In particular, Liberia's forests are under threat from expanding agriculture and mining both at industrial and subsistence levels, as well as uncontrolled and illegal logging. Its unique biodiversity, with its direct social and economic benefits are under threat due to the continued clearance and degradation of remaining forest stands. Deforestation and forest degradation arise from driving forces within the forest, agricultural, mining and energy sectors (FAO, 2016).

Deforestation rates have remained relatively low in Liberia during the past two decades because of the civil conflict that forced many to leave the countryside and migrate to the capital city and urban centers. This was also a period of relatively low international timber and agricultural exports. However, with peace restored, there has been a general return of the population to rural areas, assisted by extensive infrastructure rehabilitation of roads and bridges.

The establishment of an international initiative to compensate developing countries for reducing emissions from deforestation and forest degradation (REDD+) offers an opportunity for Liberia to serve the common interest by managing its forests in a balanced way for long-term sustainable economic growth. REDD+ seeks to support the livelihood of local and rural communities while ensuring that forests as important national and global heritage are conserved. To put in place policies and actions that will reduce emissions from deforestation and degradation of forests, Liberia has committed itself to implementing REDD+ in the context of the United Nations Framework Convention on Climate Change (UNFCCC). To do so, Liberia sought and received international support to prepare for and implement REDD+, notably from the World Bank's Forest Carbon Partnership Facility.

Liberia joined the Forest Carbon Partnership Facility (FCPF) in 2012 which is a multi-donor initiative that became operational in 2008 to assist countries in establishing the key pillars of REDD+ readiness (Voigt & Ferreira, 2015) which are:

- Developing national reference scenarios for emissions from deforestation and forest degradation;
- Adopting and complementing national strategies for stopping deforestation and forest degradation;
- Designing national measuring, reporting, and verification systems for REDD+.

To assess whether the country's actions are yielding the desired results and to participate in REDD+, Liberia needs to assess its historical emissions from forests and monitor forest emissions going forward. Forest resource assessments and research are the mandate of FDA and National academia. However, lack of adequate resources had prevented fulfillment of this mandate and the establishment of an integrated National Forest Monitoring System (NFMS) that would allow Liberia to measure, report and verify (MRV) the results from its REDD+ activities. In addition, there was a need for comprehensive national scale forest inventory data to support sustainable forest management and policy development. Therefore, reporting systems needed to be strengthened, integrated and better coordinated, and information to estimate and monitor forest emissions needed to be updated. It is within this context that Liberia has implemented its first comprehensive national forest inventory, the details of which are contained within this report.

1.2 History of Forest Inventory in Liberia

Liberia has a long history of forestry activities starting as early as the 1800s. Prior to the establishment of the Firestone Rubber Plantation in 1926, several European scientists made plant and animal collections in Liberia. Schweitzer, a German naturalist, beginning in 1875 to 1877, carried out the first serious scientific collection of plant specimens in Liberia. This was followed by a group of Swiss naturalists led by Johann Buttikofer who collected additional biological specimens from 1879-1890. One of Buttikofer's team, Fredrick Jentinks, collected specimens of Liberia's rarest antelope, which were then called Jentinks' duiker (deer) (Sachter 1968).

Contributions to Liberia's faunal knowledge from the United States began with the establishment of the Firestone Rubber Plantation Company in 1926, which provided some basic information on the flora and fauna of Liberia. In 1928 – 1929, Cooper and Record of Yale University collected about 500,000 specimens, which included 286 tree species, from 52 half-acre plots (total of 10 hectares) in the concession areas of the Firestone Plantation near Harbel, present day Margibi County (Sachter 1968). Cooper and Record calculated stand densities as well as the most important physical properties of 104 tree species. Other botanists like Dr. and Mrs. George W. Harley, Gottwald, Kryn,Fobes and Voorhoeve, also classified Liberian trees up to 1968.

In 1926 the Firestone Rubber Plantation Company shipped a pigmy hippo from Liberia as a gift to US President, Theodore Roosevelt. In the same period, four Harvard zoologists led by Glover Allen conducted field studies on Liberia's mammals, birds, reptiles, amphibians and insects (Allen, 1942). Firestone also sponsored an expedition to Liberia headed by Director of Smithsonian Zoological Park, Dr. William Mann for the US National Museum (Sachter, 1968).

In 1953, the Liberian legislature passed an Act creating the Bureau of Forest, Conservation and Wildlife, which provided the opportunity for creating National Parks and Reserves in addition to establishing the College of Forestry at the University of Liberia (Forests Act, 1953).

The Food and Agriculture Organization (FAO) of the United Nations (UN) was the first to develop and provide the curriculum and instructors for the College of Forestry at the University of Liberia. The objectives were to produce professional and technical staff for the Bureau of Forest Conservation and Wildlife. Students enrolled at the College included not only Liberians but also those from other English-speaking countries in Africa.

In 1957, a supplementary Act passed by the Liberian legislature, which incorporated regulations that set limits on hunting of certain animal species and creating wildlife refuges. In 1969, a Swedish conservationist named Kai Curry-Lindahl recommended to the Liberian government that it should invest financial resources into conservation programs following research undertaken on Mount Nimba. The program recommended that the establishment of National Parks and other reserves should be combined with hunting regulations as a means of conserving endemic wildlife.

Liberia's first forest inventory was undertaken between 1964 and 1968 through an agreement between the Government of Liberia and the German Technical Cooperation Agency (GTZ). The inventory was conducted on approximately 10% or 1.6 million ha of Liberia's forest cover. At the end of the inventory, twelve (12) National Forests were identified and classified into priority conservation areas, such as the Sapo National Forest, Krahn-Bassa National Forest, and Grebo National Forest. The German Technical Mission report included information on socioeconomic data, biophysical data, biodiversity data and other information about the forests. The inventory was undertaken by some of the first graduates of the College of Forestry at the University of Liberia: Mr. Tommy Gorgla, Mr. Willie Cooper, Mr. James Moore, Mr. Samuel Dorko, and Mr. James Sherman (Voorhoeve, 1965).

The Forestry Development Authority (FDA) was created in 1976 by the Liberian legislature replacing the 1953 Bureau of Forest Conservation and Wildlife (FDA Act, 1976). The primary objectives of the Authority were to:

a. Establish a permanent forest estate made up of reserved areas upon which scientific forestry will be practiced;

b. Devote all publicly owned forest lands to their most productive use for the permanent good of the whole people considering both direct and indirect values;

c. Stop needless waste and destruction of the forest and associated natural resources and bring about the profitable harvesting of all forest products while assuring that supplies of these products are perpetuated;

d. Correlate forestry to all other land use and adjust the forest economy to the overall national economy;

e. Conduct essential research in conservation of forest and pattern action programs upon the results of such research;

f. Give training in the practice of forestry; offer technical assistance to all those engaged in forestry activities; and spread knowledge of forestry and the acceptance of conservation of natural resources throughout;

g. Conserve recreational and wildlife resources of the country concurrently with the development of forestry program.

Primarily, FDA was organized as a public corporation with a Board of Directors for policymaking and management structure for technical, managerial and business operations and headed by a Managing Director appointed by the President of Liberia. The Authority's functions were to produce policy and regulations based on Sustainable Forest Management (SFM) and reflect best practices at all times. These included the granting of logging concessions in areas with dense forest and deforested areas while recognizing the designated twelve National Forests. Logging practices were based on selective felling of tree species with the minimum diameter at breast height graded under FDA supervision.

National Forests identified under the German forest inventory, were priority conservation areas, protected by trained rangers and wildlife officers. To date there are five (5) protected areas with seven (7) proposed protected areas across the country.

Following the end of the Liberian 14-year civil unrest, the UN Security council passed Resolution 1521 placing sanctions on Liberian logs and timber exports to UN member countries in 2003. The Accra Peace Accord mandated the interim Liberian government to restore good governance before lifting sanctions on the forest sector. Liberia responded by establishing a Forest Reform Committee headed by John T. Woods. In January 2004, US stakeholders under the US State Department organized a scoping mission to Liberia and recommended a road map for forest sector reform. The Liberia Forest Initiative (LFI) was established with a mandate to formulate a reform program for the Liberian forest sector. In 2005, the LFI comprising key forest stakeholders chaired by Frederick Cherue produced a comprehensive forest sector reform program for the interim government. In December 2005, the first international conference on community forestry was held at Baptist Theological Seminary where the Monrovia Community Forestry Declaration was issued. On February 2, 2006, President Ellen Johnson Sirleaf issued Executive Order number one containing the required forestry reform programs. A National Forest Policy based on the three C's (Conservation, Community and Commercial) principle was formulated, following this, the National Forest Reform Law (NFRL) of 2006 (National Forestry Reform Law of 2006) was enacted. The NFRL validated and issued eleven core regulations. Following the completion of the NFRL, in June 2006, sanctions on logs and timber were lifted by UN Security Council. Commercial logging activities began with the reform law of 2006 and sustainable forest management practices were put in place. In 2009, the Community Rights Law with respect to land was enacted; land reform activities were initiated through the creation of the Land Commission and the drafting of land policy and the Land Law Act (Community Rights Law of 2009).

1.3 National Forest Inventory of 2018

Within the context of the national REDD+ program, the National Forest Inventory had two main objectives; the first being that the design would enable regular forest inventory and implementation of the first national scale forest inventory, and the second being the development of local capacities to facilitate regular assessments of forest resources thereby enabling policy development and informed decision making. The targeted outputs of the National Forest Inventory are as listed:

- Forest area
    - Forest area estimates by different categories
- Tree count
    - Tree count by Priority Landscapes
    - Tree count by counties
    - Tree count by diameter classes
    - Tree count by top five genera per county
- Basal area
    - Basal area by Priority Landscapes
    - Basal area by counties
    - Basal area by diameter classes
    - Basal area by top five genera per county
- Growing stock
    - Total volume by Priority Landscapes
    - Total volume by counties
    - Total volume by diameter classes
    - Total volume by top five genera per county
- Biomass and Carbon Stocks
    - Biomass and carbon stock by Priority Landscapes
    - Biomass and carbon stock by counties
    - Biomass and carbon stock by diameter classes
    - Biomass and carbon stock by top five genera per county
- Dead Wood

    - Dead wood biomass and carbon by Priority Landscapes
    - Dead wood biomass and carbon by counties

- Biodiversity

    - Diversity metrics by Priority Landscapes
    - Diversity metrics by counties

- Non-timber Forest Products

    - Non-timber forest products for Liberia
    - Non-timber forest products by Priority Landscape
    - Non-timber forest products by counties

- Forest Regeneration

    - Regeneration by Priority Landscapes
    - Regeneration by counties

- Other Forest Metrics

    - Forest Health
    - Forest Disturbance
    - Litter
    - Land use class
    - Land ownership

The above-mentioned information was collected with the purpose of informing the national REDD+ program, specifically the Forest Reference Level. The data will also allow for informed decision making about the sustainable management of forest resources. The data collected will answer questions relating to the status and trends of forest ecosystems, distribution of plant species and their relationship to the environment, changes in forest structure and productivity resulting from disturbance, and improved prediction of forest growth and development on different sites and in response to management regimes.

This information and data will assist the government and policy makers in developing appropriate policy-decisions aimed at managing the forest resources sustainably. Natural resource managers and organizations for developing strategic implementation plans can also benefit. The scientific community, researchers, and academia will also benefit from such data and information.

1.4 Limitation of estimates

Liberia's current NFI has been designed to obtain estimates at a national level with precision of 10% and a margin of error at the 90% confidence level for all variables listed in section 1.3. The National Forest Inventory uses a systematic sampling design, which consists of 285 sampling clusters organized on a hexagonal grid at 0.179-degree intervals (approx. 19.9 km). A fully extended, nationwide systematic inventory ensures full coverage of land uses across the nation, allowing forest cover to be determined exclusively from field samples, which can be later integrated with satellite-based estimates. The reason for choosing a systematic sampling design was because Liberia's forest definition (see Section 5.1) includes fallow lands and excludes tree crops. These are both difficult to distinguish from forest with the current available satellite information. Hence, it was considered that a preliminary stratification of the country using imagery would have been inaccurate and all land use classes (excluding mangroves) are reported in the inventory with the chosen systematic sampling design.

The inventory design and execution were undertaken within a strict time frame and budget. This led to a design that favoured a reduction in transport costs and an emphasis on cluster plots where spatially independent plots were enumerated. Cluster delineation costs were further reduced by assigning smaller between-subplot distances than those typically used considering spatial correlation of biomass in tropical rainforests. While this brings limitations to the estimation due to possible intra-cluster correlations, estimates for biomass took into account the nested nature of the design, accounting for both within and between-cluster variation. In three counties (Bomi, Montserrado, and Maryland) only six clusters present, and therefore the accuracy of estimates of forest cover was likely hampered by the low sampling density. For example, the low sampling intensity in Montserrado lead to results indicating that forests are not present in this county, when in fact they are. The results at the national and subnational scales must be interpreted within this context.

The current inventory managed to enumerate just over 90% of the planned clusters, as such; results from the inventory obtained the necessary sample size to produce robust estimates of forest resources. However, the inaccessibility of 18% of cluster plots in Sinoe County could affect the results and precision in this county, which hosts most of Liberia's intact forest. Accessibility was generally a problem in remote areas where teams were not able to walk to clusters due to flooding or topographic features. In some cases the presence of dangerous wildlife such as water buffalo and forest elephants prevented access. In addition, the national scale assessment are missing crucial estimates, for example mangrove forests, which are important components of the forest estate but only account for a fraction of forest cover.

With regard to reporting of forest extent, the present inventory reports forest area using a ground sample approach, thus it is likely that these estimates will differ slightly from forest extent estimated using a remote sensing-based approach.

Finally the team endeavoured to provide robust statistics on the presence and type of non-timber forest products (NTFPs) in all landscapes. Results provided in section 5.8.2 are an excellent baseline for the development of national policies to support these commodities. However, care should be taken when interpreting estimates at the county level as there appear to be inconsistencies in the way teams reported an absence of NTFPs in plots. This may manifest itself as bias at the county level.

2 Field Methodology

The field methodology employed in the NFI was documented in an inventory field manual prepared in cooperation with the Food and Agriculture Organization of the United Nations who provided technical assistance throughout the inventory. The NFI field manual was the basis for capacity development activities associated with the field work. Each field team member received a copy of the inventory manual prior to training and each field team received a field copy of the manual for reference purposes in the field.

2.1 Sampling design

The planning and implementation of the NFI was constrained by both time and funding, as such an optimization process was undertaken to select the most suitable sampling design. This process took into account the time available to complete the inventory as well as the activities undertaken in the field such as time taken to walk to the plots and to take the actual enumeration measurements. The actual optimization made use of a continental scale preliminary biomass map (Avitabile et al, 2016), and budget and was finely tuned using an acceptable error for estimates.

Due to the stratified nature of previous inventories in Liberia and the lack of a stable stratification, above ground biomass per hectare data from Avitabile et al. (2016) was used to infer standard deviations in biomass per hectare. Most parameters for unit costs of time were taken from a previous study in tropical forests of Central Africa (Sylla and Picard, 2005), such as walking speeds, delineation and measurement times, while other parameters such as driving speed and time needed for community awareness-raising were inferred.

The optimization process resulted in a sampling frame consisting of 285 clusters to enumerate. Each cluster was composed of five plots, each with a radius of 18m. The overall calculated time spent in the field (for six teams) was 22.5 weeks (Figure 1), however partway through the inventory the managerial inventory team increased the number of field teams to 8 resulting in a shorter field inventory time.

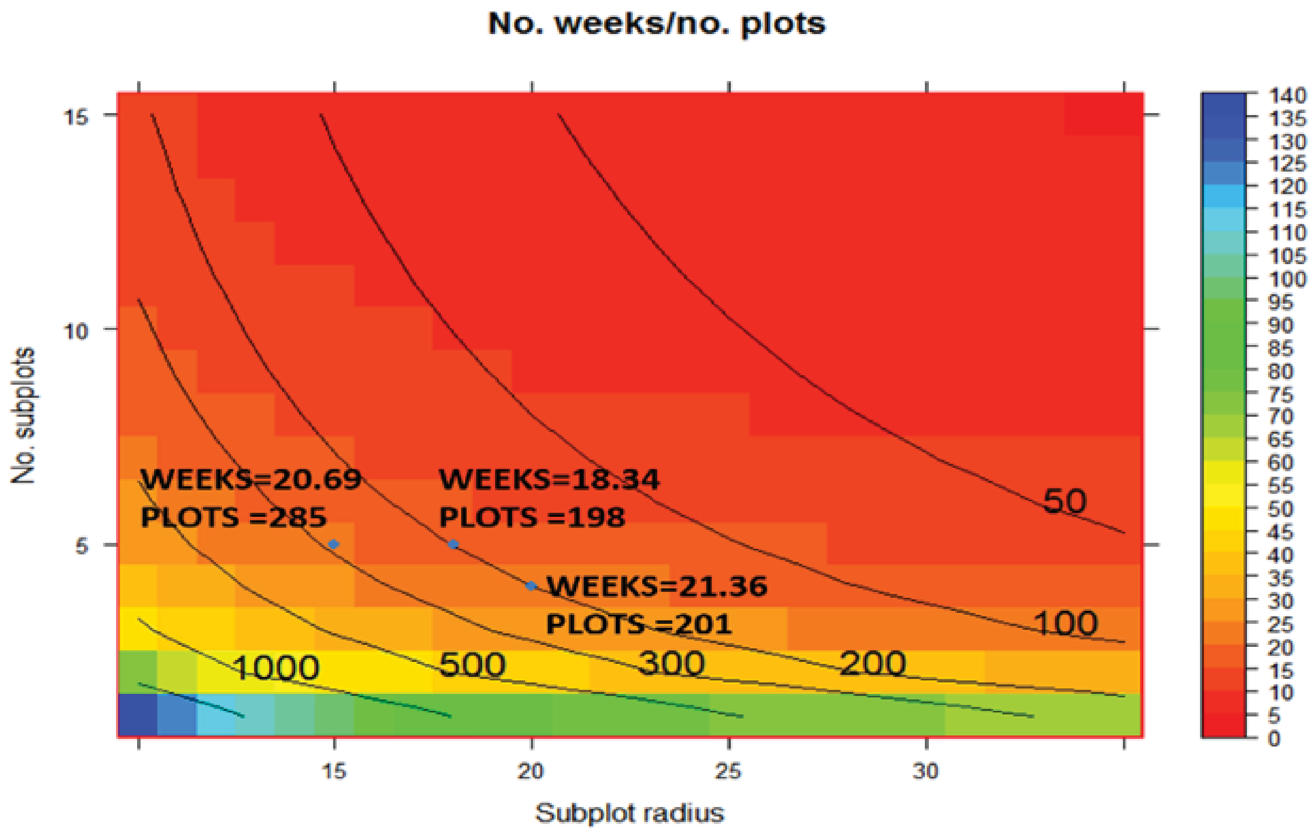

Figure 1. NFI Cluster optimization

Figure 1 provides a graphical representation of the optimization approach used by Liberia to select a suitable number of clusters while taking into account the logistical challenges associated with a national forest inventory. Contour lines indicate the total number of sampling units (clusters) that would compose the sampling size, while the coloured pixelized legend indicates the number of weeks to complete the whole NFI, based on preliminary estimates (Sylla and Picard, 2005) of time allocation and speed in the different activities taking place across the field campaign. During the early phases of design, budget constraints forced a hard threshold at around 18-20 weeks. Soft constraints, based on other NFIs across the region, recommended subplot radius larger than 15 m. A quick visual exploration aiming to fulfill the number of weeks constraint while maximizing number of plots (to achieve better representativity and potentially smaller variance) would lead towards a choice of 10 m radius, 11 subplots per plot (cluster). Given the potential accumulation of errors when measuring a large number of small subplots, and the need to establish subplot sizes closer to other values in the region, a choice was made for the leftmost blue dot with 15 m radius subplots. A posteriori budget adjustments allowed the time allotment for the whole field campaign to be expanded, allowing the design team to opt for 18 m radius subplots, while keeping the total number of cluster plots to 285.

The resulting 285 cluster plots for the National Forest Inventory were arranged according to a systematic sampling design. Laid on a hexagonal grid at 0.179° intervals (19.9 km), the inventory consisted of 285 sampling clusters. The sampling plots were not limited to forest area but covered the whole country (Figure 2). In a previous 2006 rapid inventory, inaccessibility of cluster plots reached approximately 59%, in the present inventory design a maximum of around 30% inaccessibility has been considered acceptable. The NFI constituted a land inventory with specific concentration on forestry, but also included information about agricultural parameters, which allow for the monitoring of changes over time. The design yielded a sampling intensity of 0.001% at the 10% margin of error with a 90% confidence levell for all attributes reported.

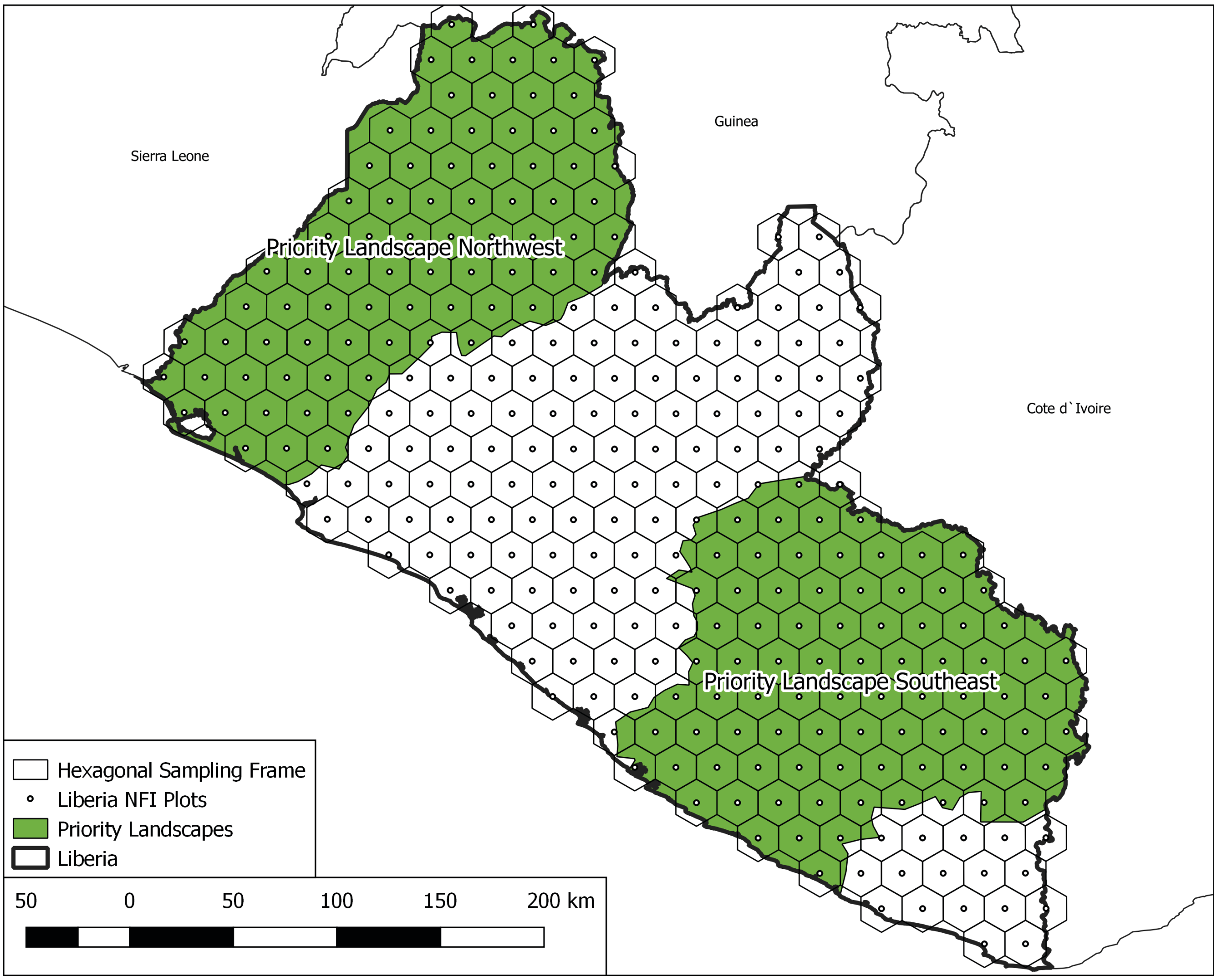

Figure 2. Hexagonal sampling framework used to guide the location of sampling clusters

2.1.1 Inventory sampling intensity: a paneled approach

The clusters were laid systematically across a hexagonal grid with equal distances of 19.9 km between the six neighboring clusters (Figure 2). Hexagonal sampling grids ensure spatially balanced designs and warrant equal distances between neighboring samples in systematic designs by avoiding orientation issues common with square sampling grids (McRoberts et al, 2015) while facilitating additional sampling later should the FDA want to increase the sampling intensity while retaining the same inclusion probabilities. Given the time constraints associated with the presence of the wet season, a two-panel approach was undertaken. The first panel, located in the northwest of the country was enumerated between June and September 2018 to avoid the difficulties of sampling in heavy rain. Enumeration of the second panel, located in the southeast, began in October 2018 and ran until March 2019. The division in two panels ensured that preliminary data from the first panel could be analyzed in the summer in order to review and potentially modify the design if necessary (Figure 3).

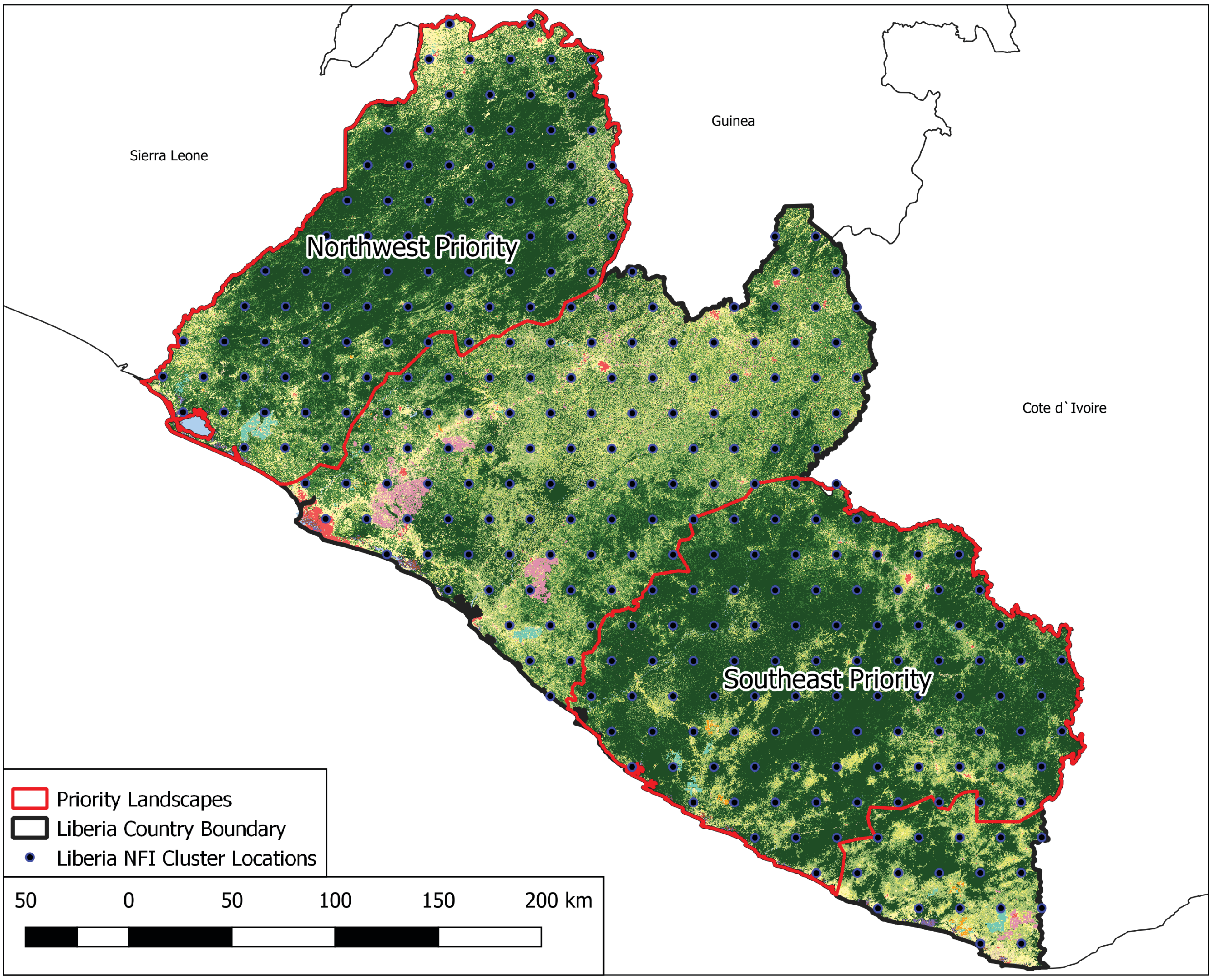

Figure 3. Two-panel inventory approach

2.1.2 Cluster Plot Design

Each inventory cluster (primary sampling unit or PSU) consists of five (5) circular plots on a backwards L-shaped transect spaced at 60 m intervals. This distance was selected based on a review of forest inventory work in West Africa (Sylla and Picard, 2005). The 60m distance ensures relative independence between plots while also avoiding topographic or climatic correlations typically appearing at larger distances (Figure 4).

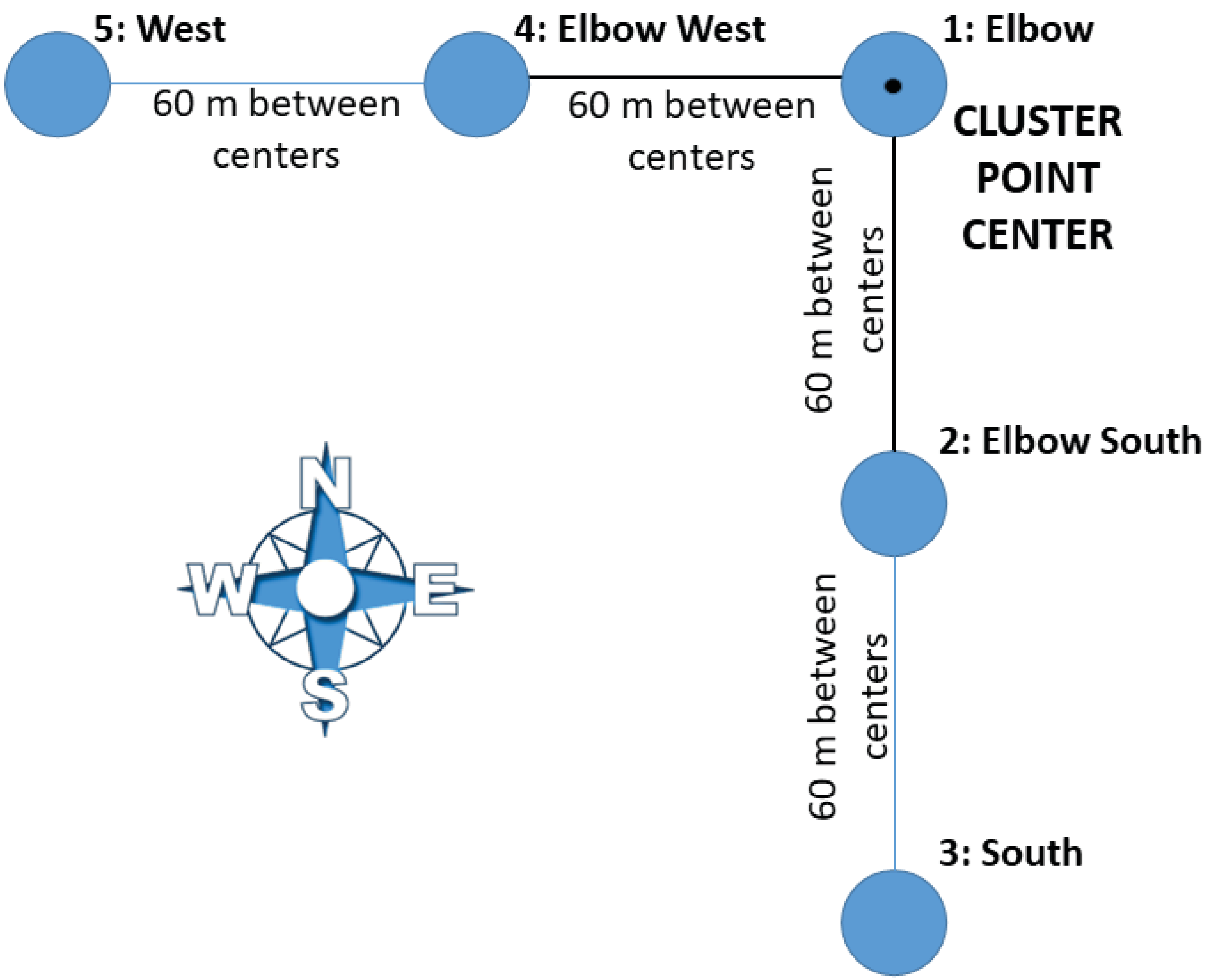

Figure 4. NFI Cluster plot design

Measuring of the cluster always began at plot no. 1 (where the cluster point center is located i.e. the elbow plot) and continue in numerical order: first southwards to 2 and 3. Then back to no. 1 and then westwards to 4 and 5.

Each circular plot (secondary sampling unit or SSU) consists of three nested circular subplots; the nested subplots were configured to guide the tree sampling according to the diameter of the trees. The 18 m radius subplot was used to collect data from trees with a DBH greater than 40cm (Figure 5). Within the middle 7 m radius subplot, trees with a DBH from 10 to 39.9 cm were also measured; finally, within the 2 m radius inner circle, trees with a DBH greater than 2 cm and less than 10 cm were measured (in addition to the two other DBH classes). Regeneration within each subplot was quantified as the total number of recruits (trees < 1.3 m height) counted within the 2 m nested subplot. Trees with a height greater than 1.3 m but a dbh of less than 2 cm were considered rare and were not enumerated. See Table 1 for more information on the subplot-sampling units.

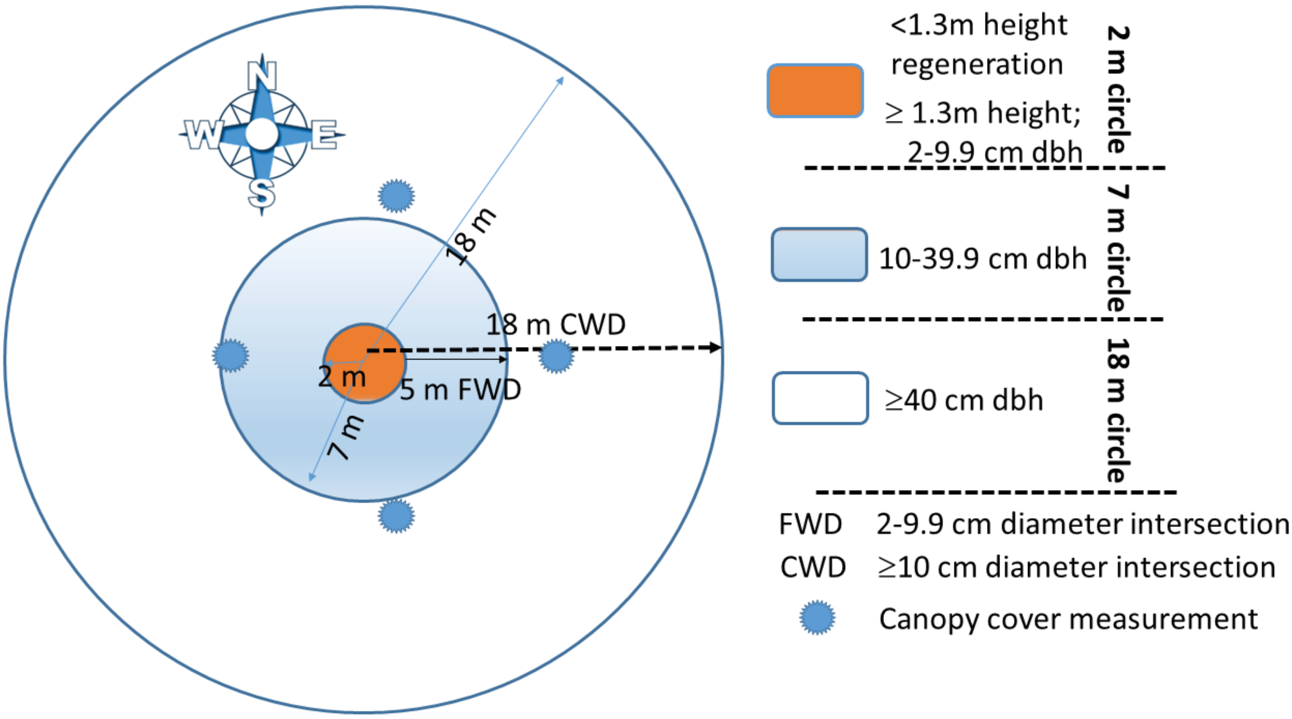

Figure 5. Nested subplot design

Coarse and fine woody debris were sampled using a transect method. Fine woody debris (diameters at intersection between 2 and 9.9 cm) was measured along a 5 m east-facing transect (from 2 to 7 m) while coarse woody debris (any dead wood piece with diameter larger or equal to 10 cm) was measured on the same east facing transect but to a distance of 18 m.

Table 1. Nested subplot sampling units

Unit	Shape	Size	Number	Tree/shrub/ piece size	Field form
PSU (cluster)	Backward "L"		1	NA	F1
Nest 1	Circle	18 m radius	5/PSU	40 cm ≤ dbh	F2-F9,F13
Nest 2	Circle	7 m radius	1/SSU	10 cm ≤ dbh < 39.9 cm	F13
Nest 3	Circle	2 m radius	1/SSU	2 cm ≤ dbh ≤ 9.9 cm	F13
Regeneration	Circle	2 m radius	1/SSU	<1.3 m height	F12
CWD transect	Line	18 m	1/SSU	10 cm ≤ d. intersection	F11
FWD transect	Line	5 m	1/SSU	2 cm ≤ d. intersection ≤ 9.9 cm	F10

3 Data

3.1 Data collection

In preparation for the field data collection, a number of capacity development activities were facilitated by the NFI technical partner (the Food and Agriculture Organization of the United Nations) in 2018 and took place in both Monrovia as well as Rome, Italy. These included a stakeholder workshop to finalize the NFI methodology as well as the variables to be collected. Following this, two practical NFI training activities took place where the field teams and supervision crew were trained in the use of the methodology as well as the tools required to undertake the NFI measurements.

The field methodology varied between six and eight teams entering the field to collect biophysical data from clusters assigned to them. Field measurement began when teams left their vehicles and began walking on foot to the inventory clusters; the first part of the survey was dedicated to capturing route information using photos and their geographic location to record significant features along the way in a diagram (see e.g. Figure 6).

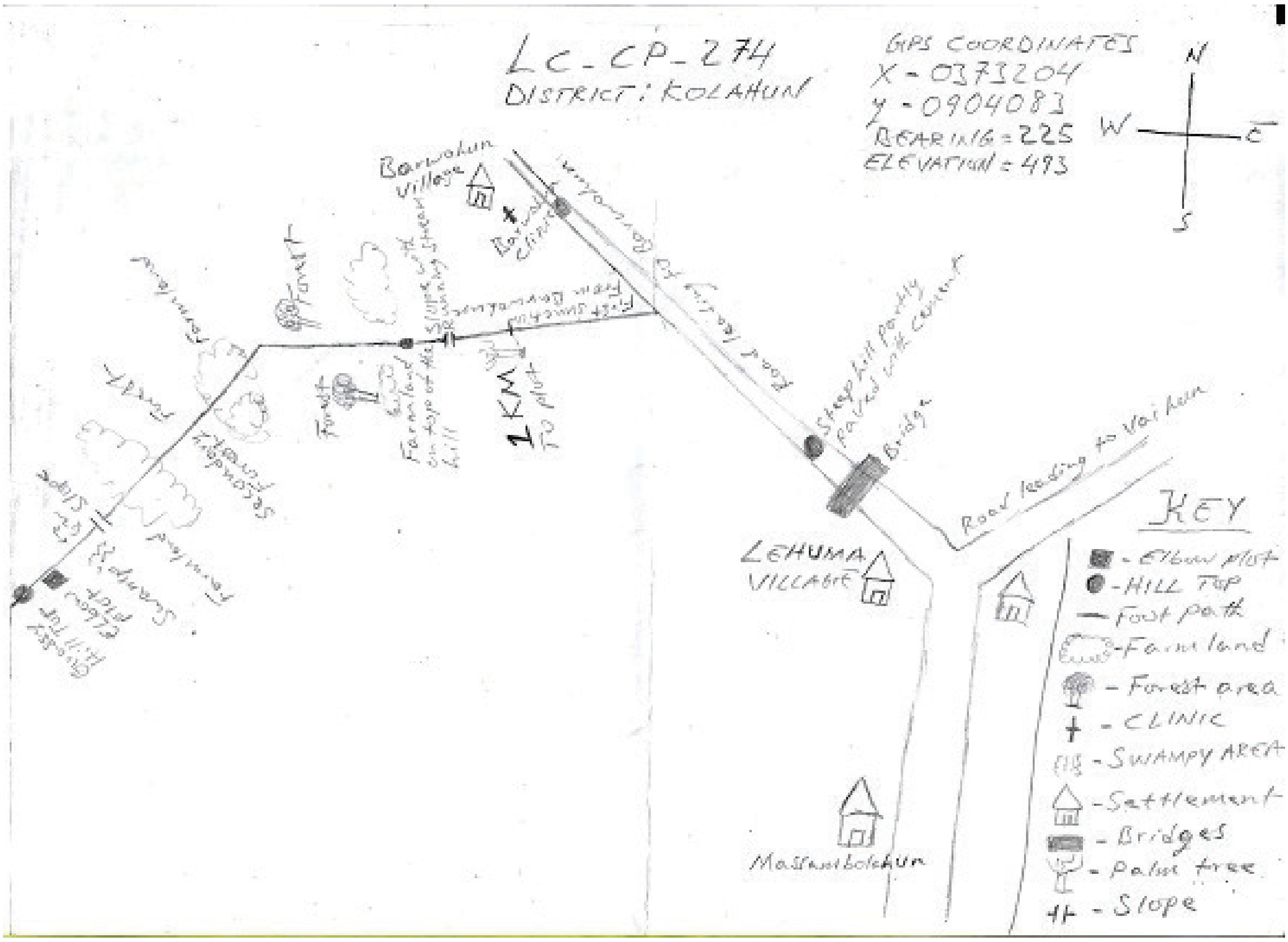

Figure 6. Cluster rout map drawn by field teams

Future remeasurement of the inventory plots will make use of these markers and drawings for navigation purposes. Hand held GPS units with the planned plot centres lead teams to the plots so that they could be established by the field teams. The team leader and or botanist then captured information relating to the general description of the plot, which included plot coordinates, slope and prominent structures (Figure 7).

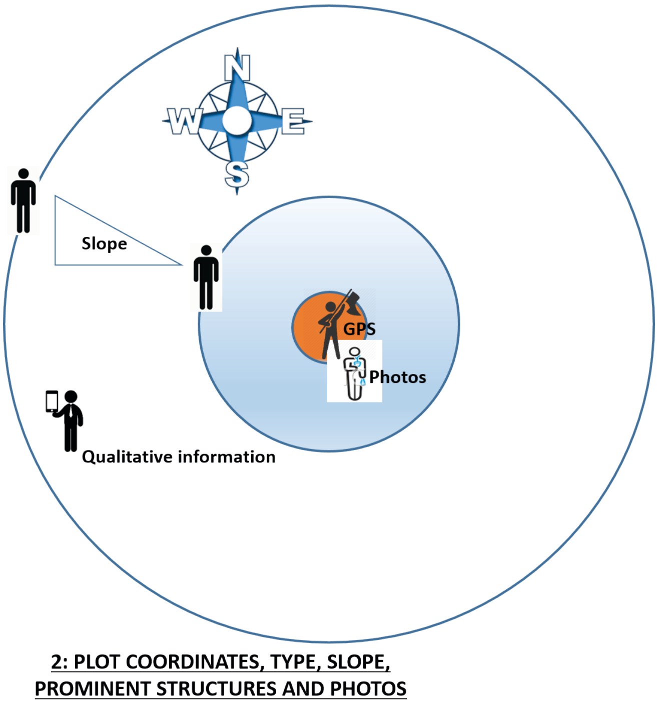

Figure 7. General description of the plot

Following the general description of the plot, the teams made observations regarding the presence of mammals, birds and reptiles.

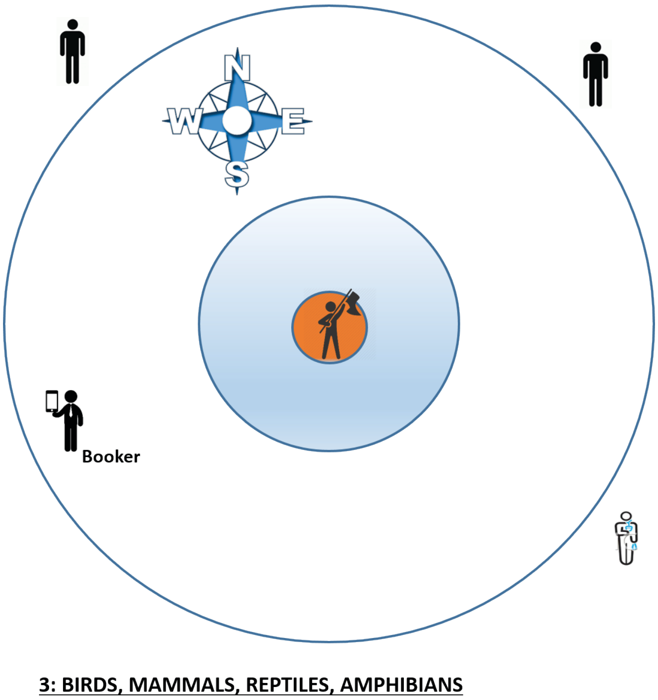

Figure 8. Presence of fauna around the plot

Once the teams have identified and recorded the additional fauna around the plot, they proceeded to work on undertaking the marking of the plot layout and the plot description. Typically, teams used wooden poles to lay out the 2, 7, and 18m locations in the North, East, South and West directions. These poles served to guide the enumeration activities especially the dead wood transects and the DBH measurements (Figure 9). Measurements proceeded in a clockwise direction starting at the 12 o'clock / North point of the plot.

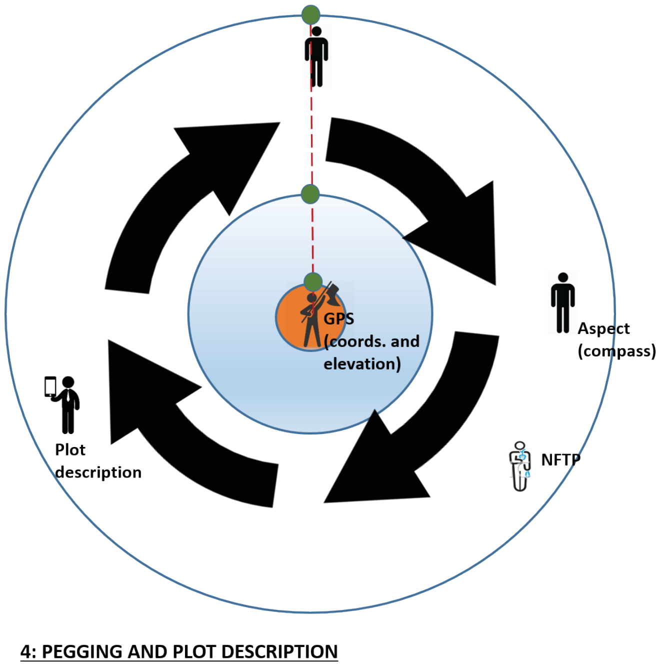

Figure 9. Plot pegging and dead wood assessment

Canopy cover estimates using a spherical densiometer were also captured. On site measurements began with enumerating fine woody debris and coarse woody debris using a transect running west to east from the centre of the plot. Live tree sampling followed with the team counting saplings (regeneration) within the 2 m radius subplot where all stems with a DBH between 2 and 9.9 cm were recorded. Within the larger 7 m subplot trees with a DBH between 10 and 39.9 cm were recorded, and finally within the 18 m subplot trees above 40 cm DBH were captured. Starting from the north, every third tree had its height recorded and all trees measured had their species name recorded as well as the DBH, distance and direction from subplot centre to the tree, general health of the tree and the canopy position.

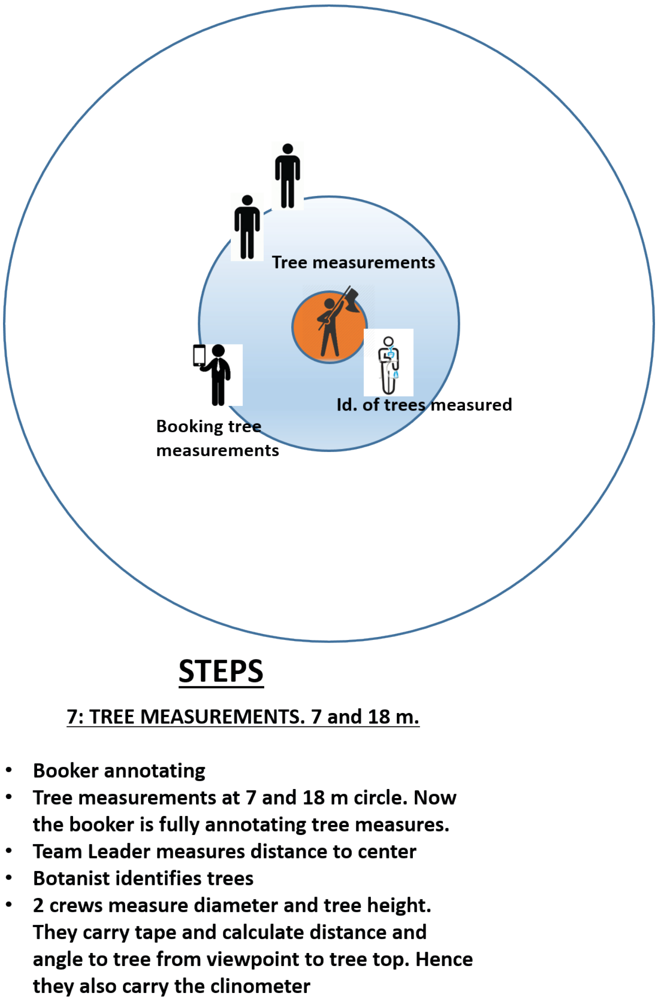

Figure 10. Tree measurements

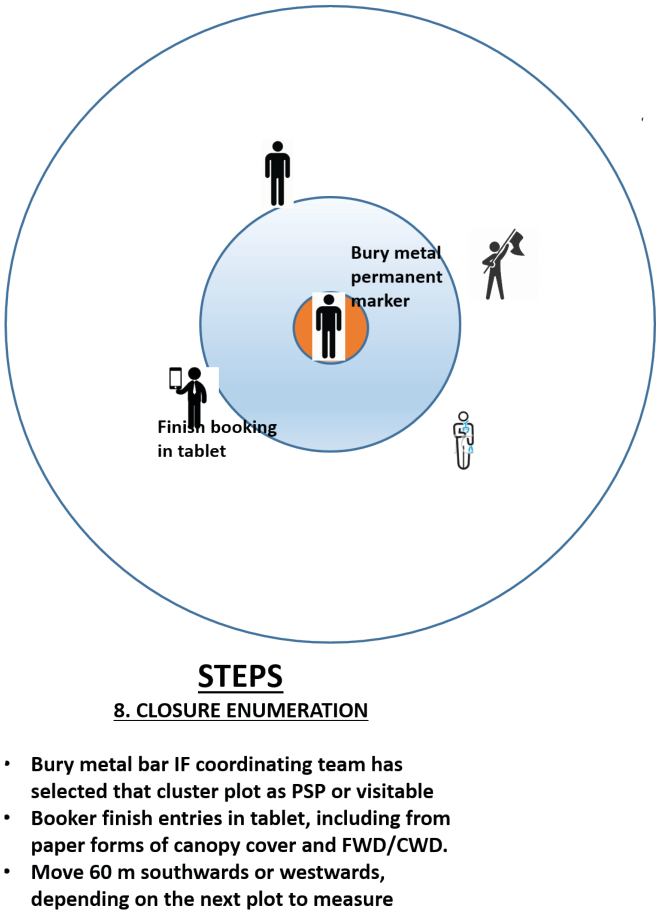

Figure 11. Plot enumeration closure

The NFI made use of digital data collection tools and customized surveys. The customized survey included a tree species list for Liberia. If the field teams were unable to find the species in the list, they recorded the tree as unlisted and entered the actual name in the survey (Figure 10). Enumeration activities were finalized on the plot following the burying of a plot marker at the centre of the plot in the form of a metal bar. The team booker then closed the survey taking care to record the time and date when the plot was completed. The enumeration team would then move onto the next plot in the cluster or to a new cluster (Figure 11).

All equipment used for the inventory was purchased by the Government of the Republic of Liberia, which included seven Toyota Land Cruiser hardtop vehicles as well as seven Yamaha AG 100cc motor bikes. These vehicles were used to transport teams into the field and facilitate fieldwork activities. The roles of the team members are described in Annex VI. Each field team received an equipment pack, which included all the necessary tools required to implement the NFI methodology. This list is provided in Table 2 below.

Table 2. NFI field equipment list

Requirement (Item Description)	Number (per team)
Topographic maps	1 (per campaign)
Clinometers (Suunto, Haglof)	2
Diameter measuring tape (DBH)	1
Clipboard	2
Range finder	1
Compass	1
Binoculars	1

Requirement (Item Description)	Number (per team)
Spherical densitometer	1
Measuring tape (50m/100m)	1
GPS receiver (Geographic Positioning System) and extra batteries + charger	1
Mobile phones	1
10' Tablet (data entry)	1
Memory cards for phones and/ or camera	1
VHF Mobile Transceiver	1
Boots	1 pair per person
Leather Gloves	5 pairs
First aid kit	1
Rain coat heavy duty	5
Cutlass	1
Tents for 6-8 persons	1
Sleeping Bags	1 per person
Mattresses	1 per person
Camp stove	1
Camp table	1
Camp chairs	5

Requirement (Item Description)	Number (per team)
Mobile batteries	1
Mobile unit charger	1
Ice chests	1
Backpacks for field crew	1
30-50cm galvanized metal bars for plot marking	200
Files	1
Flashlight and batteries	1
Knives	1
Hammer	1
Caps	5
T-shirt	5
Spade	1
hand calculator	1
pens and markers	8

Field inventory activities were split into seven campaigns where field teams were deployed to several counties to collect forest inventory data. Field activities commenced in June 2018 and continued until March 2019. The entire campaign took approximately 10 months to complete. Table 3 shows the dates and counties for each campaign.

Table 3. Overview of NFI campaigns

Landscape	Campaign	Counties	Dates	Assigned Clusters
Northwest Priority	Campaign 1	Lofa	June 2018	27
Northwest Priority	Campaign 2	Gbarpolu	August 2018	31
Northwest Priority	Campaign 3	Grand Cape Mount, Bomi, Montserrado, Margibi	September 2018	35
Southeast Priority	Campaign 4	Sinoe, Grand Kru, Maryland	October 2018	50
Southeast Priority	Campaign 5	Grand Gedeh, River Gee	November 2018	52
Non-PriorityLandscape	Campaign 6	Rivercess, Nimba	January 2019	43
Non-PriorityLandscape	Campaign 7	Bong, Grand Bassa	February 2019	47

Field campaigns were preceded by a launch attended by the county superintendent as well as county authorities and stakeholders. The launch served to introduce the activities to the county officials and to receive the support of these officials. Field teams would enter the field with letters of support from the FDA to the county authorities explaining the purpose of the fieldwork. At the same time, the supervision team along with a communications specialist would make regular appearances on local radio shows to announce to the community the impending field work activities. The radio communications served to educate the local community on the NFI field activities. The radio shows were made and presented in local dialects. The communications also included radio jingles played for several days after the launch of each campaign.

Once in the field the field teams first met with local communities living in and around the cluster area.

They introduced the work to the communities and invited them to provide two able bodied persons to support the navigation to the clusters as well as the additional activities while on site. They also served as guides and provided additional information relating to forest use and non-timber forest products. The field teams reported that communities were happy to assist in the inventory activities and interested in the use of the data.

Previous inventories in Liberia and elsewhere usually employed field data collection sheets which were manually completed using a pencil. The present inventory made use of digital data collection tools installed onto smartphones and tablets. Prior to the fieldwork team leaders and data managers were trained in the use of digital data collection tools. The FAO-developed Open Foris Collect Mobile tool was used for collecting inventory data in the field. Teams recorded all forest inventory data onto tablets and smartphones; this information was then backed up onto a laptop and transferred to a data repository where it awaited the next phase in the inventory methodology.

3.2 Data conversion and migration

The NFI data collection was facilitated using the Open Foris Collect Mobile software[1]. Data collected using this tool was exported using the built-in tools available to users. This is done by selecting the export button from the drop down field which then exported the raw field data to the devices hard drive in a format suitable for importing into Collect Desktop. However in the case of e.g. freezing or complete battery discharging of the tablets, the data was also recorded on paper forms with similar survey designs and later entered into the Liberia NFI survey in Collect. Once the data had been digitized it could then be shared with the NFI data managers. Figure 12 provides an overview of the data conversion and migration process used as part of the national forest inventory.

Figure 12. Data conversion and migration process

Initial cleaning activities made use of validation tools built into the Open Foris Collect Mobile software as well as the Desktop Collect application. The validation rules were defined when the survey was initially produced and included routines for identifying missing data. The data was then exported as comma separated values (csv) files, which were used for additional data cleaning which is described in section 3.3.

3.3 Data cleaning

Following initial collection and migration, the NFI field data was stored on a cloud-based installation of Open Foris Collect[2]. The data cleaning team then accessed the data from this location and undertook the following data cleaning activities that were split into four phases. Experienced data cleaning officers uploaded the data and made the clusters available to all for cleaning. Data cleaning activities began in October 2018 when half of the data management team remained in Monrovia and began working on cleaning the database. Between October 2018 and May 2019, a number of data cleaning events were held, the last of which took place in May of 2019 where the full data management team worked through the final steps discussed below. An interim clean database was produced and used for analysis activities.

- Step 1 of the data cleaning phase involved a review of the initial errors identified by the built-in data survey validation tools (warnings and errors);
- Step 2 involved reviewing a number of non-carbon survey attributes that help to harmonize the database and facilitate data analysis;

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

- Step 3 involved a detailed assessment of the species identified by the field teams focusing on those species listed as Unlisted. Analysts made use of online resources to verify and update Unlisted species, thereby improving the overall species data for the country;

- The final phase (step 4) sought to identify outliers using graphical tools as well as a z-score analysis which helped to identify erroneous DBH-height pairs;

- Once the data managers had completed their activities, recommendations were forwarded to the NFI supervision team and additional updates were applied to the database.

3.4 Data analysis

The NFI data analysis was undertaken using Open Foris Calc which is a robust, modular, browser-based tool for analysis and reporting of results of sample-based natural resource assessments. The tool allows for the development of customized statistical software R (R Core Team, 2020) modules to perform analysis and generates reports using Saiku, an open source software for web-based analytic solutions. Reporting parameters are outlined below. For most of the parameters estimates were initially generated at the plot and or cluster level ensuring additivity of total estimates per domain (i.e., Priority Landscape, county) and the country totals.

Reporting parameters:

All area estimates presented in this report are calculated based on total areas reported in Table 4. The sampled population was the land mass of Liberia excluding water bodies. See Equation 1 for the formula used for calculating area.

Table 4. Gross areas for the various reporting strataabl

	Area (ha)
Liberia	9,591,809
Priority Landscape 1	2,653,986
Priority Landscape 2	2,824,018
Non-PriorityLandscape	4,113,805
Bomi	210,812
Bong	838,464
Gbarpolu	924,506
Grand Cape Mount	494,535
Grand Bassa	748,051
Grand Gedeh	1,025,307
Grand Kru	368,978
Lofa	1,025,450
Margibi	280,928
Maryland	219,228
Montserrado	180,942
Nimba	1,189,753
Rivercess	528,487
River Gee	619,594
Sinoe	936,772

- Tree cover

Tree cover was measured in the field in each plot of the cluster. A field team member collected tree cover data using a hand-held spherical densiometer. Four spherical densiometer measurements were taken directly outside the 7 m sub-plot at the four main compass directions (N, E, S, and W). A spherical densiometer contains 24 squares; the field team member first checked that the instrument was level using a built-in leveling-bubble; following this the field team member would count the number of squares which were mostly shaded (i.e. not receiving direct light) and share this number with the field team member responsible for entering data into the tablet. The process was repeated for each of the four locations after which a tree cover percentage was then calculated for the plot. This information was incorporated into a tree cover calculation workflow contained in the Open Foris Calc tool. Forest cover was then calculated based on the number of plots in the inventory which returned a cover percentage of greater than 30%. The information reported in section 4.1 is derived from these measurements with plots falling in the Priority Landscapes as well as the counties used to generate estimates at these spatial scales.

- Tree counts

Stems per hectare or tree counts are reported based on a count of the DBH measurements taken within each of the clusters' sub-plots. The cluster plots each contained three sub-plots where DBH measurements of trees were recorded. The total stems per plot were then used along with the size of the plot to calculate the number of trees per hectare at the plot level; this information was then calculated for the national, Priority Landscape and county levels using appropriate expansion factors. Equation 1 provides the area of the plot in hectares while equation 2 calculates the number of trees per hectare based on the total number of trees within the plot.

Equation 1.

$$A_i = \frac{\pi R_i^2}{10000}$$

Equation 2.

$$TC = \sum_i \frac{\sum_j I_{ij}}{A_i}$$

where:

i	=	Class of subplot, depending on tree DBH. i=1,..3
Iij	=	Indicator function of the number of trees j in subplot i. Iij=1 if the tree DBH is the one corresponding to subplot i and 0 otherwise.
Ai	=	Area of Plot (ha)
π	=	3.14159
R_i	=	Radius of subplot i. Ri=2,7, or 18 m
TC	=	Tree count / hectare

- Basal area

Basal area is calculated based on the diameter at breast height (DBH) which was measured at 1.3 m above the ground over bark using a DBH tape. In the present inventory, basal area is reported in square meters per hectare (m2/ha). The basal area estimation begins at the tree level and is then up scaled to the plot using a similar method to the tree count approach above. The basal area equation used in this inventory is as follows.

Equation 3.

$$BA = \pi \cdot \left(\frac{DBH}{2 \cdot 100}\right)^2$$

where:

BA	=	Tree Basal Area
π	=	3.14159
DBH	=	Tree DBH (centimeters)

The basal area per ha is obtained through dividing Eq. 3 by Eq. 1.

- Tree height (Total and Tree Bole height)

Tree heights reported in the inventory are based on both in-field measurements as well as tree height modeling and are reported in meters (m). During the inventory, only 1 out of 3 trees had their height measured. As such tree height for those trees with reliable values was used to model the height-diameter relationship (H/DBH). This model was used to estimate the height of trees that were not measured during the inventory. The data processing workflow made use of several standard models available, including a specific Weibull West Africa model (Feldpausch et al, 2012)[3]. However, automatic model selection determined a simple power model as the one with the lowest model error, $H = a\,DBH^b$ where a and b were model parameters that were fitted to the available data (see Réjou-Méchain et al, 2017). Bole height was also modelled based on those same trees selected for tree total height measurements. A ratio bole height:total height was modelled as $H_b / H = e^a (H - 1.3)^b$. The model was later used to predict bole height in the unmeasured trees. See Figure 13 below for a graphical representation of the model used for estimating bole height.

3 http://eprints.whiterose.ac.uk/75040/1/FeldpauschEtAl2012_Height_diameterAllometryAndBiomassTropics_Biogeosciences_final.pdf

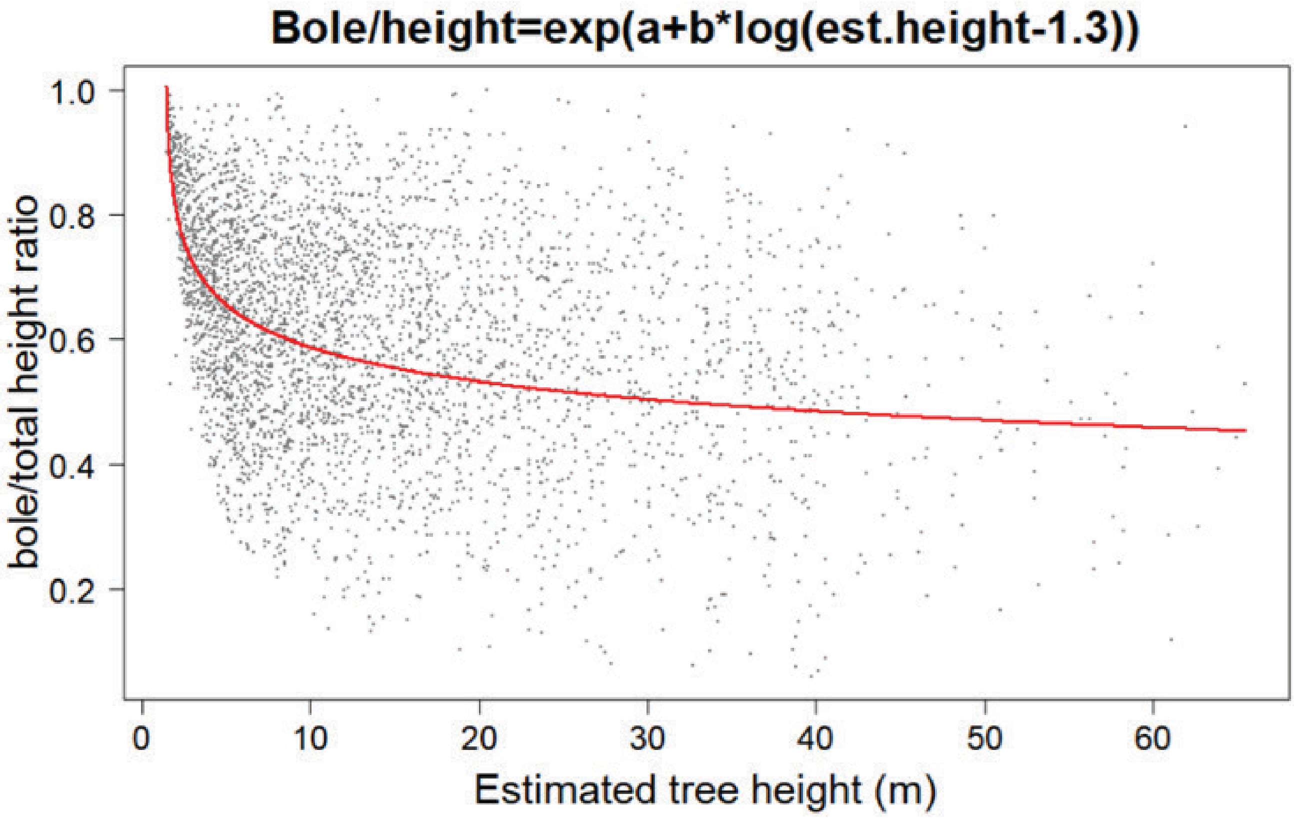

Figure 13. Bole to tree height ratio, modelled as a power function of height, where a,b <0. Observe that the equation above is an expanded version of that reported in the main text.

- Growing stock (tree volume)

Volume estimates reported in the inventory are based on per tree estimates of volume using above ground biomass and wood density measures and are reported as cubic-meters per hectare (m^3/ha). Per tree volume was calculated by dividing above ground tree biomass (see equation 5) by the wood density for the species of interest. Average per hectare estimates of tree volume were then calculated using appropriate expansion factors at the cluster level.

Equation 4.

$$Vol = \frac{AGB}{WD_i}$$

where:

Vol	=	Tree Volume (m^3)
AGB	=	Above Ground Biomass (tonnes)
WDi	=	Species-Specific Wood Density (g/cm^3)

Tree bole volume on the other hand made use of the tree basal area, estimated bole height as well as a species specific form factor provided by the Chave et al (2014) database.

Equation 5.

$$Bvol\ = tBA \times tBH\ \times FF$$

where:

Vol	=	Bole Volume
BA	=	Basal Area
BH	=	Bole Height
FF	=	Species specific form factor

- Biomass and Carbon

Above ground biomass was calculated using Chave et al (2014) pantropical models for tropical trees and reported using as tonnes per hectare (t/ha). The models were implemented using the BIOMASS[4] package available in R (Réjou-Méchain et al. 2017). The function takes as input the DBH of individual trees as well as their respective total height along with wood density. Wood density estimates were derived from a global wood density database (Chave et al. 2009, Zanne et al. 2009) and applied at the individual tree

4 https://cran.r-project.org/web/packages/BIOMASS/index.html

level using taxonomic data collected in the field. Given that heights for all trees had been calculated earlier it was possible to use the following Chave et al (2014) model.

Equation 6.

$$AGB = 0.0000673 \cdot (WD \cdot H \cdot DBH^2)^{0.976}$$

where:

AGB	=	Above Ground Biomass (tonnes)
H	=	Total Tree height (whether measured or estimated) (m)

Above ground biomass calculated at the tree level was then combined with below ground biomass estimates derived from Mokany et al (2006)[5]. The method suggested that species-specific Root: Shoot ratios were most appropriate for calculating below ground biomass of trees. The present analysis employed this approach using the following equation.

Equation 7.

$$BGB = V \cdot AGB$$

Where:

AGB	=	Above Ground Biomass
BGB	=	Below Ground Biomass
V	=	Vegetation-specific Root:Shoot ratio

Total tree biomass *B* was then calculated by combining the above and below ground estimates described in equations 4 and 5. The tree level estimates of biomass in tonnes were then converted to carbon content using the following equation:

Equation 8.

$$C_r = 0.49 \cdot B$$

Where:

C_r	=	Total Tree Carbon content
B	=	Total Tree biomass

Tree level estimates of both biomass and carbon were then scaled up to the plot level using expansion factors $\frac{1}{A_i}$ described above (see Equation 1). Additional estimates at various levels were facilitated based on the locations of plots and clusters.

- Dead wood (CWD & FWD)

Dead wood composed the sum of Coarse Woody Debris (CWD) and Fine Woody Debris (FWD) data taken from NFI transects. Tonnes per ha estimates were obtained using Marshall et al. (2000) and Waddell (2002) recommendations for Line Intersect Sampling[6]. For FWD, equation 3 of Waddell (2002) was modified to account for per hectare estimates of volume with the use of the FWD diameter measured at the intersection of the FWD with the transect line. Equation 9 below is a modified version of equation 3 in Waddell (2002) for the volume of a piece.

Equation 9.

$$FWDV_m = \left(\frac{\pi}{40000}\right) \times D^2 \times l$$

where:

$FWDV_m$	=	Volume of a FWD piece in meters cubed
π	=	Pi (3.14159)
D	=	Diameter of FWD intersecting with the line transect (centimeters)
l	=	length of FWD piece assumed to be 0.1m

Area estimates for the FWD volumes calculated above made use of equation 1 of Waddell (2002). The tw-end conic formula (Briggs, 1994) was used for the volume of CWD logs, which made use of CWD diameters measured at the start and the end of CWD log intersecting with the transect line (small end and large end).

Equation 10.

$$CWDV_m = \frac{\frac{\pi}{4} \times [(D_S^2 + D_L^2 + D_S \times D_L) \times l]}{3 \times 10000}$$

where:

$CWDV_m$	=	Volume of a CWD log in meters cubed
π	=	Pi (3.14159)
D_s	=	Diameter small end

5 https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1365-2486.2005.001043.x
6 https://naldc.nal.usda.gov/download/36292/PDF

D_l = Diameter large end
l = Length of the individual log

Biomass was obtained through multiplication of the individual piece volumes with the median of the wood density of the trees existing in the plot as well as a wood decay factor also taken from Waddell (2002). Table 5 provides the wood decay factors used for the biomass estimates.

Table 5. Wood decay factors for ead wood (FWD & CWD)

Decay Class	Wood Decay Factor
1	1
2	0.78
3	0.45
4	0.42

Carbon estimates were obtained using the same carbon fraction used for tree carbon estimation i.e. 0.49 (see Equation 8). Finally, the area (per hectare estimates) of dead wood were computed using the equation 1 in Waddell (2002).

Equation 11.

$$DW = \frac{\pi}{2L}\sum\frac{V_m}{l_i}$$

where

DW = Area estimates for dead wood (m^3/ha)
π = Pi (3.14159)
L = Length of the transect (CWD: 18m FWD: 5m)
V_m = Volume of the individual log
l_i = Length of the individual log

The forest inventory captured tree species information for all trees which had their DBH measured. This inventory information formed the basis of the biodiversity analysis. Field teams made use of Hawthorne & Gyakari (2006)[7] as the primary reference for species identification in the field. Biodiversity estimates reported for the present NFI make use of well-established metrics for ecological studies. A species diversity index, along with the Shannon and Simpson indices are used to report on the biodiversity captured by the NFI. Estimates of species diversity including abundance and a diversity estimate which focuses only on the dominant species are reported using Hill numbers as part of a rarefaction (interpolation) and extrapolation (prediction) process (R/E) (Chao & Jost, 2012)[8]. In the present report, species richness and diversity are reported at the Priority Landscape level as well as the county levels. Owing to differing sampling intensities in the various areas of interest, the reported diversity estimates are compared based on sample completeness rather than sample size (Chao et al, 2016).

- Regeneration

Regeneration estimates provided in this report were produced using similar methods to those employed for estimating stems per hectare (see above). While the stems per hectare estimates are based on the number of DBH measured trees per plot and sub-plot, regeneration is based on a count of saplings recorded in the smallest (two-meter) sub-plot within each plot. Equations 1 and 2 above were then used for estimating the number of saplings per hectare at the plot level.

- Non-Timber Forest Products (NTFPs)

Non-timber forest products were recorded by the field teams at the plot level. Guides employed from local communities typically provided field teams with information on the presence of NTFPs as well as their uses. Recorded NTFPs were then aggregated into the NTFP groups (Construction, Cosmetics, Food, Furniture, Household Goods, Medicinal, Oil Production, Rope, Spice, and Wine making). These groups and the uses of different species are enumerated in Annex II. Area estimates for each of these NTFP classes are reported at the national, and Priority Landscape levels including 90% confidence intervals.

- Other Forest Metrics

Other forest metrics reported include forest health, forest disturbance, litter, land use classification and finally land ownership. These metrics were all recorded at the plot level in every plot. Teams completed a plot description form prior to undertaking enumeration measurements. Results are presented as area estimates at the national scale and then also for the Priority Landscapes. Results including 90% confidence intervals were also calculated at the county level, however results were inconsistent with many variables not being present in the data.

7 https://www.nhbs.com/title?slug=photoguide-for-the-forest-trees-of-ghana-book
8 https://chao.shinyapps.io/iNEXTOnline/

3.5 Quality Control and Quality Assurance

3.5.1 Quality Control (QC)

Quality control (QC) was necessary to ensure that data weres collected in accordance with standard field protocols or operations procedures and was scientifically sound and reliable. The NFI Supervision team ensured this by undertaking training of the inventory field crews on the use of field protocols, proper use of field equipment and data recording. FAO provided continuous technical backstopping to the NFI crews to maintain the quality of data collection. The NFI Supervision Team undertook continuous crosschecking to ensure uniform and consistent interpretation and application of field instructions among the field crews.

The following measures facilitated quality control:

1. By ensuring reliable field measurements

2. All staff must have completed the Field Inventory training program prior to field data collection.

3. All field measurements were checked by a qualified person (the Field Team Leader) in cooperation with the field team to correct any errors in techniques.

4. Additional data support was provided by a dedicated data management support team in the field to ensure data were collected according to established protocols

In addition to the abovementioned measures, two types of field checks were undertaken: hot checks to correct errors in techniques and blind checks to estimate the field measurement error.

During 'hot checks', the QC team observed field team members during data collection on a number of field plots to verify measurement processes were followed. Hot checks permitted the correction of errors in techniques and were undertaken throughout the NFI field campaign and shortly after training was completed to ensure incorrect measurement techniques were not occurring. The NFI supervision team followed and observed measurement techniques of all team members. Errors detected or misunderstandings raised were explained and corrected.

3.5.2 Quality Assurance (QA)

In the present inventory, a blind audit was undertaken as part of the quality assurance process. The QA was a planned system of review procedures conducted by personnel not involved in the actual field inventory, which aimed to assess the replicability of the measurements. The QA campaign undertook resampling of five percent of plots at the cluster plot level (see Figure 14), which were randomly selected to be re-measured by independent teams from three universities in Liberia according to location (University of Liberia in the northwest, Cuttington University in the Central zone and Tubman University in the Southeast).

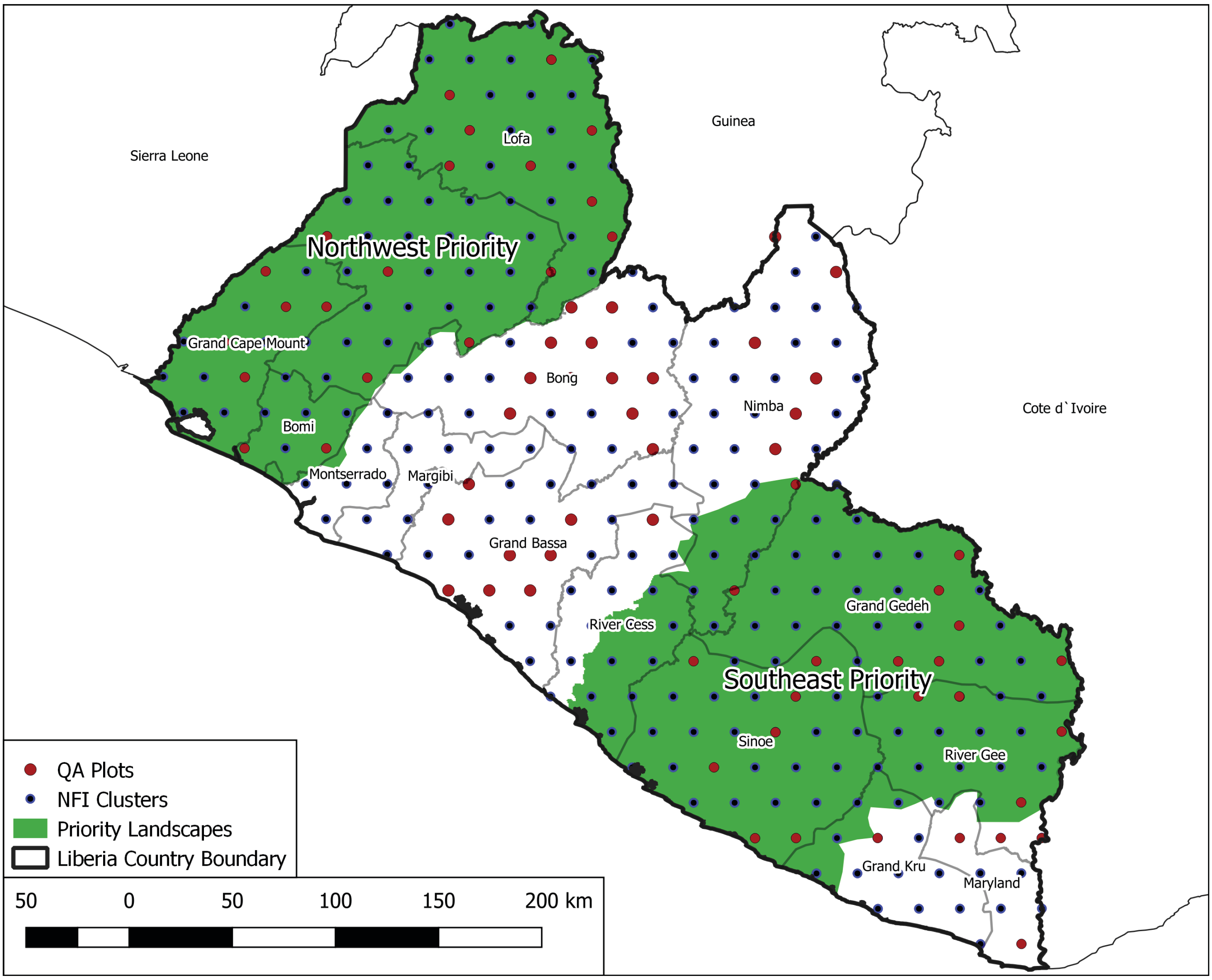

Figure 14. Quality assurance campaign - sampling frame

3.5.3 Quality Assurance (QA) Results

Quality assurance teams from the selected Universities enumerated 82 separate plots using the same tools and methods as used by the national forest inventory teams. Data cleaning and analysis methods and workflows replicated those of the national forest inventory. While QA inventories are typically undertaken during the main inventory activity as a means of assessing the quality of the inventory teams' outputs, the present assessment was undertaken following the completion of the inventory. As such, statistical comparisons between the two data sets are purely for reporting purposes and serve to reflect on the measurement errors present in the inventory data. Outputs from the QA work will inform the ongoing MRV activities in Liberia as well as other inventory activities making use of the national forest inventory methodology. The results can also help users of the data better understand the reliability of each attribute when making decisions based on the data.

QA data outputs were compared to the field inventory data using simple statistical measures which compared the overall means of key inventory metrics calculated for both the NFI and the QA inventory, focusing only on those plots enumerated in both. A total of 82 national inventory plots were enumerated by the QA teams. Table 6 provides a summary of the Welch two sample t-test comparing the mean values of each of the selected inventory metrics. The QA teams were led by university professors with many years' experience relative to the team leaders and tree finders who undertook the national inventory. As such their data is considered "correct" in the context of the QA analysis.

Table 6. Quality Assurance data t-test outputs (n = 82)

Inventory metrics	Mean NFI	Mean QA	p value
Regeneration	15.61	21.96	0.08
Mean canopy closure	48.87	54.57	0.29
Trees per hectare	2376.48	1936.29	0.19
Tree volume per hectare	261.29	307.64	0.44
Tree species count	5.72	4.45	0.07
Tree genus count	5.72	4.59	0.10
Plot level Shannon Index	0.95	0.81	0.18
Plot level Simpson Index	0.39	0.42	0.58

Results in Table 6 indicate that when comparing the NFI data collected by the field teams and the QA data collected by the University teams for all inventory variables of interest, there appear to be no significant difference between the respective means (all p-values > 0.01). Several of the variables do however return smaller p-values relative to the rest. Regeneration, tree species count and tree genus count return the lowest p-values indicating that the means for these variables differed although the difference was not statistically significant. Overall, the QA data, when compared to the NFI data indicates that the NFI was conducted with a high degree of accuracy.

4 Results

Table 7 provides an overview of the number of clusters accessible per county. The inventory was planned such that reliable inventory estimates could be produced with an 80% overall cluster completion rate. The current inventory returned an overall 90% cluster completion rate with two counties returning relatively low accessibility (River Gee and Sinoe); both do however fulfil the 80% cluster completion rate. Inaccessible clusters are mapped in Figure 15.

Table 7. Liberia NFI - Accessible Clusters

County	Planned	Actual	% Completed
Bomi	7	6	85.71
Bong	27	26	96.30
Gbarpolu	30	28	93.33
Grand Bassa	21	18	85.71
Grand Cape Mount	13	12	92.31
Grand Gedeh	28	24	85.71
Grand Kru	13	11	84.62
Lofa	27	26	96.30
Margibi	9	8	88.89
Maryland	6	6	100
Montserrado	6	6	100
Nimba	34	32	94.12
Rivercess	15	15	100
River Gee	19	16	84.21
Sinoe	28	23	82.14
Total	285	257	90.18

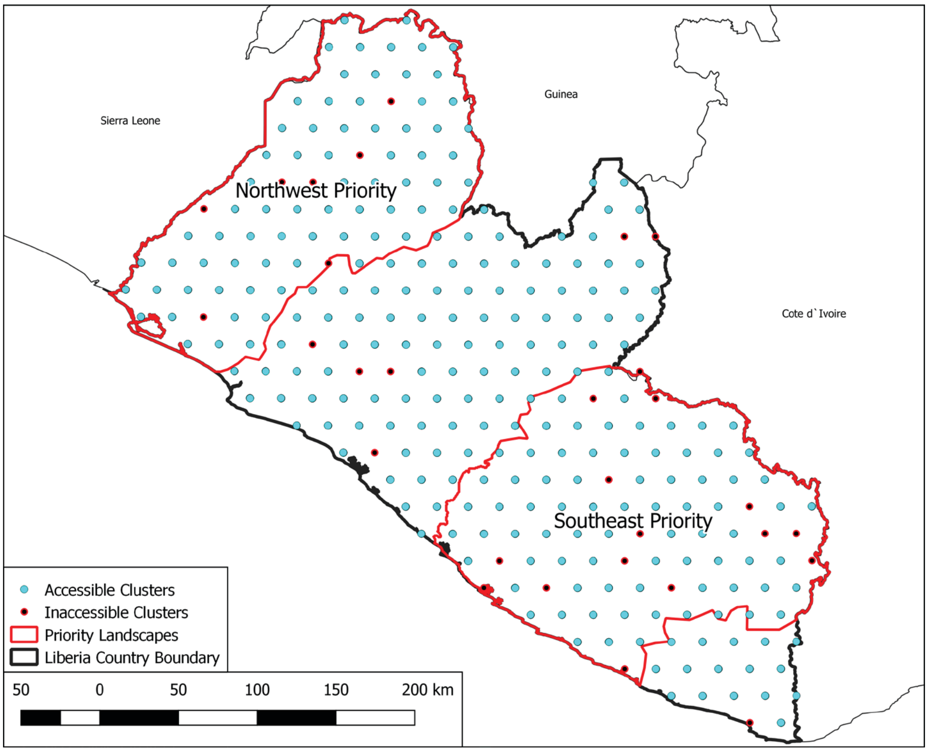

Figure 15. Liberia NFI - Cluster Accessibility

Table 8 provides information relating to the positional accuracy of the accessible clusters. All clusters were assigned geographic coordinates as part of the initial sampling framework establishment. Field teams made use of precision handheld GPS devices to navigate to these locations. The actual GPS location captured by the field teams was then compared to the planned location resulting in an in-field error estimate calculated by the digital survey used by the field teams. The average error per county is presented below with all counties except for Bomi and Gbarpolu returning mean errors of less than 10 meters.

Table 8. Positional accuracy of plot locations per county

County	Positional Accuracy (m)
Bomi	21.54
Bong	2.14
Gbarpolu	24.89
Grand Bassa	4.05
Grand Cape Mount	2.95
Grand Gedeh	3.22
Grand Kru	0.95
Lofa	5.03
Margibi	2.55
Maryland	6.60
Montserrado	3.55
Nimba	2.55
Rivercess	4.94
River Gee	0.77
Sinoe	3.51

4.1 Land Use

Field teams were asked to assign a land use class to each of the plots enumerated during the inventory. Nine classes were preselected and entered into the digital survey. Based on the nature of the plots land use, teams recorded the land use of each plot visited. This information was then used to derive area-based estimates of the land use classes. Table 9 contains the national area estimates of land use classes in Liberia with Forest (as per national definition of forest) returning the largest area followed by Cropland. The area of the forest land use class is slightly less when compared to the forest cover estimate reported below, the estimates are not too dissimilar however with their confidence intervals overlapping.

Table 9. Land use in Liberia

Land Use	Area (1 000 ha)	CI
Cropland	1,222	17%
Forest	6,605	5%
Grassland	182	40%
Other land	220	34%
Settlement	105	48%
Shrubland/Woodland	756	21%
Water	8,7	77%
Wetland	490	23%

Table 10 contains the land use area estimates disaggregated to the priority and Non-Priority Landscape level. The Southeast Priority Landscape contains the highest forest cover with over two and a half million hectares of forest present, the Non-Priority Landscape contains the second highest followed by the Northwest landscape. The Non-Priority Landscape contains the largest extent of cropland followed by the Northwest and then the Southeast. These area estimates are to be expected, as the Non-Priority Landscape is known as the agro-industrial zone where land use practices target commercial agriculture including tree crops. The Non-Priority Landscape also returned the largest wetland area followed by the Northwest and Southeast landscapes. This is of particular interest as Liberia will need to pay special attention to the conservation of these wetland areas especially within the Non-Priority Landscape where economic development is currently favored over conservation.

Table 10. Land use in Priority Landscapes

Priority Landscapes	Land use	Area (1 000 ha)	CI
Non Priority	Cropland	922	21%
	Forest	1,936	12%
	Grassland	67	62%
	Other land	176	41%
	Settlement	97	57%
	Shrubland/Woodland	519	28%
	Water	9	81%
	Wetland	278	34%
Northwest Priority	Cropland	292	37%
	Forest	1,783	11%
	Grassland	112	55%
	Other land	52	70%
	Settlement	14	68%
	Shrubland/Woodland	209	43%
	Water	0	0
	Wetland	194	39%
Southeast Priority	Cropland	97	56%
	Forest	2,667	4%
	Grassland	15	80%
	Other land	7	81%
	Settlement	0	0
	Shrubland/Woodland	82	57%
	Water	0	0
	Wetland	52	70%

4.2 Forest cover

In 2018, Liberia established for the first time a definition of forest, which was developed and validated by the Forestry Development Authority as an area of land that:

- Has a canopy cover of minimum 30%;
- Contains trees with a minimum of 5 m height or the capacity to reach it;
- Covers a minimum of 1 hectare of land.

This includes shifting cultivation in its fallow phase (as far as the threshold values are met). This does not include land with predominant agricultural use (including tree crops such as oil palm and rubber). These land uses were identified in-situ during the field inventory.

Consistent with the forest definition, plots where the canopy cover measured at the level of the subplot was greater than or equal to thirty percent meant that these plots were classified as forest. Based on this then the forest cover calculated for Liberia is presented in Table 11 along with the percent confidence interval.

Table 11. Forest and non-forest cover of Liberia

	Area (1 000 ha)	Perc Area	CI
Forest	6,605	69%	5%
Non Forest	2,986	31%	12%
Total Area	9,591		

The above table shows that Liberia forest i.e. land with tree canopy cover of greater than or equal to 30 percent covers 6.605 million hectares which is approximately 69 percent of Liberia's total land surface. This value differs from previous estimates of forest cover[1] as this is the first time forest cover has been estimated in Liberia using the new forest definition; it is also to-date the most comprehensive assessment of forest cover in Liberia.

4.2.1 Forest cover estimates by different categories

Liberia's NFI estimates forest cover for different categories/strata (Table 12) consistent with the national forest definition and by landscapes and counties. These areas are chosen as they facilitate effective forest management at both regional and county levels. Table 12 and Table 13 present the forest cover by Priority Landscape and county with each table presenting both Non-Forest (<30 % canopy cover) and Forest (≥ 30% canopy cover). Table 12 presents forest cover estimates for both priority and Non-PriorityLandscapes. As expected, the Southeast Priority Landscape returns the largest forest cover estimate and an associated small confidence interval. An interesting result is that the Non-Priority Landscape has marginally more forest cover when compared to the Northwest Priority Landscape.

Table 12. Forest cover Priority Landscapes

Landscape		Area (1 000 ha)	CI
Non Priority	Forest	2,115	11%
	Non Forest	1,894	12%
Northwest Priority	Forest	1,929	8%
	Non Forest	730	22%
Southeast Priority	Forest	2,560	5%
	Non Forest	361	33%

Table 13 provides forest cover estimate at the county scale, with Sinoe having the highest percentage of forest cover in Liberia follow by Grand Gedeh and Gbarpolu counties respectively. Interestingly, Montserrado, using the national definition of forest cover, does not contain any forest cover. The lack of forests in Montserrado is a concern as it is well known that the county contains relatively large mangrove forests which this inventory has omitted. The omission of mangrove forests is not desirable rather it is function of the sampling framework designed to facilitate national and sub-national estimates of forest resources. The Forestry Development Authority should endeavor to undertake a mangrove specific inventory in the future.

Table 13. Forest cover – Counties

County		Area (1000 ha)	CI
Bomi	Forest	133	25%
	Non Forest	77	43%

1 https://eros.usgs.gov/westafrica/land-cover/land-use-land-cover-and-trends-liberia

County		Area (1000 ha)	CI
Bong	Forest	397	20%
	Non Forest	440	18%
Gbarpolu	Forest	794	7%
	Non Forest	130	44%
Grand Bassa	Forest	423	19%
	Non Forest	324	25%
Grand Cape Mount	Forest	333	19%
	Non Forest	160	40%
Grand Gedeh	Forest	807	10%
	Non Forest	218	38%
Grand Kru	Forest	302	10%
	Non Forest	66	47%
Lofa	Forest	646	15%
	Non Forest	378	25%
Margibi	Forest	56	59%
	Non Forest	224	15%
Maryland	Forest	116	34%
	Non Forest	102	38%
Montserrado	Forest	0	0%
	Non Forest	180	0%
Nimba	Forest	695	17%
	Non Forest	494	24%
River Gee	Forest	569	6%
	Non Forest	50	68%
Rivercess	Forest	424	10%
	Non Forest	104	41%
Sinoe	Forest	891	3%
	Non Forest	44	54%

Table 14 provides estimates of the global FAO Forest Resources Assessment classes, the values reported in this table differ from those presented in Table 11 as the FRA's class definition is not consistent with Liberia's forest definition. In particular, the Liberian definition of forest includes forest fallow landuse as forest, where shifting agriculture has been left fallow for a period and the area now fulfills the requirements for being classified as forest. The forest fallow class would not be captured in the FRA definition of forests and therefore the estimates are expected to be different. In the present report, forest cover using the Liberian forest definition is significantly higher (> 100,000 ha) compared to the FRA definition even though the FRA definition has a lower canopy cover threshold for defining forest (10% (FRA) vs. 30% (Liberia)). The FRA estimates are included in this report for international reporting purposes.These values differ from past FRA based estimates[2].

Table 14. FRA classes Liberia

FRA Class	Area (1000 ha)	CI
Forest	6,570	5%
Other Wooded Land	1,406	15%

2 http://www.fao.org/3/a-az259e.pdf

FRA Class	Area (1000 ha)	CI
Other Land	1,614	17%

4.3 Tree count

Tree count provides the number of trees per unit area (hectare), which is an important measure of stand density of a given area and can be used to track the effectiveness of forest management. In the present inventory, tree counts per plot were calculated based upon the DBH measurements captured within each sub-plot. Table 15 reports that Liberia has approximately 18 billion trees within the areas classified as forests and approximately 3 billion trees outside of forests. Average stems per hectare reported for Liberia are higher when compared to regional studies (Lewis et al 2013) although the Liberian NFI included smaller DBH trees and would therefore return higher per hectare estimates. Lower cutoff values were used in order to have more relevant estimates of tree distribution and biomass for the youngest classes. These distributions are fundamental for sustainable forest management planning.

Table 15. Tree count (forest and non-forest)

Description	Tree count (/ha)	CI
Forest	2,856	7%
Non Forest	1,069	19%
Total Tree Count (1 000 000)		
Forest	18,267	9%
Non Forest	3,137	22%

4.3.1 Tree count by Priority Landscapes & counties

Average tree count was estimated for each Priority Landscape and county across the Country. Table 16 presents tree count per hectare per Priority Landscape. Priority Landscapes return marginally higher estimates when compared to the Non Priority Landscape.

Table 16. Tree count per hectare - Priority Landscapes

Priority Landscape	Tree count (/ha)	CI
Non Priority	2009	11%
Northwest Priority	2620	12%
Southeast Priority	2368	11%

Tree count per hectare across the country is generally greater than 2000 trees per hectare save for Margibi, Maryland and Montserrado counties, all of which return less than 2000 trees per hectare (Table 17). The low relative tree count in these areas is the result of persistent human intervention through cultivation of cash crops, such as rubber, oil palm and other crops coupled with higher human population density. Conversely, Gbarpolu, Grand Kru and Grand Cape Mount have much higher tree count per hectare, as these counties have less agricultural activities and infrastructural development.

Table 17. Tree count per hectare – Counties

Counties	Tree count (/ha)	CI
Bomi	2,367	27%
Bong	2,139	18%
Gbarpolu	2,842	20%
Grand Bassa	2,155	22%

Counties	Tree count (/ha)	CI
Grand Cape Mount	2,751	22%
Grand Gedeh	2,307	19%
Grand Kru	2,794	22%
Lofa	2,384	19%
Margibi	1,393	37%
Maryland	1,629	32%
Montserrado	1,743	37%
Nimba	2,055	21%
River Gee	2,439	20%
Rivercess	2,071	24%
Sinoe	2,200	13%

4.3.2 Tree count by diameter classes

Tree count is reported using DBH classes that are actively used by the Forestry Development Authority for management purposes especially implementing diameter cut limits in commercial forestry concessions. Eleven (11) classes were selected for reporting purposes and included the following; less than 10 cm, 10-19.99 cm, 20-29.99 cm, 30-39.99 cm, 40-49.99 cm, 50-59.99 cm, 60-69.99cm, 70-79.99cm, 80-89.99 cm, 90-99.99 and greater than 100 cm.

Table 18 provides estimates of total trees per hectare by different diameter classes for Priority Landscapes. The distributions of tree counts per DBH class reflects the expected characteristics of Upper Guinean natural forest. Tree counts are higher in the Priority Landscapes with the majority of the trees per hectare found in classes with a DBH of less than 40 cm. This structural characteristic is a result of the strict diameter cut limits imposed by the FDA on forestry operations in Liberia. A code of harvesting practices has been in place for some time with operators required to adhere to minimum cut limits at the species level. The overall reverse J-shaped distribution is typical of any unevenly aged forest with less than 2% of the total trees per hectare located in diameter classes above 40 cm.

Table 18. Tree count per hectare - Priority Landscape and DBH Class

Priority Landscape	DBH class (cm)	Tree count (/ha)	CI
Non Priority	< 10	1,702.71	12%
	10-19	178.55	11%
	20-29	72.59	17%
	30-39	32.45	19%
	40-49	8.00	15%
	50-59	4.71	18%
	60-69	3.96	20%
	70-79	2.33	21%
	80-89	1.08	23%
	90-99	0.85	25%
	>= 100	1.50	36%

Priority Landscape	DBH class (cm)	Tree count (/ha)	CI
Northwest Priority	< 10	2,192.79	13%
	10-19	248.21	15%
	20-29	94.81	20%
	30-39	44.18	25%
	40-49	12.83	17%
	50-59	9.48	20%
	60-69	5.82	19%
	70-79	3.11	21%
	80-89	3.07	35%
	90-99	1.52	29%
	>= 100	4.56	34%
Southeast Priority	< 10	1,907.17	12%
	10-19	249.57	10%
	20-29	107.88	15%
	30-39	52.01	21%
	40-49	13.77	12%
	50-59	10.39	14%
	60-69	7.38	17%
	70-79	4.72	19%
	80-89	3.62	23%
	90-99	1.96	24%
	>= 100	9.89	31%

4.3.3 Tree count by tree genus by county

Table 19 provides information on the top five genera per county in terms of tree count. Genus level tree count is useful to understand which genera are dominating the landscape and how these genera vary across the country. This information is useful for management planning. For example, in Gbarpolu County the genus *Theobroma* is the most abundant genus per hectare with on average 251 examples present per hectare. Theobroma cacao is the best-known species used for making chocolate and therefore it may be that Gbarpolu County has the potential for agroforestry focusing on the production of cacao beans. Further in Grand Gedeh, genus Diospyros is the most prevalent on a per hectare basis with over 177 found per hectare on average. Species of the *Diospyros* are valued for their hard, heavy dark timber while others are known for their fruit. Finally, Sinoe County contains Liberia's largest protected area Sapo National park. Results from the National Forest Inventory indicate that on a per hectare basis *Diospyros* is once again the most prevalent genus within the county followed by *Drypetes* which is known to contain mustard oils and may be a useful non-timber forest product. Additional analysis and interpretation will be required at the county level to best understand how these results will be used to manage forest resources in a sustainable manner.

Table 19. Tree count per ha of forest by tree genus by county

County	Genus	Tree count (/ha)	CI
Bomi	*Anthonotha*	393	36%
	Samanea	248	57%
	Anthocleista	169	54%
	Napoleonaea	140	60%
	Margaritaria	111	60%

County	Genus	Tree count (/ha)	CI
Bong	*Anthonotha*	143	33%
	Macaranga	135	41%
	Harungana	120	36%
	Myrianthus	92	41%
	Alchornea	90	51%
Gbarpolu	*Theobroma*	252	62%
	Diospyros	175	26%
	Anthonotha	138	34%
	Carapa	133	29%
	Homalium	120	48%
Grand Bassa	*Anthonotha*	216	40%
	Macaranga	168	42%
	Myrianthus	136	49%
	Baphia	126	62%
	Uapaca	82	50%
Grand Cape Mount	*Harungana*	296	58%
	Anthonotha	221	46%
	Cola	178	57%
	Funtumia	168	41%
	Alchornea	166	45%
Grand Gedeh	*Diospyros*	177	33%
	Microdesmis	106	48%
	Carapa	85	36%
	Calpocalyx	79	43%
	Strombosia	78	39%
Grand Kru	*Diospyros*	235	41%
	Harungana	213	60%
	Macaranga	170	50%
	Anthonotha	131	45%
	Musanga	119	59%
Lofa	*Myrianthus*	212	43%
	Mareya	122	31%
	Macaranga	92	43%
	Carapa	90	35%
	Anthonotha	86	40%
Margibi	*Hevea*	278	41%
	Funtumia	233	59%
	Voacanga	123	55%
	Drypetes	97	60%
	Macaranga	72	42%

County	Genus	Tree count (/ha)	CI
Maryland	*Diospyros*	170	50%
	Uapaca	94	38%
	Xylopia	92	39%
	Unknown	85	59%
	Synsepalum	80	60%
Montserrado	*Anthocleista*	282	52%
	Rauvolfia	220	55%
	Mareya	197	59%
	Anthonotha	154	46%
	Xylopia	109	49%
Nimba	*Myrianthus*	243	37%
	Macaranga	158	41%
	Carapa	122	59%
	Anthonotha	97	40%
	Harungana	95	47%
River Gee	*Macaranga*	250	42%
	Xylopia	244	40%
	Myrianthus	159	53%
	Harungana	132	48%
	Microdesmis	112	41%
Rivercess	*Tetraberlinia*	160	41%
	Diospyros	86	37%
	Cola	83	47%
	Macaranga	81	38%
	Anthonotha	75	52%
Sinoe	*Diospyros*	159	33%
	Drypetes	130	39%
	Garcinia	91	36%
	Carapa	83	36%
	Anthonotha	82	39%

4.4 Basal area

Basal area or stand basal area is the tree cross-sectional area at breast height summed over all the trees in a stand and expressed per unit ground area (Bettinger et al, 2017). It indicates the extent of area covered by tree stems and is an easily measurable attribute for assessing stock density. The basal area of a tree is reported to be positively correlated to its crown cover. It therefore serves as an important measurement for understanding the competition among trees growing in an area.

Basal area is used to determine more than just forest stock density; it is also linked with timber stand volume and growth. Therefore, it is often the basis for making important forest management decisions such as estimating forest regeneration needs and wildlife habitat requirements.

Table 20 provides the basal area per hectare in Liberia which is very similar to results found in central and West Africa (Lewis et al 2013). The basal area reported below incorporates data from both the priority and Non-PriorityLandscapes.

Table 20. Basal area per hectare – Liberia

	BA (m^2/ ha)	CI
Liberia	32.43	13.1%

4.4.1 Basal area by Priority Landscapes & counties

Basal area estimates for the priority and Non-Priority Landscapes are presented in Table 21. Results reflect the primary land use within each area. The Non-Priority Landscape returns the lowest basal area per hectare compared to the two Priority Landscapes with the Southeast Priority Landscape returning the highest value of over 47 m2/ha. It is well known that the Priority Landscapes contain the majority of the primary Upper Guinea Forest in Liberia and thus are expected to return higher stand density forest metrics when compared to the Non-PriorityLandscape. The low value recorded in the Non-Priority Landscape explains why the overall basal area for Libe ria is so much lower compared to the Northwest and Southeast Priority Landscapes (Table 20).

Table 21. Basal area per hectare - Priority Landscapes

Priority Landscape	BA (m^2/ ha)	CI
Non Priority	20.54	13%
Northwest Priority	34.28	22%
Southeast Priority	47.10	20%

Table 22 provides a breakdown of the basal area results per county; Rivercess returns the highest basal area followed by Gbarpolu and Grand Gedeh. These three counties are the least affected by ongoing agricultural and agro-industrial expansion seen elsewhere in the country. Margibi, Bong, Bomi and Nimba all return basal area estimates well below 20 m2 per hectare indicating forests that have been heavily impacted by human activities.

Table 22. Basal area per forest hectare – Counties

County	BA (m^2/ha)	CI
Bomi	11.69	38%
Bong	11.39	22%
Gbarpolu	56.67	29%
Grand Bassa	30.71	24%
Grand Cape Mount	18.46	25%
Grand Gedeh	49.58	29%
Grand Kru	25.88	22%
Lofa	23.53	18%
Margibi	9.72	27%
Maryland	21.88	30%
Montserrado	41.82	28%
Nimba	16.09	15%
River Gee	26.93	14%
Rivercess	70.76	34%

County	BA (m^2/ha)	CI
Sinoe	33.38	23%

4.4.2 Basal area by diameter classes

As indicated previously in section 4.3.2, the Forestry Development Authority has established for the NFI, eleven DBH classes based on the Liberian Code of Forest Harvesting Practices of 2017. The basal area per hectare per DBH class by Priority Landscapes is provided in Table 23 below. This disaggregation is important for forest timber stand volume and growth, which is important for forest management decision making. As seen in the stems per hectare results, there appears to be a drop in values for basal area above the 30-39cm DBH class across the Priority Landscapes. Interestingly the Southeast Priority landscape returns an unusually large basal area for trees above 100cm in diameter (16.71 m^2).

Table 23. Basal area per hectare per DBH class - Priority Landscapes

Priority Landscape	Tree - DBH class (cm)	BA (m^2/ha)	CI
Non Priority	< 10	3.49	11%
	10-19	2.85	11%
	20-29	3.41	17%
	30-39	2.99	19%
	40-49	1.24	15%
	50-59	1.08	18%
	60-69	1.29	21%
	70-79	1.01	21%
	80-89	0.61	23%
	90-99	0.59	24%
	>= 100	2.00	38%
Northwest Priority	< 10	4.49	14%
	10-19	4.04	15%
	20-29	4.39	21%
	30-39	4.12	25%
	40-49	1.98	17%
	50-59	2.21	21%
	60-69	1.85	19%
	70-79	1.33	21%
	80-89	1.71	36%
	90-99	1.07	29%
	>= 100	7.11	39%

Priority Landscape	Tree - DBH class (cm)	BA (m^2/ha)	CI
Southeast Priority	< 10	4.61	13%
	10-19	4.01	10%
	20-29	4.78	14%
	30-39	4.90	21%
	40-49	2.12	12%
	50-59	2.37	14%
	60-69	2.35	17%
	70-79	2.02	19%
	80-89	1.95	23%
	90-99	1.32	24%
	>= 100	16.67	32%

4.4.3 Basal area by tree genus by county

Table 24 provides basal area estimates for the top five tree genera for each of Liberia's counties. Basal area estimates for the top five genera in each county provide useful information relating to the genus and species dominating the stand densities. The highest basal area per genus was recorded in Montserrado where Hevea returns a county level basal area of 11.2 m^2/ha. This value is unusually high but is understandable given that Montserrado hosts the largest rubber plantation in the world and that the Liberian national forest inventory captured both rubber and palm species as part of the inventory. While rubber and palm species are not included in the definition of forest, the present report includes trees from both forest and non-forest areas. In Rivercess county, Tetraberlinia returns the highest basal area reporting 8.02 m^2/ha. Species of Tetraberlinia are harvested locally for its wood which is used for construction and furniture making. Other genera of interest include Parinari which returns a basal area of 5.69 m^2/ha in Gbarpolu county and Sacoglottis which returns the highest genus basal area in Sinoe county (2.54 m^2/ha). The genus has many uses including food, medicines, and household products.

Table 24. Basal area per ha per tree genus per county

County	Genus	BA (m^2/ha)	CI
Bomi	*Anthonotha*	1.24	38%
	Anthocleista	0.99	44%
	Gilbertiodendron	0.81	60%
	Diospyros	0.61	49%
	Xylopia	0.60	50%
Bong	*Musanga*	0.53	36%
	Elaeis	0.52	42%
	Macaranga	0.45	35%
	Funtumia	0.35	47%
	Albizia	0.34	41%
Gbarpolu	*Parinari*	5.69	50%
	Piptadeniastrum	2.79	36%
	Anthonotha	2.28	40%
	Theobroma	2.18	62%
	Diospyros	2.16	34%

County	Genus	BA (m²/ha)	CI
Grand Bassa	*Anthonotha*	3.17	41%
	Uapaca	2.48	49%
	Anthocleista	1.57	39%
	Funtumia	1.39	42%
	Xylopia	1.02	48%
Grand Cape Mount	*Anthocleista*	1.10	40%
	Sacoglottis	0.96	56%
	Tarrietia	0.93	51%
	Calpocalyx	0.92	48%
	Xylopia	0.82	42%
Grand Gedeh	*Gilbertiodendron*	3.72	49%
	Diospyros	3.08	39%
	Dialium	2.03	35%
	Calpocalyx	1.67	40%
	Piptadeniastrum	1.58	34%
Grand Kru	*Coula*	1.38	49%
	Piptadeniastrum	1.22	52%
	Diospyros	1.18	45%
	Uapaca	1.09	45%
	Macaranga	1.00	49%
Lofa	*Piptadeniastrum*	2.04	33%
	Albizia	1.16	36%
	Funtumia	0.90	33%
	Carapa	0.85	36%
	Sterculia	0.80	56%
Margibi	*Hevea*	4.94	42%
	Funtumia	1.15	50%
	Albizia	0.41	43%
	Ceiba	0.22	56%
	Voacanga	0.20	59%
Maryland	*Cynometra*	1.11	49%
	Uapaca	1.05	47%
	Parkia	0.82	43%
	Hevea	0.80	60%
	Xylopia	0.73	30%
Montserrado	*Hevea*	11.22	59%
	Anthocleista	5.69	46%
	Anthonotha	4.16	45%
	Maranthes	2.33	49%
	Rauvolfia	2.01	44%

County	Genus	BA (m^2/ha)	CI
Nimba	*Hevea*	1.39	42%
	Albizia	1.01	37%
	Terminalia	0.67	32%
	Macaranga	0.62	39%
	Piptadeniastrum	0.60	42%
River Gee	*Uapaca*	2.10	43%
	Musanga	1.43	50%
	Klainedoxa	1.11	46%
	Sacoglottis	1.03	47%
	Funtumia	1.03	61%
Rivercess	*Tetraberlinia*	8.01	45%
	Gilbertiodendron	4.82	45%
	Tarrietia	3.56	45%
	Cola	2.91	46%
	Lophira	2.79	51%
Sinoe	*Sacoglottis*	2.58	33%
	Calpocalyx	1.98	49%
	Diospyros	1.66	43%
	Loesenera	1.16	38%
	Lophira	1.04	38%

4.5 Growing stock

Liberia has significant forest resources available for both conservation and commercial use. Growing stock which is reported here in meters cubed for both tree and tree bole are important management variables used to determine the sustainability of harvesting and management practices guided by the Liberian Code of Forest Harvesting Practices of 2017. In addition, repeated volumetric measurements provide insight into the mean annual increment of species and or landscapes, providing data required for informed decision making. Table 25 provides the average per hectare estimates of both tree and tree bole volume across the Liberian landscape. National scale estimates reported in Table 25 are significantly higher than previously reported figures (158 m^3/ha)[3] which were derived from sub regional studies. It should be highlighted here that the difference between the previous FRA estimates reported in 2010 were based on an outdated definition of growing stock which is closer to the definition of bole volume than total tree volume. Two explanations can be given for the differences in volume estimates; firstly the present NFI included trees with a DBH of less than 10cm while the the 1989 study used for the FRA reporting measured trees above 20 cm DBH (Atlanta Consult, 1989). Secondly, the 1989 inventory made use of a different methodology that used an upper diameter for the bole calculation that differed from the one employed in this inventory. Further, it may also be the case that the 1989 inventory favoured plots that were close to roads and easily accessible thereby omitting the larger trees captured by the more comprehensive inventory undertaken in 2018 and 2019.

Table 25. Tree and Bole Volume per ha - Liberia

	Vol (m^3/ha)	CI	Bole Vol (m^3/ha)	CI
Liberia	386.61	15%	235.27	15%

3 http://www.fao.org/3/al551E/al551E.pdf

4.5.1 Tree and bole volume by Priority Landscapes & counties

Table 26 provides both tree and tree bole volume estimates for the Priority Landscapes in Liberia. The Southeast Priority Landscape returns the highest estimates of both metrics followed by the Northwest. The Non-Priority Landscape returns significantly smaller estimates which reflects the current nature of agricultural investment in Liberia and its impact on forest cover especially in the agro-industrial zone. This value also provides insight into what Liberia's forest resources are likely to look like if forest loss and agricultural expansion are not managed correctly.

Table 26. Tree and Bole Volume per ha - Priority Landscapes

Priority Landscapes	Vol (m^3/ha)	Vol CI	Bole Vol (m^3/ha)	Bole Vol CI
Non Priority	217.64	15%	130.65	15%
Northwest Priority	405.40	24%	245.60	24%
Southeast Priority	601.74	22%	369.65	23%

4.5.2 Tree and bole volume by county

Table 27 provides both tree volume and bole volume per hectare for each of Liberia's counties. Rivercess, Gbarpolu and Grand Gedeh return the highest overall per hectare volumes well over 500 m^3/ha. Gbarpolu is located within the Northwest while Rivercess and Grand Gedeh are in the Southeast Priority Landscape. Overall, the volume and bole volume per hectare estimates follow the trends associated with land use in Liberia.

Table 27. Tree and bole volume – Counties

Counties	Vol (m^3/ha)	Vol CI	Bole Vol (m^3/ha)	Bole Vol CI
Bomi	84.22	43%	51.66	44%
Bong	113.45	28%	67.86	29%
Gbarpolu	689.69	30%	420.13	31%
Grand Bassa	306.66	29%	189.23	29%
Grand Cape Mount	193.15	32%	108.62	32%
Grand Gedeh	632.20	31%	390.08	32%
Grand Kru	350.26	27%	194.01	29%
Lofa	282.16	21%	172.36	21%
Margibi	77.80	29%	49.13	28%
Maryland	275.48	33%	173.61	33%
Montserrado	342.76	29%	216.85	29%
Nimba	180.82	19%	109.21	18%
River Gee	354.81	16%	208.29	16%
Rivercess	899.69	37%	561.40	38%
Sinoe	399.92	25%	238.73	25%

4.5.3 Tree and bole volume by diameter classes

Tree and bole volume per hectare per diameter class are presented in Table 28. The results are grouped by the Priority Landscapes for ease of reporting. The distribution of volume by diameter class provides useful information for forest management planning. The results indicate that there is a fairly uniform distribution of volume save for the class greater than 100cm DBH where significantly higher volumes are recorded in the southeast when compared to the northwest Priority Landscape. Once again, forest management activities making use of diameter cut limits result in lower volumes in classes above 30-39 cm with the exception of trees with a DBH larger than 100 cm. This is however expected as this class will contain the large to very large trees, which are not always selected for felling.

Table 28. Tree and bole volume per ha by DBH Classes – Liberia and the Priority Landscapes

Priority Landscapes	Tree - DBH class (cm)	Vol (m^3/ha)	Vol CI	Bole Vol (m^3/ha)	Bole Vol CI
Liberia	< 10	21.09	8%	12.56	8%
	10-19	27.00	7%	16.42	8%
	20-29	36.59	10%	22.15	10%
	30-39	41.17	14%	25.06	14%
	40-49	21.62	10%	12.90	10%
	50-59	22.84	11%	13.84	11%
	60-69	24.65	12%	14.74	12%
	70-79	21.12	13%	12.53	13%
	80-89	18.90	18%	11.89	18%
	90-99	15.31	17%	9.14	17%
	>= 100	136.30	26%	84.04	26%
Non Priority	< 10	17.77	13%	10.32	13%
	10-19	21.37	11%	12.92	11%
	20-29	30.43	16%	18.74	16%
	30-39	31.57	19%	19.14	20%
	40-49	15.09	15%	9.18	16%
	50-59	13.85	18%	8.50	19%
	60-69	17.45	21%	10.32	20%
	70-79	15.94	23%	9.21	23%
	80-89	9.41	24%	5.50	23%
	90-99	9.73	25%	5.73	26%
	>= 100	35.04	36%	21.10	37%
Northwest Priority	< 10	24.64	14%	14.88	15%
	10-19	31.73	15%	19.31	15%
	20-29	41.05	18%	24.10	18%
	30-39	46.13	25%	27.95	25%
	40-49	26.18	17%	15.29	17%
	50-59	28.52	19%	16.83	20%
	60-69	26.93	19%	16.11	20%
	70-79	20.98	21%	12.50	21%
	80-89	22.12	32%	14.27	33%
	90-99	17.48	28%	10.72	28%
	>= 100	119.65	39%	73.65	40%

Priority Landscapes	Tree - DBH class (cm)	Vol (m^3/ha)	Vol CI	Bole Vol (m^3/ha)	Bole Vol CI
Southeast Priority	< 10	22.46	13%	13.56	12%
	10-19	30.51	10%	18.64	10%
	20-29	41.07	13%	25.10	13%
	30-39	49.93	21%	30.59	21%
	40-49	26.50	13%	15.88	14%
	50-59	30.11	14%	18.49	14%
	60-69	32.49	16%	19.57	17%
	70-79	28.37	18%	17.10	19%
	80-89	29.06	21%	18.55	22%
	90-99	21.03	25%	12.42	25%
	>= 100	290.21	31%	179.76	32%

4.5.4 Tree and bole volume by tree genus and county

Table 29 provides volume and bole volume estimates for the top five genera for each county as well as the associated percent confidence interval. In general, per region the top five genera by volume and the top five genera by bole volume are often the same, however there are exceptions. The information in Table 29 as well as the data contained in the database are especially useful for commercial forestry. In Gbarpolu, *Parinari* is once again the genus with the highest per hectare volume and bole volume estimates while *Sacoglottis*, *Tetraberlinia*, and *Uapaca* dominate in Sinoe, Rivercess and Grand Gedeh respectively. Uapaca is not usually seen as a commercial timber species but is used mostly for local construction, charcoal production or as fuel wood. Other genera of interest in Table 29 include *Piptadeniastrum* which is prominent in Gbarpolu and Grand Kru and is a highly sought-after timber species exported to Europe and other destinations. The genus *Gilbertiodendron* is prominent in Bomi, Grand Gedeh, and Rivercess; the timber is used for making dugout canoes, furniture, carpentry tools and is also a source of raw material for charcoal production. Finally *Calpocalyx* is prominent in Grand Cape Mount, Grand Gedeh, and Sinoe, and while not as sought-after as an export tree *Calpocalyx* is widely used for medicinal purposes, the seeds are edible after cooking and burnt seed pods are rich in potash and used as a salt alternative.

Table 29. Tree and bole volume per ha by tree genus and county

County	Genus	Vol (m^3/ha)	CI	Genus	Bole Vol (m^3/ha)	Bole Vol CI
Liberia	*Piptadeniastrum*	19.38	23%	*Piptadeniastrum*	11.08	21%
	Parinari	14.42	40%	*Parinari*	9.10	40%
	Gilbertiodendron	13.42	39%	*Gilbertiodendron*	8.39	39%
	Tetraberlinia	11.96	40%	*Tetraberlinia*	7.34	40%
	Uapaca	11.00	23%	*Diospyros*	6.52	24%
Bomi	*Anthonotha*	9.38	42%	*Anthonotha*	5.74	46%
	Anthocleista	6.81	45%	*Gilbertiodendron*	4.19	60%
	Gilbertiodendron	6.50	60%	*Anthocleista*	3.63	45%
	Afrolicania	6.06	60%	*Diospyros*	3.43	50%
	Diospyros	5.39	50%	*Afrolicania*	3.33	60%

County	Genus	Vol (m³/ha)	CI	Genus	Bole Vol (m³/ha)	Bole Vol CI
Bong	*Elaeis*	5.74	44%	*Elaeis*	3.66	42%
	Ricinodendron	4.26	59%	*Musanga*	2.57	38%
	Musanga	4.04	37%	*Ricinodendron*	2.42	58%
	Piptadeniastrum	3.45	46%	*Piptadeniastrum*	2.17	47%
	Funtumia	3.38	50%	*Anthonotha*	1.99	44%
Gbarpolu	*Parinari*	81.12	51%	*Parinari*	53.06	50%
	Piptadeniastrum	49.50	41%	*Piptadeniastrum*	26.55	40%
	Brachystegia	26.80	59%	*Brachystegia*	19.42	58%
	Parkia	25.14	34%	*Heritiera*	15.56	53%
	Heritiera	23.32	53%	*Parkia*	14.26	33%
Grand Bassa	*Uapaca*	33.19	51%	*Uapaca*	21.85	52%
	Anthonotha	23.02	41%	*Anthonotha*	14.44	41%
	Anthocleista	17.12	47%	*Funtumia*	10.86	48%
	Funtumia	15.73	44%	*Anthocleista*	9.75	46%
	Parkia	11.23	58%	*Parkia*	8.01	58%
Grand Cape Mount	*Sacoglottis*	18.10	57%	*Sacoglottis*	9.14	55%
	Tarrietia	12.40	50%	*Calpocalyx*	7.41	54%
	Calpocalyx	11.92	54%	*Tarrietia*	7.08	50%
	Parinari	10.23	50%	*Parinari*	4.23	53%
	Parkia	9.12	60%	*Parkia*	4.00	59%
Grand Gedeh	*Gilbertiodendron*	53.15	53%	*Gilbertiodendron*	31.37	53%
	Dialium	34.29	39%	*Dialium*	20.17	38%
	Diospyros	29.62	38%	*Tetraberlinia*	17.83	54%
	Lophira	27.30	44%	*Diospyros*	17.70	38%
	Piptadeniastrum	25.12	36%	*Tarrietia*	17.30	50%
Grand Kru	*Piptadeniastrum*	26.36	51%	*Coula*	15.70	46%
	Coula	23.50	46%	*Piptadeniastrum*	15.34	51%
	Sacoglottis	18.91	59%	*Sacoglottis*	8.57	57%
	Erythrophleum	14.63	53%	*Cynometra*	7.06	52%
	Diospyros	13.58	49%	*Diospyros*	6.99	48%
Lofa	*Piptadeniastrum*	27.33	33%	*Piptadeniastrum*	16.10	34%
	Albizia	14.49	35%	*Albizia*	8.04	35%
	Funtumia	9.18	38%	*Funtumia*	5.68	41%
	Terminalia	8.71	37%	*Parkia*	5.64	43%
	Carapa	7.97	42%	*Carapa*	5.57	43%
Margibi	*Hevea*	40.34	42%	*Hevea*	25.73	42%
	Funtumia	9.59	50%	*Funtumia*	6.24	48%
	Albizia	4.57	44%	*Albizia*	2.83	44%
	Ceiba	2.78	52%	*Voacanga*	1.41	60%
	Voacanga	2.01	60%	*Ceiba*	1.32	50%

County	Genus	Vol (m^3/ha)	CI	Genus	Bole Vol (m^3/ha)	Bole Vol CI
Maryland	*Cynometra*	23.16	50%	*Cynometra*	13.54	50%
	Piptadeniastrum	14.97	53%	*Uapaca*	8.36	49%
	Uapaca	13.00	50%	*Piptadeniastrum*	7.89	52%
	Parkia	12.47	46%	*Parkia*	6.66	42%
	Tieghemella	8.61	60%	*Tieghemella*	5.95	60%
Montserrado	*Hevea*	100.99	59%	*Hevea*	65.07	59%
	Anthocleista	36.82	47%	*Anthocleista*	24.25	47%
	Anthonotha	34.20	44%	*Anthonotha*	21.43	43%
	Maranthes	23.72	48%	*Maranthes*	12.74	48%
	Rauvolfia	16.64	48%	*Rauvolfia*	10.57	48%
Nimba	*Hevea*	14.66	42%	*Hevea*	8.99	43%
	Albizia	12.02	37%	*Albizia*	7.39	36%
	Piptadeniastrum	10.84	44%	*Piptadeniastrum*	6.25	44%
	Terminalia	10.53	39%	*Terminalia*	6.10	37%
	Pycnanthus	6.88	38%	*Pycnanthus*	4.60	40%
River Gee	*Uapaca*	28.93	47%	*Uapaca*	16.44	47%
	Sacoglottis	24.18	61%	*Sacoglottis*	14.04	61%
	Klainedoxa	19.00	47%	*Didelotia*	10.13	58%
	Didelotia	16.44	58%	*Piptadeniastrum*	9.62	48%
	Piptadeniastrum	15.90	48%	*Klainedoxa*	9.33	44%
Rivercess	*Tetraberlinia*	104.49	48%	*Tetraberlinia*	63.83	48%
	Gilbertiodendron	62.60	48%	*Gilbertiodendron*	42.88	49%
	Tarrietia	59.50	48%	*Tarrietia*	38.74	49%
	Lophira	46.01	52%	*Lophira*	29.83	52%
	Piptadeniastrum	44.57	49%	*Piptadeniastrum*	22.73	47%
Sinoe	*Sacoglottis*	39.79	38%	*Sacoglottis*	24.48	38%
	Calpocalyx	27.55	51%	*Calpocalyx*	15.65	52%
	Diospyros	17.00	50%	*Diospyros*	10.46	51%
	Piptadeniastrum	14.64	41%	*Piptadeniastrum*	10.13	43%
	Uapaca	14.49	34%	*Lophira*	8.41	38%

4.6 Biomass and Carbon Stocks

Biomass and carbon stocks are reported for the country as well as the counties; disaggregation continues to diameter classes. Biomass is an important variable to report as Liberia progresses with its REDD+ program: forest biomass as well as carbon content are key variables used to determine the country's Forest Reference Level which is used as a baseline to assess the impact of REDD+ interventions. In addition, tree biomass is a useful indicator of ecological and management processes in forests. Table 30 provides national per hectare estimates of both tree biomass and tree carbon.

Table 30. Biomass and carbon per ha – Liberia

	Tree Biomass (t/ha)	Tree Carbon (t/ha)	Tree B/C CI
Liberia	313.15	153.45	15.5%

4.6.1 Biomass and carbon stock by Priority Landscapes & counties

Table 31 provides biomass and carbon estimates for the Priority Landscapes. The southeast Priority Landscape returns the highest biomass and carbon contents followed by the northwest and finally the Non-PriorityLandscape, respectively.

Table 31. Biomass and Carbon per hectare - Priority Landscape

Priority Landscape	Tree Biomass (t/ha)	Tree Carbon (t/ha)	CI
Non Priority	161.73	79.25	15%
Northwest Priority	319.98	156.79	24%
Southeast Priority	514.92	252.31	23%

Table 32 provides average tree biomass per hectare per county. As with previous metrics, Rivercess, Gbarpolu, and Grand Gedeh return the highest estimates of biomass and carbon. Sustainable forest management should be prioritized in these counties while also acknowledging the need for communities to benefit from the forest resources that surround them.

Table 32. Biomass and carbon per ha - Counties

County	Tree Biomass (t/ha)	Tree Carbon (t/ha)	CI
Bomi	70.31	34.45	44%
Bong	79.35	38.88	32%
Gbarpolu	559.29	274.05	30%
Grand Bassa	238.27	116.75	28%
Grand Cape Mount	154.57	75.74	34%
Grand Gedeh	544.12	266.62	32%
Grand Kru	295.90	144.99	29%
Lofa	205.12	100.51	22%
Margibi	52.25	25.60	30%
Maryland	211.10	103.44	34%
Montserrado	269.83	132.22	29%
Nimba	125.82	61.65	20%
River Gee	281.51	137.94	19%
Rivercess	753.99	369.46	38%
Sinoe	338.44	165.83	25%

4.6.2 Biomass and carbon stock by diameter classes

Table 33 provides biomass and carbon stocks for each of the specified diameter classes. The distribution of biomass and carbon reflects results seen elsewhere in the report with the higher biomass concentrated in trees with a DBH greater than or equal to 100 cm. The pattern of significant drops in biomass and carbon seen after the 30-39 cm DBH class is once again seen in Table 33.

Table 33. Biomass and Carbon per ha by DBH class – Liberia and the Priority Landscapes

Priority Landscape	Tree - DBH class (cm)	Tree Biomass (t/ha)	Tree Carbon (t/ha)	Tree B/C CI
Liberia	< 10	16.32	8.00	8%
	10-19	20.47	10.03	8%
	20-29	28.84	14.13	10%
	30-39	33.49	16.41	15%
	40-49	17.00	8.33	10%
	50-59	18.55	9.09	11%
	60-69	19.41	9.51	12%
	70-79	16.85	8.26	13%
	80-89	15.05	7.38	17%
	90-99	12.45	6.10	17%
	≥ 100	114.71	56.21	27%
Non Priority	< 10	12.73	6.24	13%
	10-19	15.13	7.41	12%
	20-29	23.25	11.39	17%
	30-39	24.61	12.06	21%
	40-49	11.09	5.43	16%
	50-59	10.68	5.23	19%
	60-69	12.80	6.27	21%
	70-79	12.12	5.94	23%
	80-89	7.24	3.55	24%
	90-99	8.15	3.99	26%
	≥ 100	23.93	11.72	34%
Northwest Priority	< 10	19.40	9.51	14%
	10-19	24.58	12.04	15%
	20-29	32.96	16.15	19%
	30-39	37.95	18.60	25%
	40-49	20.86	10.22	18%
	50-59	23.38	11.46	20%
	60-69	21.56	10.56	19%
	70-79	16.52	8.09	21%
	80-89	16.94	8.30	32%
	90-99	13.22	6.48	28%
	≥ 100	92.62	45.38	41%

Priority Landscape	Tree - DBH class (cm)	Tree Biomass (t/ha)	Tree Carbon (t/ha)	Tree B/C CI
Southeast Priority	< 10	18.49	9.06	13%
	10-19	24.14	11.83	10%
	20-29	32.82	16.08	14%
	30-39	41.68	20.42	22%
	40-49	21.67	10.62	13%
	50-59	25.04	12.27	15%
	60-69	26.57	13.02	17%
	70-79	23.64	11.59	19%
	80-89	24.08	11.80	21%
	90-99	17.68	8.66	25%
	≥ 100	259.11	126.96	31%

4.6.3 Biomass and carbon stock by tree genus and county

Table 34 provides per hectare estimates of the tree biomass and carbon for each of the five highest reporting tree genera per county. The tree genus with the highest biomass or carbon per hectare is Hevea found in Montserrado which hosts a large rubber plantation. The tree genus with the second highest biomass or carbon per hectare is *Tetraberlinia* found in Rivercess which returns approximately 82.18 t/ha. The tree genera reported in this table with a per hectare biomass of greater than 20 tonnes should be prioritized for conservation as these are the tree genera which contain the majority of Liberia's biomass and carbon. Should Liberia wish to continue commercial logging, then practices and or guidelines should be put in place to limit the harvesting of these genera in particular.

Table 34. Biomass and carbon per tree genus per county

County	Genus	Tree Biomass (t/ha)	Tree Carbon (t/ha)	Tree B/C CI
Liberia	*Piptadeniastrum*	15.16	7.43	23%
	Parinari	13.15	6.44	39%
	Gilbertiodendron	12.01	5.89	39%
	Sacoglottis	11.37	5.57	29%
	Lophira	11.18	5.48	32%
Bomi	*Anthonotha*	9.63	4.72	44%
	Gilbertiodendron	5.49	2.69	60%
	Diospyros	5.10	2.50	50%
	Afrolicania	4.99	2.45	60%
	Synsepalum	4.59	2.25	60%
Bong	*Elaeis*	4.26	2.09	44%
	Lophira	3.20	1.57	61%
	Piptadeniastrum	2.63	1.29	46%
	Anthonotha	2.63	1.29	43%
	Pericopsis	2.40	1.17	62%

County	Genus	Tree Biomass (t/ha)	Tree Carbon (t/ha)	Tree B/C CI
Gbarpolu	*Parinari*	73.74	36.13	51%
	Piptadeniastrum	38.73	18.98	41%
	Maranthes	20.43	10.01	47%
	Heritiera	19.44	9.52	53%
	Anthonotha	19.42	9.51	43%
Grand Bassa	*Uapaca*	26.30	12.89	51%
	Anthonotha	24.10	11.81	42%
	Anthocleista	11.13	5.46	47%
	Funtumia	8.64	4.23	44%
	Gluema	7.65	3.75	62%
Grand Cape Mount	*Sacoglottis*	18.44	9.03	57%
	Calpocalyx	10.93	5.35	54%
	Tarrietia	10.09	4.94	50%
	Parinari	9.46	4.64	50%
	Parkia	5.17	2.54	60%
Grand Gedeh	*Gilbertiodendron*	48.01	23.53	53%
	Dialium	36.59	17.93	39%
	Lophira	32.18	15.77	44%
	Diospyros	30.01	14.70	38%
	Piptadeniastrum	19.81	9.70	36%
Grand Kru	*Coula*	27.20	13.33	46%
	Piptadeniastrum	20.34	9.97	51%
	Sacoglottis	19.25	9.43	59%
	Erythrophleum	15.13	7.41	53%
	Diospyros	13.91	6.82	50%
Lofa	*Piptadeniastrum*	21.26	10.42	33%
	Albizia	9.35	4.58	35%
	Carapa	6.23	3.05	42%
	Uapaca	5.20	2.55	47%
	Xylopia	5.19	2.55	47%
Margibi	*Hevea*	29.25	14.33	42%
	Funtumia	5.26	2.58	50%
	Albizia	2.90	1.42	44%
	Nauclea	1.55	0.76	55%
	Voacanga	1.44	0.71	60%
Maryland	*Cynometra*	25.00	12.25	50%
	Piptadeniastrum	11.81	5.79	53%
	Uapaca	10.38	5.09	50%
	Parkia	7.23	3.54	46%
	Coula	6.95	3.40	55%

County	Genus	Tree Biomass (t/ha)	Tree Carbon (t/ha)	Tree B/C CI
Montserrado	*Hevea*	73.76	36.14	59%
	Anthonotha	37.24	18.25	44%
	Maranthes	26.92	13.19	49%
	Anthocleista	23.64	11.58	47%
	Rauvolfia	10.04	4.92	48%
Nimba	*Hevea*	10.68	5.23	42%
	Piptadeniastrum	8.39	4.11	44%
	Albizia	8.03	3.94	37%
	Terminalia	6.11	3.00	39%
	Calpocalyx	5.49	2.69	52%
River Gee	*Sacoglottis*	24.53	12.02	61%
	Uapaca	22.86	11.20	46%
	Klainedoxa	22.56	11.05	47%
	Piptadeniastrum	12.46	6.11	48%
	Didelotia	11.79	5.78	58%
Rivercess	*Tetraberlinia*	79.28	38.85	48%
	Gilbertiodendron	56.00	27.44	48%
	Lophira	53.73	26.33	52%
	Tarrietia	48.93	23.97	48%
	Cynometra	39.15	19.18	48%
Sinoe	*Sacoglottis*	40.99	20.08	38%
	Calpocalyx	25.24	12.37	51%
	Diospyros	16.52	8.09	50%
	Lophira	15.37	7.53	37%
	Piptadeniastrum	11.58	5.67	41%

4.7 Dead Wood

Dead wood is included in Liberia's national forest inventory as it provides information on a relevant carbon pool which Liberia will include in its REDD+ MRV related reporting. Dead wood plays an important role in ecosystem functioning and processing. It is estimated that 20–40 percent of organisms in forested ecosystems depend, during some part of their life cycle, on wounded or decaying woody material from living, weakened, or dead trees. In addition to its habitat function, it has been recognized that dead wood plays important roles in carbon, nutrient, and hydrological cycles and is a key structural component influencing ecosystem processes such as erosion (Bauhus, et al, 2018). This means, a higher distribution of dead wood implies a healthier ecosystem with low human intervention. Moreover, dead wood estimates are useful for fire behavior modelling and provide proxy measurements for biodiversity and sustainable forest management. Over and above the ecological relevance of dead wood it is estimated that over 48%[4] of Liberian households rely on fuel wood for their daily energy requirements. Typically fuel wood is sourced from forests and as such dead wood data provide an estimate of energy availability to forest dependent communities. Table 35 provides per hectare estimates of both fine and coarse woody debris for both biomass and carbon at the national scale.

Table 35. National dead wood biomass and carbon per ha for fine and coarse woody debris (CI provided

4 https://knoema.com/WBGS2019/gender-statistics?tsId=1532270

for both biomass and carbon estimates)

	FWD B (t/ha)	FWD C (t/ha)	FWD CI	CWD B (t/ha)	CWD C (t/ha)	CWD CI
Liberia	0.56	0.27	14.6%	2.69	1.32	20.5%

4.7.1 Dead wood biomass and carbon by Priority Landscapes & counties

Table 36 provides estimates of both biomass and carbon of coarse and fine woody debris for the Priority Landscapes recognized by the Government of Liberia. There are higher amounts of both in the Priority Landscapes as compared to the Non-PriorityLandscapes which indicates healthier ecosystems and low human activity. While population density in these Priority Landscapes is lower than the Non-PriorityLandscape, communities within the Priority Landscapes do have increased access to fuel wood. Forest fires are not typically seen as drivers of forest loss or degradation, however, the results presented in Table 36 should highlight the need for dead wood management and or investigations into the role dead wood could play in the mitigation of future forest fires.

Table 36. Coarse and fine woody debris - Priority Landscapes (CI provided for both biomass and carbon estimates)

Priority Landscape	FWD B (t/ha)	FWD C (t/ha)	FWD CI	CWD B (t/ha)	CWD C (t/ha)	CWD CI
Non Priority	0.40	0.19	23%	1.05	0.52	34%
Northwest Priority	0.74	0.36	21%	5.18	2.54	24%
Southeast Priority	0.61	0.30	24%	2.69	1.32	35%

Table 37 provides estimates of dead wood biomass and carbon for each of Liberia's counties. Estimates of woody debris tend to follow the results for biomass and forest cover presented earlier. Gbarpolu, Sinoe, Lofa and Grand Cape Mount return the highest amounts of coarse woody debris with counties present in the agro-industrial zones returning lower estimates for both fine and coarse woody debris. This result is not unexpected as forests within the Priority Landscapes (especially the southeast) are less likely to be impacted by human activities. Data for Montserrado County are not available due to an error in data collection and processing.

Table 37. Coarse and fine woody debris – Counties (CI provided for both biomass and carbon estimates)

County	FWD B (t/ha)	FWD C (t/ha)	FWD CI	CWD B (t/ha)	CWB C (t/ha)	CWD CI
Bomi	0.40	0.19	60%	2.41	1.18	58%
Bong	0.40	0.20	36%	1.11	0.55	54%
Gbarpolu	0.72	0.35	28%	6.47	3.17	26%
Grand Bassa	0.38	0.18	51%	0.06	0.03	54%
Grand Cape Mount	0.81	0.40	34%	4.08	2.00	41%
Grand Gedeh	0.44	0.22	37%	1.41	0.69	38%
Grand Kru	0.50	0.24	31%	1.05	0.51	38%
Lofa	0.80	0.39	32%	5.01	2.46	41%
Margibi	0.12	0.06	59%	0.00	0.00	49%
Maryland	0.55	0.27	42%	3.52	1.73	47%
Montserrado	no data	no data	no data	no data	no data	no data
Nimba	0.37	0.18	38%	1.84	0.90	45%

County	FWD B (t/ha)	FWD C (t/ha)	FWD CI	CWD B (t/ha)	CWB C (t/ha)	CWD CI
River Gee	0.79	0.39	30%	1.89	0.93	35%
Rivercess	0.32	0.16	44%	0.32	0.15	54%
Sinoe	0.97	0.48	32%	5.57	2.73	43%

4.8 Biodiversity

Biodiversity statistics reported below focus on well-known diversity estimates including a species diversity index, along with the Shannon and Simpson indices. Tables including the standard errors and confidence intervals for all data reported below are available in Annex IV: Biodiversity Tables. The three diversity estimates are calculated in increasing diversity order based on sample completeness (coverage) and not sample size. Sample coverage is used as opposed to size as sample size-based estimates are negatively affected by the relative size of each assemblage (Colwell et al. 2012, Chao and Jost 2012, Chao et al. 2014). Hence only an equally-complete, standardized sample coverage-based approach allows comparison between categories that might otherwise have had different sample sizes. Figure 16 presents a sample completeness curve for Hill based diversity measures of order q=0 (species richness), 1 (Shannon diversity), and 2 (Simpson diversity) interpolated to produce a line graph for Liberia. Hill numbers generalize diversity measures at rational orders, but the most used are orders 0, 1 and 2. As the order increases, species abundance takes more weight at the expense of pure species richness (where all species are equally weighted). The estimated profile typically increases with order q, revealing the existence of undetected diversity (Chao et al. 2020). For each of the diversity measures at the national scale, as values approach 1 the sample is considered complete and suitable for comparisons across multiple assemblages. In general, estimates with sample completeness above 0.7 are seen as reliable and potentially with low bias. The complement of sample completeness at q=0 represents a lower bound for the proportion of undetected species. The 90% confidence interval was obtained by a bootstrap method based on 50 replications. Analysis and graphics were produced using an online version of the iNEXT software[5].

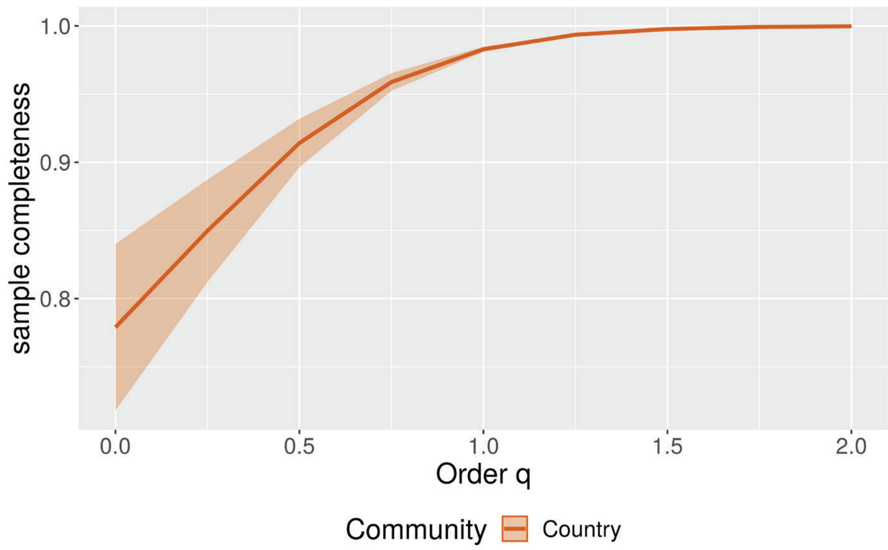

Figure 16. Sample completeness: Liberia

Figure 17 disaggregates the sample completeness data to the Priority Landscapes. Sample completeness across the Priority Landscapes is a little lower than the national estimates but is all well above 0.5 for the species richness index with the Northwest returning the lowest sample completeness of 0.69, the Non-Priority Landscape returning an estimate of 0.75 while the Southeast returned a slightly higher value of 0.77. Sample completeness for the Shannon and Simpson indices are all well above 0.9 indicating that the data can be used for diversity-based comparisons at the Priority Landscape level.

5 iNEXT Online: Chao, A., Ma, K. H., and Hsieh, T. C. (2016) iNEXT (iNterpolation and EXTrapolation) Online. Program and User's Guide published at http://chao.stat.nthu.edu.tw/wordpress/software_download/

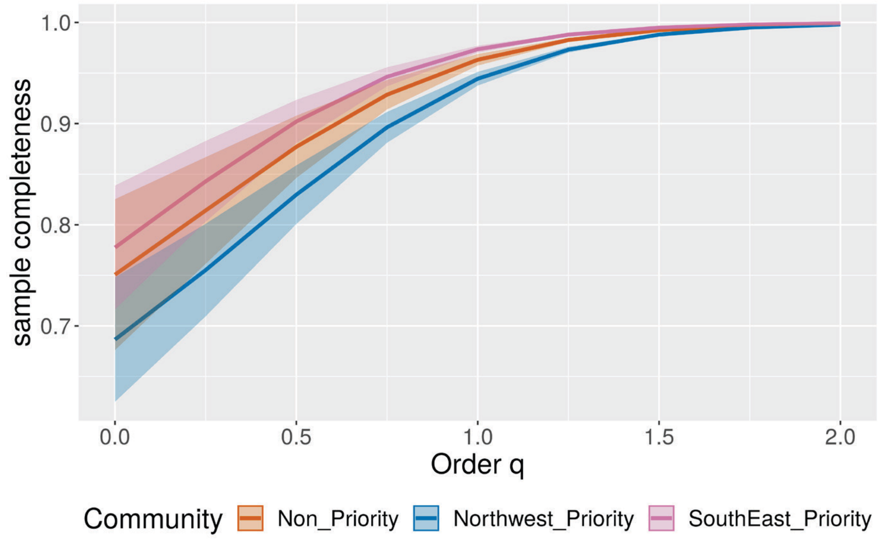

Figure 17. Sample completeness: Priority Landscapes

Figure 18 further disaggregates sample completeness to the county level. Sample completeness for Simpson and Shannon are all well above 0.75 while for the species richness Montserrado and Margibi return a completeness value of below 0.5. The 90% confidence interval for Bomi, Lofa, Grand Bassa, Margibi, Maryland and Montserrado all have their lower bounds below 0.5 indicating that diversity estimates should, where possible, be interpreted with additional biodiversity information. Given the relatively low values of sample completeness for species richness at county level, only 7 counties have large enough sample sizes for reliable species richness estimates, while both Shannon and Simpson indices can still be reliably applied at county level with the current NFI design.

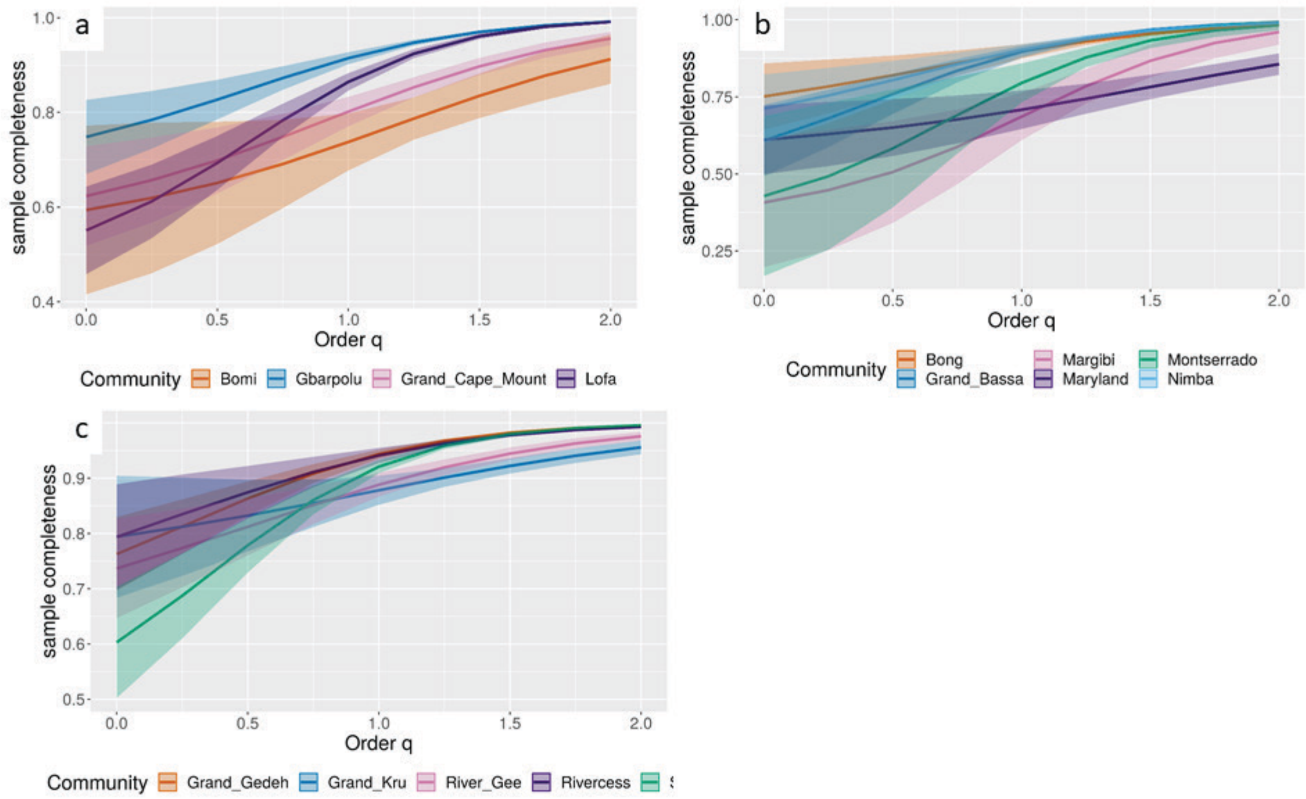

Figure 18. Sample completeness: Counties (a. Northwest Priority Landscape. b. Non-PriorityLandscape. c. Southeast Priority Landscape)

4.8.1 Diversity metrics for Liberia

Figure 19 provides overall Hill values for the three diversity metrics. The species diversity index returns a value of 511 while the Shannon diversity value is 192 and the Simpson index value is 116.97. It is important to remark that Hill numbers of *q= 1, 2* correspond in reality to the effective Shannon and Simpson indices (Jost 2006). They are respectively presented in equation 11 and 12 below, where H and λ are, respectively, the Shannon and Simpson traditional indices. Since the order q of the Hill number identifies the weight given to the abundance of the species, one can interpret ^{1}D and ^{2}D as the traditional Shannon and Simpson indices.

Equation 12.

$$2D = {}^{1}/_{\lambda}$$

Equation 13.

$$1D = e^{H}$$

where

^{1}D	=	Diversity of the singlemost dominant species
^{2}D	=	Diversity of the most dominant ones
H	=	Traditional Shannon Index
λ	=	Traditional Simpson Index

Liberia's diversity profile indicates that there is strong dominance among tree species and that the national assemblage should be considered moderately to highly uneven which reflects the high levels of biodiversity of tree species present in the field inventory data set.

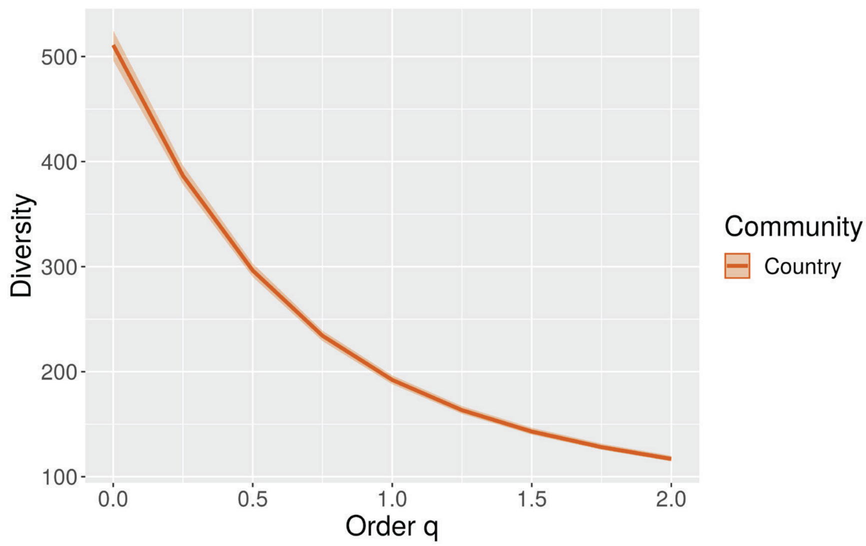

Figure 19. Diversity profile: Liberia

4.8.2 Diversity metrics by Priority Landscapes

Figure 20 provides the diversity profiles for the two Priority Landscapes as well as the Non-PriorityLandscape. The diversity profiles once again reveal that the species assemblages are uneven with the Northwest landscape returning higher diversity when compared to the Southeast landscape. The difference between the two Priority Landscapes is larger for the lower diversity order (richness) indicating that the Northwest landscape has greater richness of rare species. This difference however becomes less as the order is increased and the diversity profiles become more sensitive to the relative abundance of species as well as the dominant species. It appears that the diversity profiles begin to converge indicating that the two landscapes have similar numbers of dominant species. Comparing the Non-Priority Landscape and the Southeast indicates an inverse change whereby both landscapes have similar species richness however the Southeast landscape contains more dominant species.

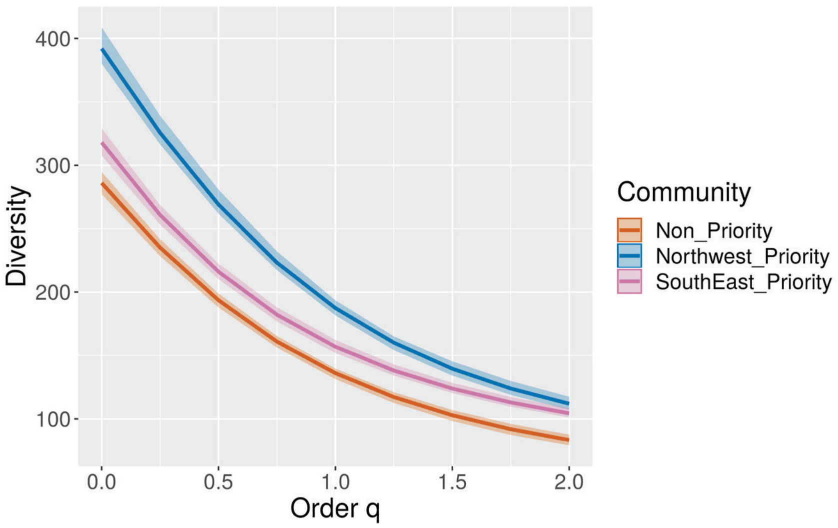

Figure 20. Diversity profile: Priority Landscapes

4.8.3 Diversity metrics by counties

Figure 21 shows the diversity profiles for each of Liberia's counties graphed according to those counties which fall within the Priority Landscapes. Panel a shows the diversity profiles for the counties located in the Northeast landscape, Bomi County returns a profile which is only slightly uneven indicating that there is less rare tree species richness present in this county. Gbarpolu on the other hand returns a high degree of unevenness when compared to counties in the Northeast Priority Landscape as well as other counties in Liberia. The diversity profile indicates that Sinoe is, in terms of tree species, the most diverse county in Liberia followed by Grand Gedeh, Gbarpolu, Lofa, and Rivercess. Panel b reports the diversity profiles for those counties located in the Non-Priority Landscape which is most impacted by human activities and is commonly known as the agro-industrial zone. Diversity profiles within this area are a lot flatter compared to the more forested areas and are similar to Bomi. The diversity values are also a lot lower compared to the Priority Landscapes. This finding is not unexpected as these counties contain the least amount of forest and have experienced the largest amount of forest loss.

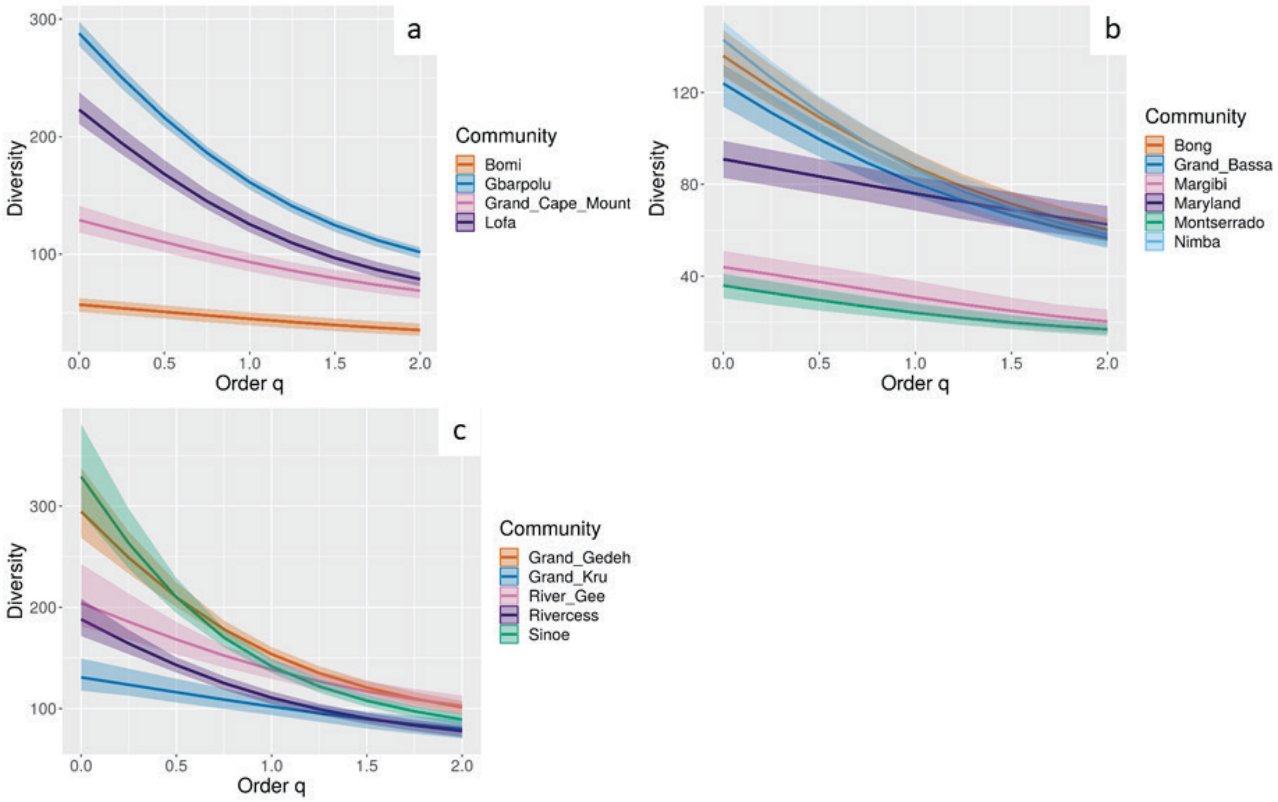

Figure 21. Diversity indices: Counties (a. Northwest Priority Landscape. b. Non-PriorityLandscape. c. South-east Priority Landscape)

4.9 Non-timber forest products

Non-timber forest products are reported according to NTFP groups and are reported as area of forest known to contain the group of products. Annex II: Non-Timber Forest Products contains a harmonized list of the NTFPs identified by the field teams along with the groups the NTFPs were assigned to. The harmonized list identifies and acknowledges that a single species may have multiple uses as a non-timber forest product and records these multiple uses in the table. Note that this means that areas reported do not sum to the area of the reporting unit.

4.9.1 Non-timber forest products for Liberia

At the national scale, results reported in Table 38 indicate that the top three NTFP categories are Construction, Food and Furniture, which all occur in over 7 million hectares of forest and non-forest and are therefore the most widely available NTFP categories; these are followed closely by NTFPs associated with Wine making, Oil production and Medicinal NTFPs. The widespread prevalence of these NTFPs indicates the massive role they play in Liberia in terms of supporting local communities and providing additional services to communities in both the rural and urban areas. It is well known that forests serve as both the pharmacy and supermarket to communities providing food and medicinal products used on a daily basis. At the national scale, it is certainly evident that NTFPs, especially food-based products have a real contribution to be made to food security and poverty alleviation. Liberia should explore the development of key food-based value chains to improve the diet and nutritional content of local foods.

Table 38. Area estimates for NTFP categories - Liberia

NTFP Category	Area (1 000 ha)	CI
Construction	4,886	7%
Cosmetics	15	69%
Food	4,573	8%
Furniture	4,695	7%

NTFP Category	Area (1 000 ha)	CI
Household goods	337	31%
Medicinal	1,746	14%
Oil production	3,232	10%
Rope	202	39%
Spice	307	27%
Wine-making	3,944	9%
No NTFPs	42	56%

4.9.2 Non-timber forest products by Priority Landscapes

Table 39 provides the areas of NTFP groups for each of the priority and Non-PriorityLandscapes. Due to the size of the Non-PriorityLandscape, the areas for each of the groups appear to be larger in the Non-PriorityLandscapes compared to the Priority Landscapes. Overall it appears that Construction, Food, Furniture, Wine-making and Oil production are the dominant NTFP categories available in all landscapes with food NTFPs dominating in the Non-Priority Landscape only. Both Priority Landscapes share the same characteristics as the national scale results and as such, NTFP availability appears to be uniform throughout the country. Uniformity in NTFP availability indicates that it may be possible to develop a policy at the national level for management and exploitation along with the required value chains.

Table 39. Area estimates for NTFP categories - Priority Landscapes

Priority Landscapes	NTFP Category	Area (1000 ha)	CI
Non Priority	Construction	2,329	9%
	Cosmetics	7	81%
	Food	2,250	9%
	Furniture	2,197	9%
	Household goods	120	47%
	Medicinal	659	22%
	Oil production	1,853	11%
	Rope	30	72%
	Spice	97	41%
	Wine-making	2,153	10%
	No NTFPs	20	69%
Northwest Priority	Construction	1,484	11%
	Cosmetics	7	81%
	Food	1,394	12%
	Furniture	1,484	11%
	Household goods	112	41%
	Medicinal	614	21%
	Oil production	937	17%
	Rope	82	46%
	Spice	120	42%
	Wine-making	1,147	14%
	No NTFPs	0	17%

Priority Landscapes	NTFP Category	Area (1000 ha)	CI
Southeast Priority	Construction	1,073	16%
	Cosmetics	0	14%
	Food	929	18%
	Furniture	1,014	16%
	Household goods	105	52%
	Medicinal	472	23%
	Oil production	442	26%
	Rope	90	56%
	Spice	90	40%
	Wine-making	644	21%
	No NTFPs	26	68%

4.10 Forest Regeneration

Liberia is dominated by forests which regenerate naturally but face numerous stressors including invasive plants, illegal logging (pit-sawing), grazing, lack of management and climate change to name a few. To maintain the forest estate, regeneration is required. In natural forests, this typically occurs via seed from trees, seeds in soils, wind-blown seeds from adjacent stands, coppicing from stumps and root sprouts. Information on how well forests are regenerating is critically important for understanding and projecting future forest state and ultimately determines the sustainability of forests. Regeneration also provides insight into the effectiveness of forest management activities and overall health. Regeneration is reported on a per hectare basis using sapling counts within the smallest sub plot of the sampling units. Table 40 provides the average number of saplings per hectare for Liberia (both forest and non-forest).

Table 40. National regeneration

	Regeneration (sap/ha)	CI
Liberia	17,848	9%

4.10.1 Regeneration by Priority Landscapes & counties

Table 41 provides estimates of regeneration for each of the Priority Landscapes. The Non-Priority Landscape returns the lowest number of saplings per hectare while the Southeast landscape returns only slightly higher numbers, indistinguishable due to the overlap of confidence intervals. The Northwest Priority Landscape returns the highest number of saplings or recruits which can be attributed to the common use of shifting agriculture in the area. Farmers typically clear forested land for either rice or cassava production, once cultivation is completed the following year, the land is left fallow and forests regenerate with the area soon dominated by saplings. The difference between the two Priority Landscapes could be attributed to the level of human interventions within the landscapes. However, the land use management that is dominated by agricultural activities explains the lower value of regeneration in the Non-PriorityLandscape.

Table 41. Priority Landscape regeneration

Priority Landscapes	Regeneration (sap/ha)	CI
Non Priority	15,925.93	14%
Northwest Priority	22,501.61	14%
Southeast Priority	16,325.30	12%

Table 42 provides estimates of regeneration per county. Those counties located in the Non-Priority Landscape return lower estimates of saplings per hectare compared to counties located in the Priority Landscapes. It is abundantly clear that land use practices play a significant role in the regeneration potential of landscapes in Liberia with the Northwest landscape counties returning consistently higher numbers compared to the Southeast and the Non-PriorityLandscape.

Table 42. County level regeneration

County	Regeneration (sap/ha)	CI
Bomi	28,658	30%
Bong	10,836	18%
Gbarpolu	22,782	22%
Grand Bassa	26,344	27%
Grand Cape Mount	23,240	24%
Grand Gedeh	20,864	16%
Grand Kru	22,895	24%
Lofa	20,422	23%
Margibi	8,759	28%
Maryland	10,110	33%
Montserrado	5,844	41%
Nimba	17,401	25%
River Gee	8,382	22%
Rivercess	14,943	17%
Sinoe	14,660	16%

4.11 Other Forest Metrics

The final section of this report will include selected estimates called Other Forest Metrics. Field inventory teams filled forms in each plot visited relating to Forest Health, Forest Disturbance (fire presence and type), Litter, and Land ownership. This information was collected as part of the plot description section of the survey where field teams recorded information regarding the general state of the plot and the overall characteristics of the forest contained in the plot.

4.11.1 Forest Health

Table 43 presents the overall area estimates of lands considered to have pests present. It is clear to see that pests do not appear to have a significant impact on forests in Liberia. At the national level around 10% of Liberia's lands are considered to have a pest or disease present.

Table 43. Presence of pests in Liberian lands

Pest presence (ha)	Area (1 000 ha)	CI
no	8,909	2%
yes	681	29%

Table 44 presents area estimates of lands affected by pests and diseases for the priority and Non-PriorityLandscapes. There appears to be no discernable difference in the presence of pests and disease in lands between the various landscapes.

Table 44. Presence of pests in Priority Landscapes forests

Priority Landscapes		Pest presence (1 000 ha)	CI
Non Priority	no	3,761	3%
	yes	247	43%
Northwest Priority	no	2,457	4%
	yes	202	44%
Southeast Priority	no	2,690	4%
	yes	232	45%

4.11.2 Forest Disturbance

Forest disturbance is reported as area estimates of forests affected by fires and the type of fires followed by grazing incidence and finally timber extraction. Table 45 provides area estimates for fire presence in Liberia, the results indicate that less than 10% of the land area in Liberia showed signs of fires. When signs of fire are present it is predominantly light fires which are due to seasonal farming activities associated with slash and burn agriculture.

Table 45. Presence of fire in Liberian lands

Fire Type	Area (1 000 ha)	CI
Heavy Fire	60	56%
Moderate Fire	75	40%
Light Fire	315	32%
No Fire	9,140	1%

Table 46 provides data on the presence of fire within the priority and Non-PriorityLandscapes. Once again, less than 10% of the land areas were affected by fire. The Northwest Priority Landscape returns the highest area of land affected by fire with over 150,000 hectares experiencing light fire, which is higher than both the Southeast and Non-PriorityLandscape. Interestingly the Non-Priority Landscape records the highest presence of heavy fires compared to the two Priority Landscapes and is likely due to the land use practices in this landscape. Slash and burn agriculture is practiced throughout Liberia but is more prominent in the agro-industrial zone as well as the Northwest landscape. The inventory was not able to identify heavy fires in the Southeast Priority Landscape where human activity is less prevalent than elsewhere. Additionally, the Southeast Priority Landscape is typically wet throughout the year and the forest is evergreen.

Table 46. Presence of fire in Priority Landscape forests

Priority Landscapes	Fire Type	Area (1 000 ha)	CI
Non Priority	Heavy Fire	45	61%
	Moderate Fire	27	59%
	Light Fire	117	41%
	No Fire	3,819	2%
Northwest Priority	Heavy Fire	15	80%
	Moderate Fire	30	55%
	Light Fire	145	47%
	No Fire	2,468	3%

Priority Landscapes	Fire Type	Area (1 000 ha)	CI
Southeast Priority	Heavy Fire	-	-
	Moderate Fire	26	59%
	Light Fire	54	51%
	No Fire	2,841	1%

The field inventory also recorded the types of fires present in the country, Table 47 outlines the types of fires observed and recorded by field teams. At the national scale it appears that surface fires are the most prevalent which is expected given the nature of land use and land use change in Liberia especially associated with the slash and burn agricultural activities.

Table 47. Fire type in Liberia

Fire Type	Presence of fire (1 000 ha)	CI
Crown	30	63%
No fire signs	9,132	1%
Not Sure	97	48%
Surface	331	31%

Table 48 provides area estimates for fire type for each of the Priority Landscapes. Surface fires dominate the results with the Northwest Priority Landscape returning the largest areas affected by surface fires. This is once again the result of the land use and farming practices in the region - slash and burn agriculture.

Table 48. Area by Fire type in Priority Landscapes

Priority Landscape	Fire Type	Presence of fire (1 000 ha)	CI
Non Priority	Crown	15	81%
	No fire signs	3,828	2%
	Not Sure	60	61%
	Surface	105	42%
Northwest Priority	Crown	14	68%
	No fire signs	2,465	3%
	Not Sure	22	61%
	Surface	157	45%
Southeast Priority	Crown	-	-
	No fire signs	2,839	1%
	Not Sure	15	68%
	Surface	67	52%

Table 49 provides information on the presence of grazing in Liberia. Based on the data collected during the national forest inventory it is clear to see that in terms of forest disturbance grazing from animals has minimal impact on forest resources with less than 2 % of the land being affected by animal grazing.

Table 49. Grazing incidence in Liberian forests

Severity	Grazing Incidence (1 000 ha)	CI
None	9,387	1%
Moderate	121	46%

Severity	Grazing Incidence (1 000 ha)	CI
Slight	83	48%

Table 50 provides information on grazing incidence reported for the priority and Non-PriorityLandscapes. Following the national estimates, the area affected by grazing is limited. The Southeast Priority Landscape returns almost 70,000 ha of land showing slight incidence while the Non-Priority Landscape has 53,593 ha of moderate grazing incidence. As Liberia's agricultural sector expands into forest, management activities may require adjustment for the mitigation of potential impacts of grazing especially with regards to regeneration.

Table 50. Grazing incidence in priority and non-landscapes

Priority Landscapes	Grazing Incidence	Area (1 000 ha)	CI
Non Priority	None	3,941	1%
	Slight	15	81%
	Moderate	52	59%
Northwest Priority	None	2,622	1%
	Slight	-	-
	Moderate	37	74%
Southeast Priority	None	2,822	2%
	Slight	69	49%
	Moderate	30	55%

Timber extraction has been identified as a driver of forest degradation and, when coupled to a change in land use, deforestation. Field teams recorded the presence of timber extraction within the sample plots as part of the plot description form. Field teams who identified evidence of timber extraction discussed the nature of the clearance with guides employed from local communities. Initial analysis of the timber extraction data indicates that at the national scale close to one million hectares of land had evidence of timber extraction in the area. This is not surprising given the importance Liberia places on timber extraction and the potential role forests can play in terms of alleviating poverty.

Table 51. Timber extraction in Liberian lands

Timber Extraction	Area (1 000 ha)	CI
No Felling	8,456	3%
Others	105	56%
Yes, Clear Cutting	383	35%
Yes, Group Felling	30	56%
Yes, Selective Felling	616	30%

Table 52 contains information regarding timber extraction within the priority and Non-PriorityLandscapes. There is a distinct difference between timber extractions in the landscapes: clearing in the Non-Priority Landscape is primarily through clear cutting while clearing in the Priority Landscapes is primarily through selective felling. The difference between the timber extraction types could be attributed to the way land and forests are managed in the priority and Non-PriorityLandscapes. This may be explained by differeing approaches to land management in these areas and the legal rights of entities engaging in extractive practices.

Table 52. Timber extraction in Priority Landscape lands

Priority Landscapes	Timber Extraction	Area (1 000 ha)	CI
Non Priority	No Felling	3,602	4%
	Others	37	74%
	Yes, Clear Cutting	286	41%
	Yes, Group Felling	-	-
	Yes, Selective Felling	82	65%
Northwest Priority	No Felling	2,210	6%
	Others	67	64%
	Yes, Clear Cutting	67	49%
	Yes, Group Felling	22	61%
	Yes, Selective Felling	292	38%
Southeast Priority	No Felling	2,643	4%
	Others	-	-
	Yes, Clear Cutting	30	72%
	Yes, Group Felling	7	81%
	Yes, Selective Felling	241	43%

4.11.3 Litter

Litter is considered as a key carbon pool in Liberia. Teams recorded the depth of litter at each plot using various measures and methods. The data in the following tables collates this data and reports the average depth per hectare. The average per hectare litter depth for Liberia is presented in Table 53 below.

Table 53. Litter depth in Liberian forests

	Litter Depth (cm)	CI
Liberia	4.06	11%

Litter depths for the priority and Non-PriorityLandscapes are presented in Table 54. Depth of litter is highest in the Southeast Priority Landscape followed by the Northwest landscape. The Non-Priority Landscape returns a litter depth almost half that of the Southeast landscape. The difference seen between the landscapes highlights how forests are managed and the impact humans have on these metrics. The Southeast landscape is by far the least affected by humans while the Northwest is currently experiencing increased clearance and anthropogenic impacts. The difference seen between the Priority Landscapes may also be related to the evergreen and deciduous nature of the Southeast and Northwest forests respectively.

Table 54. Litter depth in Liberian forests

Priority Landscape	Litter Depth (cm)	CI
Non Priority	2.75	13%
Northwest Priority	3.84	22%
Southeast Priority	6.06	16%

Table 55 provides county level estimates of average litter depths recorded by the inventory field teams; depths in the counties differ largely based on forest cover within the county and perhaps forest type. For example, Sinoe, Rivercess, and Grand Gedeh have ample forest cover and return high relative values of litter depth. On the other hand, Gbarpolu and Lofa also have high forest cover but relatively small litter depths. Ecological differences in deciduous and evergreen forests may explain the differences between counties with some counties also returning lower depths due to land use practices.

Table 55. Litter depth in Priority Landscape forests

County	Litter depth (cm)	CI
Bomi	2.76	24%
Bong	2.22	22%
Gbarpolu	4.29	19%
Grand Bassa	3.86	22%
Grand Cape Mount	1.42	26%
Grand Gedeh	7.03	22%
Grand Kru	1.37	26%
Lofa	4.74	35%
Margibi	0.74	35%
Maryland	3.60	20%
Montserrado	1.84	31%
Nimba	2.14	21%
River Gee	1.97	28%
Rivercess	6.31	18%
Sinoe	7.26	25%

4.11.4 Land ownership

The plot description section of the digital survey included questions on land ownership. Field teams typically gathered this information from the local guides employed from the community closest to the clusters of interest. The survey included five options for land ownership; Table 56 presents national scale estimates of each. Communal land makes up over 70% of land ownership in Liberia followed by Private and Protected.

Table 56. Land Ownership in Liberia

Ownership	Area (1 000 ha)	CI
Communal	7,778	3%
Private	1,111	24%
Protected	271	44%
Sacred	15	69%

Table 57 contains land ownership information disaggregated to priority and Non-PriorityLandscapes. Communal land ownership dominates the landscapes followed by private land ownership. Private land ownership is highest in the Non-Priority Landscape where most of the commercial agriculture takes place in Liberia. The Northwest landscape has the largest protected area while the Southeast landscape is dominated by communal land ownership.

Table 57. Land Ownership in Priority Landscapes

Priority Landscape	Ownership	Area (1 000 ha)	CI
Non Priority	Communal	3,071	5%
	Private	862	25%
	Protected	75	68%
	Sacred	-	0%

Priority Landscape	Ownership	Area (1 000 ha)	CI
Northwest Priority	Communal	2,397	3%
	Private	112	56%
	Protected	135	55%
	Sacred	15	68%
Southeast Priority	Communal	2,725	8%
	Private	136	55%
	Protected	60	67%
	Sacred	-	0%

5 Conclusion and recommendations

5.1 Recommendations: Technical Improvements

In the next NFI, it will be important to consider the following:

1. As Liberia seeks to continue forest monitoring as part of the REDD+ initiative as well as sustainable forest management, it is critical for the Forestry Development Authority to retain a core group of field inventory officers who are able to undertake forest inventory activities supporting development as well as ongoing FDA monitoring work.

2. It is important to note that this inventory did not measure mangrove forests and therefore has not reported on the characteristics of this important coastal forest type. In the future Liberia would benefit from a dedicated small-scale inventory focusing on mangrove forests using an enumeration methodology aligned to the national inventory. Outputs from this inventory will provide useful information on carbon stocks as well as biodiversity and coastal resilience. This inventory would serve as a precursor to the establishment of a dedicated mangrove stratum in the national inventory.

3. Liberia should in the future seek to undertake a full-scale national soil survey by making use of the permanent sampling units used for the NFI. This information will not only benefit the FREL and emissions calculations, but it would also be invaluable to the agricultural sector as well as land use planning. This should also involve the establishment of at least the basic soil lab facilities, possibly hosted in a university, since currently any soil sample needs to be sent overseas for analysis.

4. The current NFI did not estimate biomass and carbon in litter due to the uncertainty of data collected. MRV activities planned on an annual basis should seek to improve the data collected in the national inventory. Improving litter estimates will result in superior biomass and carbon estimates, which will ultimately result in more robust FREL reporting, and other GHG emission estimates from Liberia.

5. As done by other countries, it would be advisable to expand its technical capabilities to assess forest resources by establishing a herbarium, and national databases with locally developed allometric equations for some of the more important species, as well as a local database of wood density values. Estimation of wood densities would make use of the same laboratory facilities as the one described for the soil lab.

6. Other technical developments should include a continuous capacity development program to train more crews in species identification, including possibly the development of taxonomy applications for mobile phones. This has proven successful in previous experiences in other countries. Also, a database with NTFPs-associated scientific and local names should be kept and updated by FDA.

7. The NFI database provides abundant information on the value of Liberia's forests however, at present the Forestry Development Authority lacks the scientific capacity to exploit this valuable resource. Liberia and its people would benefit from a targeted capacity development program aimed at improving the scientific and analytical capacity of FDA staff.

8. The NFI data collected as part of this inventory represent a valuable knowledge base for forest management in Liberia with many scientific and related applications. Moving forward this knowledge base must become the backbone of a Forest Management Information System.

9. Building on the recommendation made above regarding the scientific potential of the data, it would be prudent to explore the use of the inventory data as part of graduate and post-graduate coursework in the country. As custodians of the forestry knowledge base, the FDA is in an excellent position to share with and benefit from formal relationships with tertiary education systems in Liberia.

10. The results of the NFI should be used to re-establish the permanent sample plots for monitoring purposes. Estimation of change is important for REDD+ and international reporting, and this is best done by remeasuring the same plots.

5.2 Recommendations: Commercial

It is important to know that Liberia has great potential for commercial logging in designated areas. The country's commercial logging potential is heavily concentrated within the Priority Landscapes.

1. For Liberia to continue to benefit from logging, it will have to continue to ensure sustainable forest management using selective logging practice and the Liberian Code of Harvesting Practice.

2. Ensure robust monitoring and evaluation of commercial logging activities to assure rules and regulation.

3. Results from the national forest inventory clearly indicate that there are areas in Liberia more suitable to commercial logging activities. Liberia is now in a position to manage these forest resources in a sustainable manner for the benefit of all Liberians.

4. The Liberian commercial forestry industry stands to benefit from an enhanced scientific nomenclature of lesser known species currently valued by commercial operations.

5. Sustainable forest management in Liberia relies on adherence to the Code of Forest Harvesting Practices. A cornerstone of these practices is the diameter cut limit regulations. Using the information contained in the NFI database the FDA should consider establishing an ad hoc committee to review and update regulations associated with diameter cut limits for timber species.

6. The information provided in this report regarding biodiversity and dominant species may greatly contribute to fine-tuning silvicultural practices that ensure not only sustainability in timber stock, but also those regarding species composition at the Priority Landscape or county level.

5.3 Recommendations: Communities

1. The NFI database has the potential to enhance community knowledge on forest resources and sustainable forest management. The Forestry Development Authority through its Community Forest Department (CFD) should share relevant information with communities engaging in community forestry.

2. The NFI database contains a wealth of information on the prevalence of non-timber forest products. Unfortunately, there are some inconsistencies with the recording of an absence of NTFPs at some sites. Given the importance communities place on NTFPs, the FDA through its CFD must ensure that future surveys recognize the importance of consistent data collection methods.

3. The FDA should consider establishing an ad hoc committee to actualize community benefits associated with NTFPs.

4. Use information in the NFI database to identify and encourage communities to carry out small-scale forest enterprises as well as lowland agricultural activities within their forests.

5. Communities engaged in community forestry require a range of forest related information; the NFI database can potentially help communities to rank their priorities in terms of the collection, sales, sustainable management and usage of NTFPs. The CFD is encouraged to take the lead role in facilitating this support.

6. Communities who wish to engage in community forestry and enter third-party agreements require capacity development to understand how to manage their forests. The NFI trained almost 50 officers to enumerate forests throughout Liberia. These forestry officers are now in a position to pass on their learning and experience to communities using the NFI as an example for sustainable forest management.

7. The Forestry Development Authority is in an excellent position to enhance community awareness regarding the prevalence of NTFPs as well as their uses. With the newly established NFI, data base the FDA and its relevant departments are encouraged to engage communities on this subject.

8. Communicating the findings presented in this report as well as the data contained in the NFI database is key for realizing the full potential of sustainable forestry in Liberia. Communications should be in local vernaculars whenever possible and make use of a variety of media including creative solutions such as T-shirts, stickers, flyers and radio dramas.

9. Cooperation is key to successful forest management. The FDA is encouraged to prepare a data sharing policy for the inventory data and to share this information with Technical Service Providers working in the project landscapes who have a stake in community activities.

10. Using established policies and regulations, the FDA is encouraged to employ relevant portions of the NFI database for the purposes of supporting the nine-step process as well as other relevant community forestry activities.

11. Finally, the FDA as well as its Community Forest Department are encouraged to embark on a nationwide roadshow sharing results with local authorities and communities.

5.4 Recommendations: Conservation

The National Forest Inventory reveals that Liberia has great potential forest resources and their conservation is key for ecosystem services, prevention of soil erosion and water cycle management. The following recommendations cover sustainable forest management and conservation:

1. The NFI data on forest regeneration shows that Liberia has high forest regrowth and conservation potential. It is important to improve good forest management practices in order to conserve the forest for future generations. The outputs from the national forest inventory provide Liberia with the relevant information to enable regrowth and conservation for the benefit of all Liberians.

2. Results from analyses of dead wood indicate that both Priority Landscapes have excellent potential to host vital ecosystem processes and functions. The FDA along with its conservation department are encouraged to make use of the NFI results to improve the management of protected areas.

3. The National Forestry Reform Law mandates the FDA to create a network of protected areas covering a minimum of 30% of Liberia's forested estate. The analysis of biodiversity metrics reveals that across the country, especially in the northwest and southeast landscapes, Liberia currently hosts a great deal of biodiversity. The publishing of the results from the first National Forest Inventory should act as a catalyst to drive the continued development of a network of protected areas in Liberia.

4. The forest resources of Liberia (6.692 Mha) are under heavy pressure from deforestation and forest degradation as a result of shifting cultivation, oil palm production, illegal pit-sawing, mining, logging and rubber farming among others. The NFI database contains information that the Government of Liberia can use to manage forest resources such that the peoples of Liberia can benefit from both development and conservation.

5. Using the species data contained in the NFI database, the research department of the FDA should embark on the preparation of a conservation-based species list relevant for improved forest management and conservation.

6. The NFI data should inform the Forest Landscape Restoration initiative in Liberia.

5.5 Recommendations: Carbon

Carbon resources contained within Liberia (151.22 tC/ha) have the potential to contribute to the global mitigation of climate change. With the publication of this document, Liberia is now in a position to do the following:

1. Participate in the international carbon market through REDD+and other international market mechanisms.

2. To conserve its forest resources and demonstrate its commitment to the Paris Agreement through its Natioanlly Determined Contribution(s) and other carbon reporting.

3. The NFI results should serve as a basis to promote the establishment of the fourth C (Carbon) of Liberian forest management which could focus on the potential forest carbon has for supporting communities and reducing poverty. The national forest inventory should serve as a platform for the government to roll out livelihood activities associated with sustainable forest management and emissions reductions.

4. The establishment of the fourth C will further enhance the FDA's ability to enable poverty reduction in Liberia. Carbon, as a crosscutting issue, has the potential to bring together each of the three Cs under a common objective focused on sustainable forest management for poverty alleviation and forest conservation. The data contained in the NFI database has the potential to enable this transition to a carbon-focused approach to forest management.

5. Market-based approaches to financing REDD+ activities are becoming more popular in countries seeking to benefit from improved land use management with respect to forests. While the NFI database provides Liberia with the necessary baseline information to enable market-based approaches to financing REDD+, staff within the FDA require capacity development to facilitate this work. Using the momentum created by the National Forest Inventory the FDA is encouraged to explore innovative ways to capacitate staff and expand the footprint of REDD+ projects in Liberia.

6. The government of Liberia and the FDA should explore the establishment of the dedicated mangrove forest stratum as this will add completeness to Liberia's communications to the UNFCCC. The lack of data associated with the soil carbon pool should also be remedied with a dedicated nationwide soil survey.

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Annex I. List of National Forest Inventory crew members

Liberia strove to achieve gender diversity in the field teams with over 12% of participants being women.

Num	Team	Position	Name
1	1	Team Leader	Armandu K. Daniels
2	1	Assistant TL	Trokon B. Randall
3	1	Field Team	Yassah B. Kargbo
4	1	Field Team	Nowai K. Joekai
5	1	Field Team	Soclortay K. Soclor
6	2	Team Leader	Anthony Koigbli
7	2	Assistant TL	Albertha K. Mulbah
8	2	Field Team	Augustine K. Tarnue
9	2	Field Team	Moses Gonigalee
10	2	Field Team	Yassah Gbelee
11	3	Team Leader	Stephen T. Seleweyan
12	3	Assistant TL	Patrick Garteh
13	3	Field Team	Winifred H.M. Sauser
14	3	Field Team	Charles B. Kanneh
15	3	Field Team	Pesoe G. Menscole
16	3	Field Team	Torlo F. Woiwor
17	4	Team Leader	Bernard D. Zakpa
18	4	Assistant TL	Teta Bonar
19	4	Field Team	Royson Richards III
20	4	Field Team	David N. Toe
21	4	Field Team	Lucy Woiballah
22	5	Team Leader	Sylvester P. Chenikan
23	5	Assistant TL	Sonnie M. Taylor
24	5	Field Team	Moses Wenyanpulu
25	5	Field Team	Mentor Y. Sarvah
26	5	Field Team	Samuel M. Gorrez
27	6	Team Leader	J. Amos Barlingar
28	6	Team Leader	Daniel Dorbor
29	6	Assistant TL	Joshua N. Quawah
30	6	Field Team	Ezekiel Gaye
31	6	Field Team	Carina Pinky Dunbar

Num	Team	Position	Name
32	6	Field Team	Jeraline B. Gardee
33	7	Team Leader	Martha Sammie
34	7	Assistant TL	George G.M. Kannah
35	7	Field Team	Julius N. Lepolu
36	7	Field Team	Mohamed Sheriff
37	7	Field Team	Philomena Yarwoah
38	8	Team Leader	Richard Boakai Johnson
39	8	Assistant TL	Albert G. Weay
40	8	Field Team	Myers G. Wymah
41	8	Field Team	Gayduo Zayzay
42	8	Field Team	Jefferson B. Sackie
43	Socio-1	Team Leader	John S. Mckay, Jr.
44	Socio-1	Team member	Florence G. Kolleh
45	Socio-1	Team member	Eliza M. Horace
46	Socio-2	Team Leader	Quoiquoi Y. Dorborson
47	Socio-2	Team member	Dianna Y. Gbanyah
48	Socio-2	Team member	Sylvester F. Larbeindee
49	Data collection Team	Team Leader	Sayon S. Fofana
50	Data Team	Assistan Team Leader	Emmanuel S. Ciapha
51	Data Team	Team Member	Morris Kiazolu
52	Data Team	Team Member	Champhbell S. Glee
53	Data Cleaning	Team Member	Abraham N. Tumbey
54	Data Cleaning	Team Member	Laurent Marshall
55	Data Cleaning	Team Member	Charlesetta Gono
56	Supervision	Team Leader/NFI coordinator	James T. Kpadehyea
57	Supervision	Assistan Team Leader/MRV officer	Isaac Nyaneyon Kannah
58	Supervision	Assistan Team Leader/MRV officer	J Negatus Wright
59	Supervision	Communications Expert	Anthony F Vanwen
60	QA Team 1	Team leader	William W. Draper
61	QA Team 1	Asst. Team leader	Michael Bohlen
62	QA Team 1	Member	Jerry Yekeh
63	QA Team 1	Member	Othello Bleedy
64	QA Team 1	Member	Augustine Teeklo
65	QA Team 2	Team leader	Wollor E. Topor
66	QA Team 2	Asst. Team leader	Frankis Nimely Donnie
67	QA Team 2	Member	Marthaline K. Williams
68	QA Team 2	Member	Peter Kah
69	QA Team 2	Member	Sirlef Gray
70	QA Team 3	Team leader	Larry C. Hwang
71	QA Team 3	Asst. Team leader	Caroline Daywhea
72	QA Team 3	Member	John W Kolva
73	QA Team 3	Member	Franklin Kwenah

Num	Team	Position	Name
74	QA Team 3	Member	David Fehnkpolo
75	Drivers	Driver	Anthony Suah
76	Drivers	Driver	Papa J. Konneh
77	Drivers	Driver	James F. Kollie
78	Drivers	Driver	Fayiah Kawauda
79	Drivers	Driver	Jacson Bloe
80	Drivers	Driver	Dennis Smith
81	Drivers	Driver	Abraham A. Kamara
82	Drivers	Driver	Francis Mulbah
83	Drivers	Driver	Varney Pabai
84	Drivers	Driver	Sam Myers
85	Drivers	Driver	George M. Jarman
86	Drivers	Driver	Moses Quayee
87	Drivers	Driver	Gbassey Passawe
88	Drivers	Driver	Selekie Jalloh
89	Drivers	Driver	Lloyd Kulee
90	Drivers	Driver	Emmanuel B. Wilson
91	Drivers	Driver	Omaru Dukuly
92	Drivers	Driver	Joseph Gorligo
93	Drivers	Driver	Samsone Doe
94	Drivers	Driver	Flomo K. Daddeh
95	Drivers	Driver	Ojuku Gaye
96	Drivers	Driver	Emmanuel N. Slebo
97	Drivers	Driver	Bill G. Kpaybah
98	Drivers	Driver	Pedesco P. Jalloh
99	Drivers	Driver	Sortee Dukuly
100	Drivers	Driver	James Lewis
101	Drivers	Driver	Morris A. Dagoseh
102	Drivers	Driver	Morris Kehelee
103	Drivers	Driver	Mohammed Kaba
104	Drivers	Driver	Augustine Kofa
105	Drivers	Driver	Steve V. Jamah
106	Drivers	Driver	Varney Pabai
107	Drivers	Driver	Sam Kpah
108	Drivers	Driver	Sam Menlor
109	Supervision	Transport officer	Gabriel A. Weah
110	Supervision	Asst. Transport officer	Amah B. Johnson

Annex II. Non-Timber Forest Products

Num	Harmonized NTFP	Medicinal	Food	Cosmetics	Wine making	Construction	Furniture	Rope	Oil Production	HH Goods	Spice
1	*Abura*	1									
2	*Aframomum melegueta*	1	1								
3	*African walnut*		1								
4	*Albizia zygia*	1	1								1
5	*Alchornea cordifolia*	1									
6	*Allanblackia*			1							
7	*Annika polycarpa*	1									
8	*Anthocleista nobilis*	1									
9	*Anthonotha fragrans*					1					
10	*Anthonotha macrophylla*	1									
11	Bamboo				1						
12	*Bambusa hookeri*				1						
13	*Bambusa vulgaris*					1					
14	Bitter root	1	1								
15	Bitter rope						1	1			
16	*Bracaena calocephala*	1									
17	Bush cherry		1								
18	*Bussea occidentalis*		1								
19	*Calamus derratus*		1				1				
20	*Calpocalyx aubrevillei*		1								
21	*Campylospermum duparquetianum*	1									
22	*Carapa tree*		1								
24	*Ceiba pentandra*	1	1			1					
25	*Cercestis afzelii*					1					
26	Cherry tree		1								
27	*Chromolaena odorata*	1									
28	*Cocos nucifera*		1						1		
29	*Coula edulis*		1								
30	*Cola gigantea*		1								
31	*Cola lateritia*	1	1			1					
32	*Cola nitida*		1								

Num	Harmonized NTFP	Medicinal	Food	Cosmetics	Wine making	Construction	Furniture	Rope	Oil Production	HH Goods	Spice
33	*Cola umbratalis*		1								
34	*Costus dubius*	1	1								
35	*Craisterospermum Spp*	1									
36	*Dacryodes klaineana*		1								
37	*Danda*	1									
38	*Danthonia*					1					
39	*Diaspora sansaminica*	1									
40	*Dioscorea minutiflora*	1	1								
41	*Diospyros*	1									
42	*Dosser*	1									
43	*Dracaena aubrevillei*	1									
44	*Dracaena aubryana*	1									
45	*Dracaena calocephala*	1									
46	*Drypetes*										1
47	*Elaeis guineensis*		1		1	1	1		1		
48	*Enantia polycarpa*	1									
49	*Eremospatha dransfieldii*			1		1		1			
50	*Fagara*					1					
51	*Ficus sur*	1	1			1					
52	*Funtumia elastica*	1									
53	*Garcina afzelii*	1									
54	*Garcina kola*	1	1								
55	*Hallea ciliata*									1	
56	*Haldina cordifolia*	1				1					
57	*Halopegia azurea*	1									
58	*Harungana madagascariensis*	1				1				1	
59	*Heisteria parvifolia*		1								
60	*Heritiera utilis*		1								
61	*Hymenocoleus hirsutus*	1									
62	*Khaya Anthotheca*	1									
63	*Laccosperma acutflorum*	1	1		1		1		1		
64	*Laccosperma opacum*		1			1	1	1		1	
65	*Lepisanthes alata*		1								
66	Lianas					1		1			
67	*Limnophyton angolensis*	1	1								
68	*Macaranga heterophylla*	1									1
69	*Maesobotrya barteri*		1								

Num	Harmonized NTFP	Medicinal	Food	Cosmetics	Wine making	Construction	Furniture	Rope	Oil Production	HH Goods	Spice
70	*Manniophyton fulvum*	1									
71	*Mapania*					1					
72	*Marantochloa congensis*									1	
73	*Marantochloa purpurea*									1	
74	*Mareya micrantha*	1									
75	*Marinatas libericus*		1								
76	*Marattia fraxinea*		1								
77	*Megaphrynium macrostachyum*									1	
78	*Microdesmis keayana*	1	1			1					
79	Monkey rope							1			
80	Monkey apple	1	1								
81	Monkey plum		1								
82	Monkey vine					1					
83	*Musa acuminata*		1								
84	*Musanga Cecropioides*	1									
85	Mushroom		1								
86	*Musa sapientum*		1								
87	*Musanga Spp*					1					
88	*Mussaenda chippi*	1									
89	*Myrianthus libericus*	1	1								
90	*Napoleonaea heudelotii*	1									
91	*Newtonia aubrevillei*	1	1								
92	*Nauclea latifolia*	1									
93	Oil bean tree		1								
94	*Olyra latifolia*									1	
95	*Palisota hirsuta*	1									
96	*Parinari*	1	1								
97	*Parkia*		1								
98	*Pentaclethra macrophylla*		1								
99	*Piper guineense*	1	1								1
100	Pineapple		1								
101	*Perennial woody herbs.*					1					
102	*Raphia hookeri*				1	1	1				
103	*Raphia vinifera*				1	1	1			1	
104	Rattan					1	1				
105	*Salacia miegei*					1					
106	*Santira tremire*		1								

Num	Harmonized NTFP	Medicinal	Food	Cosmetics	Wine making	Construction	Furniture	Rope	Oil Production	HH Goods	Spice
107	*Sarcophrynium brachystachyum*									1	
108	*Scleroderma sp. af. manni*					1					
109	Silver thatch					1					
110	*Strephonema pseudocola*	1									
111	*Tetracera affinis*	1								1	
112	*Thaumatococcus daniellii*						1				
113	*Theobroma cacao*		1								
114	*Tiliacorea Spp*					1					
115	*Trichilia species*	1									
116	*Uapaca guineensis*		1								
117	Woody lianas					1					
118	*Xylopia acutiflora*	1	1			1					
119	*Xylopia aethiopica*	1	1								1
120	*Xylopia Antropica*	1									
121	*Xylopia parviflora*	1									
122	*Xylopia spp*	1	1								
123	*Xylopia studii*					1					
124	*Xylopia tree species*	1									1
125	*Zanthoxylum giletii*	1	1			1					

Annex III. Final Tree Species List

Tree Species Code	Species Scientific Name
ADENANTH_PAVONIN	Adenanthera pavonina
AEGLOPSI_CHEVALI	Aeglopsis chevalieri
AFROLICA_ELAEOSP	Afrolicania elaeosperma
AFZELIA_BELLA	Afzelia bella
AFZELIA_PARVIFL	Afzelia parviflora
ALBIZIA_ADIANTH	Albizia adianthifolia
ALBIZIA_ALTISSI	Albizia altissima
ALBIZIA_CHEVALI	Albizia chevalieri
ALBIZIA_FERRUGI	Albizia ferruginea
ALBIZIA_ZYGIA	Albizia zygia
ALCHORNE_CORDIFO	Alchornea cordifolia
ALCHORNE_FLORIBU	Alchornea floribunda
ALCHORNE_HIRTELL	Alchornea hirtella
ALLOPHYL_HAMATUS	Allophylus hamatus
ALSTONIA_BOONEI	Alstonia boonei
AMANOA_BRACTEO	Amanoa bracteosa
AMPHIMAS_PTEROCA	Amphimas pterocarpoides
ANDROSIP_ADENOST	Androsiphonia adenostegia
ANISOPHY_MENIAUD	Anisophyllea meniaudii
ANNICKIA_CHLORAN	Annickia chlorantha
ANNICKIA_POLYCAR	Annickia polycarpa
ANNONA_GLABRA	Annona glabra
ANOPYXIS_KLAINEA	Anopyxis klaineana
ANTHOCLE_NOBILIS	Anthocleista nobilis
ANTHOCLE_VOGELII	Anthocleista vogelii
ANTHONOT_CRASSIF	Anthonotha crassifolia
ANTHONOT_FRAGRAN	Anthonotha fragrans
ANTHONOT_MACROPH	Anthonotha macrophylla
ANTHONOT_PYNAERT	Anthonotha pynaertii
ANTHOSTE_SENEGAL	Anthostema senegalense
ANTIARIS_TOXICAR	Antiaris toxicaria
ANTIDESM_LACINIA	Antidesma laciniatum
ANTIDESM_MEMBRAN	Antidesma membranaceum
ANTIDESM_OBLONGU	Antidesma oblongum
ANTIDESM_RUFESCE	Antidesma rufescens
ANTROCAR_MICRAST	Antrocaryon micraster
APHANOCA_MICROPH	Aphanocalyx microphyllus
APODISCU_CHEVALI	Apodiscus chevalieri
ARGOMUEL_MACROPH	Argomuellera macrophylla
ARTOCARP_ALTILIS	Artocarpus altilis
AUBREVIL_PLATYCA	Aubrevillea platycarpa
AULACOCA_JASMINI	Aulacocalyx jasminiflora
BAPHIA_NITIDA	Baphia nitida
BAPHIA_OBANENS	Baphia obanensis
BAPHIA_SPATHAC	Baphia spathacea
BAUHINIA_MONANDR	Bauhinia monandra
BEILSCHM_CHEVALI	Beilschmiedia chevalieri
BEILSCHM_MANNII	Beilschmiedia mannii
BERLINIA_AURICUL	Berlinia auriculate
BERLINIA_BRACTEO	Berlinia bracteosa
BERLINIA_GRANDIF	Berlinia grandiflora
BERLINIA_TOMENTE	Berlinia tomentella
BERTIERA_RACEMOS	Bertiera racemose
BERTIERA_RETROFR	Bertiera retrofracta
BERTIERA_SPICATA	Bertiera spicata
BLIGHIA_SAPIDA	Blighia sapida
BLIGHIA_UNIJUGA	Blighia unijugata
BOMBAX_BUONOPO	Bombax buonopozense
BRACHYST_LEONENS	Brachystegia leonensis
BRENANDE_DONIANU	Brenandendron donianum
BRENANDE_FRONDOS	Brenandendron frondosum
BREYNIA_DISTICH	Breynia disticha

Tree Species Code	Species Scientific Name
BRIDELIA_FERRUGI	Bridelia ferruginea
BRIDELIA_GRANDIS	Bridelia grandis
BRIDELIA_MICRANT	Bridelia micrantha
BUSSEA_OCCIDEN	Bussea occidentalis
CAESALPI_PULCHER	Caesalpinia pulcherrima
CALONCOB_BREVIPE	Caloncoba brevipes
CALONCOB_ECHINAT	Caloncoba echinata
CALPOCAL_AUBREVI	Calpocalyx aubrevillei
CALPOCAL_BREVIBR	Calpocalyx brevibracteatus
CAMPYLOS_AMPLECT	Campylospermum amplectens
CAMPYLOS_FLAVUM	Campylospermum flavum
CAMPYLOS_RETICUL	Campylospermum reticulatum
CAMPYLOS_SCHOENL	Campylospermum schoenleinianum
CARAPA_PROCERA	Carapa procera
CARICA_PAPAYA	Carica papaya
CARPOLOB_ALBA	Carpolobia alba
CARPOLOB_LUTEA	Carpolobia lutea
CASSIA_FIKIFIK	Cassia fikifiki
CASSIA_JAVANIC	Cassia javanica
CASSIPOU_GUMMIFL	Cassipourea gummiflua
CASSIPOU_HIOTOU	Cassipourea hiotou
CASUARIN_EQUISET	Casuarina equisetifolia
CEIBA_PENTAND	Ceiba pentandra
CELTIS_ADOLFI-	Celtis adolfi-friderici
CELTIS_MILDBRA	Celtis mildbraedii
CHIDLOWI_SANGUIN	Chidlowia sanguinea
CHRYSOBA_ICACO	Chrysobalanus icaco
CHRYSOPH_AFRICAN	Chrysophyllum africanum
CHRYSOPH_ALBIDUM	Chrysophyllum albidum
CHRYSOPH_GIGANTE	Chrysophyllum giganteum
CHRYSOPH_PERPULC	Chrysophyllum perpulchrum
CHRYSOPH_SPLENDE	Chrysophyllum splendens
CHRYSOPH_ SUBNUDU	Chrysophyllum subnudum
CHRYSOPH_TAIENSE	Chrysophyllum taiense
CHYTRANT_ANGUSTI	Chytranthus angustifolius
CITROPSI_GABUNEN	Citropsis gabunensis
CLEISTOP_PATENS	Cleistopholis patens
COELOCAR_SPHAERO	Coelocaryon sphaerocarpum
COFFEA_LIBERIC	Coffea liberica
COFFEA_MANNII	Coffea mannii
COLA_ACUMINA	Cola acuminata
COLA_ANGUSTI	Cola angustifolia
COLA_BALDWIN	Cola baldwinii
COLA_BUNTING	Cola buntingii
COLA_CARICIF	Cola caricifolia
COLA_CHLAMYD	Cola chlamydantha
COLA_DIGITAT	Cola digitata
COLA_GABONEN	Cola gabonensis
COLA_HETEROP	Cola heterophylla
COLA_HISPIDA	Cola hispida
COLA_LATERIT	Cola lateritia
COLA_NITIDA	Cola nitida
COPAIFER_SALIKOU	Copaifera salikounda
CORYNANT_PACHYCE	Corynanthe pachyceras
COULA_EDULIS	Coula edulis
CRATERIS_CAUDATU	Craterispermum caudatum
CROTONOG_CATERVI	Crotonogyne caterviflora
CRUDIA_GABONEN	Crudia gabonensis
CRUDIA_SENEGAL	Crudia senegalensis
CUSSONIA_ BANCOEN	Cussonia bancoensis
CYNOMETR_ANANTA	Cynometra ananta
CYNOMETR_ LEONENS	Cynometra leonensis
DACRYODE_EDULIS	Dacryodes edulis
DACRYODE_KLAINEA	Dacryodes klaineana
DACTYLAD_BARTERI	Dactyladenia barteri
DALBERGI_HEUDELO	Dalbergia heudelotii
DANIELLI_OGEA	Daniellia ogea
DANIELLI_THURIFE	Daniellia thurifera
DEINBOLL_CUNEIFO	Deinbollia cuneifolia
DEINBOLL_GRANDIF	Deinbollia grandifolia

Tree Species Code	Species Scientific Name
DESPLATS_SUBERIC	Desplatsia subericarpa
DETARIUM_MICROCA	Detarium microcarpum
DETARIUM_SENEGAL	Detarium senegalense
DIALIUM_AUBREVI	Dialium aubrevillei
DIALIUM_DINKLAG	Dialium dinklagei
DIALIUM_GUIANEN	Dialium guianense
DIALIUM_GUINEEN	Dialium guineense
DICHAPET_HEUDELO	Dichapetalum heudelotii
DICHAPET_MADAGAS	Dichapetalum madagascariense
DICHAPET_ZENKERI	Dichapetalum zenkeri
DIDELOTI_AFZELII	Didelotia afzelii
DIDELOTI_IDAE	Didelotia idae
DIDELOTI_UNIFOLI	Didelotia unifoliolata
DIOSPYRO_CHEVALI	Diospyros chevalieri
DIOSPYRO_COOPERI	Diospyros cooperi
DIOSPYRO_DICHROP	Diospyros dichrophylla
DIOSPYRO_ELLIOTI	Diospyros elliotii
DIOSPYRO_ GABUNEN	Diospyros gabunensis
DIOSPYRO_HEUDELO	Diospyros heudelotii
DIOSPYRO_KAMERUN	Diospyros kamerunensis
DIOSPYRO_LIBERIE	Diospyros liberiensis
DIOSPYRO_MANNII	Diospyros mannii
DIOSPYRO_PISCATO	Diospyros piscatoria
DIOSPYRO_SANZA-M	Diospyros sanza-minika
DIOSPYRO_THOMASI	Diospyros thomasii
DIOSPYRO_VIGNEI	Diospyros vignei
DISCOCLA_HEXANDR	Discoclaoxylon hexandrum
DISCOGLY_CALONEU	Discoglypremna caloneura
DISTEMON_ BENTHAM	Distemonanthus benthamianus
DONELLA_UBANGIE	Donella ubangiensis
DRYPETES_AFZELII	Drypetes afzelii
DRYPETES_AUBREVI	Drypetes aubrevillei
DRYPETES_AYLMERI	Drypetes aylmeri
DRYPETES_CHEVALI	Drypetes chevalieri
DRYPETES_FLORIBU	Drypetes floribunda
DRYPETES_INAEQUA	Drypetes inaequalis
DRYPETES_IVORENS	Drypetes ivorensis

Tree Species Code	Species Scientific Name
DRYPETES_KLAINEI	Drypetes klainei
DRYPETES_LEONENS	Drypetes leonensis
DRYPETES_PRINCIP	Drypetes principum
ELAEIS_GUINEEN	Elaeis guineensis
ENGLEROP_LAURENT	Englerophytum laurentii
ENTANDRO_ ANGOLEN	Entandrophragma angolense
ENTANDRO_ CANDOLL	Entandrophragma candollei
ENTANDRO_CYLINDR	Entandrophragma cylindricum
ENTANDRO_UTILE	Entandrophragma utile
ERIOCOEL_KERSTIN	Eriocoelum kerstingii
ERYTHRIN_SENEGAL	Erythrina senegalensis
ERYTHROP_IVORENS	Erythrophleum ivorense
ERYTHROP_SUAVEOL	Erythrophleum suaveolens
ERYTHROX_MANNII	Erythroxylum mannii
EUCALYPT_UTILIS	Eucalyptus utilis
EUGENIA_KALBREY	Eugenia kalbreyeri
EUGENIA_WHYTEI	Eugenia whytei
FICUS_BARTERI	Ficus barteri
FICUS_EXASPER	Ficus exasperata
FICUS_KAMERUN	Ficus kamerunensis
FICUS_LEONENS	Ficus leonensis
FICUS_MUCUSO	Ficus mucuso
FICUS_NATALEN	Ficus natalensis
FICUS_SUR	Ficus sur
FICUS_VOGELIA	Ficus vogeliana
FUNTUMIA_AFRICAN	Funtumia africana
FUNTUMIA_ELASTIC	Funtumia elastica
GARCINIA_AFZELII	Garcinia afzelii
GARCINIA_EPUNCTA	Garcinia epunctata
GARCINIA_KOLA	Garcinia kola
GARCINIA_MANNII	Garcinia mannii
GARCINIA_OVALIFO	Garcinia ovalifolia
GARCINIA_SMEATHM	Garcinia smeathmannii
GARUGA_PINNATA	Garuga pinnata
GILBERTI_BILINEA	Gilbertiodendron bilineatum
GILBERTI_IVORENS	Gilbertiodendron ivorense

Tree Species Code	Species Scientific Name
GILBERTI_LIMBA	Gilbertiodendron limba
GILBERTI_PREUSSI	Gilbertiodendron preussii
GILBERTI_SPLENDI	Gilbertiodendron splendidum
GLENNIEA_ADAMII	Glenniea adamii
GLUEMA_IVORENS	Gluema ivorensis
GREWIA_PRAECOX	Grewia praecox
GROSSERA_VIGNEI	Grossera vignei
GUIBOURT_COPALLI	Guibourtia copallifera
GUIBOURT_DINKLAG	Guibourtia dinklagei
GUIBOURT_EHIE	Guibourtia ehie
GUIBOURT_LEONENS	Guibourtia leonensis
HAPLORMO_MONOPHY	Haplormosia monophylla
HARRISON_ABYSSIN	Harrisonia abyssinica
HARUNGAN_MADAGAS	Harungana madagascariensis
HEISTERI_PARVIFO	Heisteria parvifolia
HERITIER_DENSIFL	Heritiera densiflora
HEVEA_BRASILI	Hevea brasiliensis
HIBISCUS_STERCUL	Hibiscus sterculiifolius
HOMALIUM_AFRICAN	Homalium africanum
HOMALIUM_LE-TEST	Homalium le-testui
HOMALIUM_LONGIST	Homalium longistylum
HOMALIUM_SMYTHEI	Homalium smythei
HOMALIUM_STIPULA	Homalium stipulaceum
HYMENOST_GRACILI	Hymenostegia gracilipes
IRVINGIA_GABONEN	Irvingia gabonensis
IXORA_SPP	Ixora sp.
JATROPHA_CURCAS	Jatropha curcas
KHAYA_IVORENS	Khaya ivorensis
KIGELIA_AFRICAN	Kigelia africana
KLAINEDO_GABONEN	Klainedoxa gabonensis
LECANIOD_CUPANIO	Lecaniodiscus cupanioides
LEPTONYC_OCCIDEN	Leptonychia occidentalis
LEUCAENA_LEUCOCE	Leucaena leucocephala
LOPHIRA_ALATA	Lophira alata
LOVOA_TRICHIL	Lovoa trichilioides
MACARANG_BARTERI	Macaranga barteri

Tree Species Code	Species Scientific Name
MACARANG_HETEROP	Macaranga heterophylla
MACARANG_HEUDELO	Macaranga heudelotii
MACARANG_HURIFOL	Macaranga hurifolia
MAESOBOT_BARTERI	Maesobotrya barteri
MAMMEA_AFRICAN	Mammea africana
MANGIFER_INDICA	Mangifera indica
MANILKAR_OBOVATA	Manilkara obovata
MARANTHE_AUBREVI	Maranthes aubrevillei
MARANTHE_CHRYSOP	Maranthes chrysophylla
MARANTHE_GLABRA	Maranthes glabra
MAREYA_MICRANT	Mareya micrantha
MARGARIT_DISCOID	Margaritaria discoidea
MARKHAMI_TOMENTO	Markhamia tomentosa
MELIA_AZEDARA	Melia azedarach
MEMECYLO_LATERIF	Memecylon lateriflorum
MEMECYLO_POLYANT	Memecylon polyanthemos
MICRODES_PUBERUL	Microdesmis puberula
MILICIA_EXCELSA	Milicia excelsa
MILICIA_REGIA	Milicia regia
MILLETTI_CHRYSOP	Millettia chrysophylla
MILLETTI_GRIFFON	Millettia griffoniana
MILLETTI_LANE-PO	Millettia lane-poolei
MILLETTI_PALLENS	Millettia pallens
MILLETTI_WARNECK	Millettia warneckei
MITRAGYN_LEDERMA	Mitragyna ledermannii
MONODORA_CRISPAT	Monodora crispata
MONODORA_MYRISTI	Monodora myristica
MORINDA_LUCIDA	Morinda lucida
MORINGA_OLEIFER	Moringa oleifera
MUSANGA_CECROPI	Musanga cecropioides
MYRIANTH_ARBOREU	Myrianthus arboreus
MYRIANTH_LIBERIC	Myrianthus libericus
MYRIANTH_SERRATU	Myrianthus serratus
NAPOLEON_ALATA	Napoleonaea alata
NAPOLEON_SAPOENS	Napoleonaea sapoensis
NAPOLEON_TALBOTI	Napoleonaea talbotii

Tree Species Code	Species Scientific Name
NAPOLEON_VOGELII	Napoleonaea vogelii
NAUCLEA_DIDERRI	Nauclea diderrichii
NAUCLEA_LATIFOL	Nauclea latifolia
NECEPSIA_AFZELII	Necepsia afzelii
NEOBOUTO_MANNII	Neoboutonia mannii
NEOLEMON_CLITAND	Neolemonniera clitandrifolia
NEOSTENA_GABONEN	Neostenanthera gabonensis
NEOSTENA_HAMATA	Neostenanthera hamata
NESOGORD_PAPAVER	Nesogordonia papaverifera
NEWBOULD_LAEVIS	Newbouldia laevis
NEWTONIA_AUBREVI	Newtonia aubrevillei
NEWTONIA_DUPARQU	Newtonia duparquetiana
NEWTONIA_GRIFFON	Newtonia griffoniana
OCHNA_AFZELII	Ochna afzelii
OCTOKNEM_BOREALI	Octoknema borealis
OKOUBAKA_AUBREVI	Okoubaka aubrevillei
OLDFIELD_AFRICAN	Oldfieldia africana
OMPHALOC_AHIA	Omphalocarpum ahia
OMPHALOC_ELATUM	Omphalocarpum elatum
ONGOKEA_GORE	Ongokea gore
OPHIOBOT_ZENKERI	Ophiobotrys zenkeri
PANDA_OLEOSA	Panda oleosa
PARAMACR_COERULE	Paramacrolobium coeruleum
PARINARI_CONGENS	Parinari congensis
PARINARI_EXCELSA	Parinari excelsa
PARKIA_BICOLOR	Parkia bicolor
PENTACLE_MACROPH	Pentaclethra macrophylla
PENTADES_BUTYRAC	Pentadesma butyracea
PETERSIA_MACROCA	Petersianthus macrocarpus
PIPTADEN_AFRICAN	Piptadeniastrum africanum
PIPTOSTI_FASCICU	Piptostigma fasciculatum
PLAGIOSI_EMARGIN	Plagiosiphon emarginatus
PLEIOCER_AFZELII	Pleioceras afzelii
POLYCERA_PARVIFL	Polyceratocarpus parviflorus

Tree Species Code	Species Scientific Name
POLYSTEM_DINKLAG	Polystemonanthus dinklagei
POUTERIA_CUSPIDA	Pouteria cuspidata
PROTOMEG_STAPFIA	Protomegabaria stapfiana
PSEUDOSP_MICROCA	Pseudospondias microcarpa
PSYCHOTR_LIMBA	Psychotria limba
PSYDRAX_ARNOLDI	Psydrax arnoldiana
PTEROCAR_MILDBRA	Pterocarpus mildbraedii
PTEROCAR_SANTALI	Pterocarpus santalinoides
PTERYGOT_BEQUAER	Pterygota bequaertii
PYCNANTH_ANGOLEN	Pycnanthus angolensis
PYCNOCOM_MACROPH	Pycnocoma macrophylla
QUASSIA_UNDULAT	Quassia undulata
RAPHIA_HOOKERI	Raphia hookeri
RAUVOLFI_MANNII	Rauvolfia mannii
RAUVOLFI_VOMITOR	Rauvolfia vomitoria
RINOREA_AYLMERI	Rinorea aylmeri
RINOREA_BRACHYP	Rinorea brachypetala
RINOREA_CLAESSE	Rinorea claessensii
RINOREA_ILICIFO	Rinorea ilicifolia
RINOREA_OBLONGI	Rinorea oblongifolia
RINOREA_PREUSSI	Rinorea preussii
RINOREA_WELWITS	Rinorea welwitschii
ROTHMANN_HISPIDA	Rothmannia hispida
ROTHMANN_WHITFIE	Rothmannia whitfieldii
SACOGLOT_GABONEN	Sacoglottis gabonensis
SALACIA_LEHMBAC	Salacia lehmbachii
SANTIRIA_TRIMERA	Santiria trimera
SCOTTELL_CORIACE	Scottellia coriacea
SCOTTELL_KLAINEA	Scottellia klaineana
SCYTOPET_TIEGHEM	Scytopetalum tieghemii
SENNA_ALATA	Senna alata
SENNA_PODOCAR	Senna podocarpa
SENNA_SIAMEA	Senna siamea
SHIRAKIO_AUBREVI	Shirakiopsis aubrevillei
SMEATHMA_PUBESCE	Smeathmannia pubescens

Tree Species Code	Species Scientific Name
SOLANUM_ANGUIVI	Solanum anguivi
SOLANUM_UMBELLA	Solanum umbellatum
SOPHORA_TOMENTO	Sophora tomentosa
SPONDIAN_PREUSSI	Spondianthus preussii
SPONDIAS_DULCIS	Spondias dulcis
SPONDIAS_MOMBIN	Spondias mombin
STACHYOT_STAPFIA	Stachyothyrsus stapfiana
STERCULI_LONGIFO	Sterculia longifolia
STERCULI_OBLONGA	Sterculia oblonga
STERCULI_TRAGACA	Sterculia tragacantha
STEREOSP_ACUMINA	Stereospermum acuminatissimum
STREBLUS_USAMBAR	Streblus usambarensis
STREPHON_PSEUDOC	Strephonema pseudocola
STROMBOS_NANA	Strombosiopsis nana
STROMBOS_PUSTULA	Strombosia pustulata
SYMPHONI_GLOBULI	Symphonia globulifera
SYNSEPAL_AFZELII	Synsepalum afzelii
SYNSEPAL_BREVIPE	Synsepalum brevipes
SYZYGIUM_GUINEEN	Syzygium guineense
SYZYGIUM_JAMBOS	Syzygium jambos
SYZYGIUM_ROWLAND	Syzygium rowlandii
SYZYGIUM_SAMOENS	Syzygium samoense
TABERNAE_AFRICAN	Tabernaemontana africana
TERMINAL_IVORENS	Terminalia ivorensis
TERMINAL_SUPERBA	Terminalia superba
TETRABER_TUBMANI	Tetraberlinia tubmaniana
TETRAPLE_CHEVALI	Tetrapleura chevalieri
TETRAPLE_TETRAPT	Tetrapleura tetraptera
TETRORCH_DIDYMOS	Tetrorchidium didymostemon
TETRORCH_OPPOSIT	Tetrorchidium oppositifolium
TIEGHEME_HECKELI	Tieghemella heckelii
TRECULIA_AFRICAN	Treculia africana
TRICALYS_RETICUL	Tricalysia reticulata

Tree Species Code	Species Scientific Name
TRICHILI_MONADEL	Trichilia monadelpha
TRICHILI_ORNITHO	Trichilia ornithothera
TRICHILI_TESSMAN	Trichilia tessmannii
TRICHOSC_ARBOREA	Trichoscypha arborea
TRICHOSC_BALDWIN	Trichoscypha baldwinii
TRICHOSC_BARBATA	Trichoscypha barbata
TRICHOSC_BIJUGA	Trichoscypha bijuga
TRICHOSC_CAVALLI	Trichoscypha cavalliensis
TRICHOSC_LIBERIC	Trichoscypha liberica
TRICHOSC_LONGIFO	Trichoscypha longifolia
TRILEPIS_MADAGAS	Trilepisium madagascariense
TRIPLOCH_SCLEROX	Triplochiton scleroxylon
TURRAEA_LEONENS	Turraea leonensis
UAPACA_GUINEEN	Uapaca guineensis
UAPACA_HEUDELO	Uapaca heudelotii
UAPACA_PYNAERT	Uapaca pynaertii
VEPRIS_SUAVEOL	Vepris suaveolens
VEPRIS_TABOUEN	Vepris tabouensis
VISMIA_GUINEEN	Vismia guineensis
VITEX_CHRYSOC	Vitex chrysocarpa
VITEX_CONGOLE	Vitex congolensis
VITEX_GRANDIF	Vitex grandifolia
VITEX_MICRANT	Vitex micrantha
VITEX_RIVULAR	Vitex rivularis
VOACANGA_THOUARS	Voacanga thouarsii
WARNECKE_FASCICU	Warneckea fascicularis
XYLIA_EVANSII	Xylia evansii
XYLOPIA_ACUTIFL	Xylopia acutiflora
XYLOPIA_AETHIOP	Xylopia aethiopica
XYLOPIA_ELLIOTI	Xylopia elliotii
XYLOPIA_LE-TEST	Xylopia le-testui
XYLOPIA_PARVIFL	Xylopia parviflora
XYLOPIA_QUINTAS	Xylopia quintasii
XYLOPIA_RUBESCE	Xylopia rubescens
XYLOPIA_STAUDTI	Xylopia staudtii
XYLOPIA_VILLOSA	Xylopia villosa
ZANTHOXY_ATCHOUM	Zanthoxylum atchoum

Annex IV. Biodiversity Tables

Annex IV provides additional information relating to the biodiversity analysis undertaken using the NFI data collected. The tables are included as an additional resource available to academia as well as those interested in biodiversity in Liberia.

Sample Completeness Data

The columns contain the following data

Diversity Order: The sample completeness order of q between 0 and 2 in increments of 0.25. The diversity order is reported using Hill numbers, which generalize diversity measures at rational orders.

s.e: Standard error of the estimated sample completeness.

Estimate: Estimated sample completeness

LCL, UCL: The bootstrap lower and upper confidence limits for the sample completeness of order q at the specified level (with a default value of 0.95).

Table 58. Sample completeness: Liberia

Diversity Order	s.e.	90% LCL	Estimate	90% UCL
0	0.03713	0.72	0.78	0.84
0.25	0.02282	0.81	0.85	0.89
0.5	0.01083	0.90	0.91	0.93
0.75	0.00395	0.95	0.96	0.97
1	0.00117	0.98	0.98	0.98
1.25	0.00035	0.99	0.99	0.99
1.5	0.00015	1.00	1.00	1.00
1.75	0.00007	1.00	1.00	1.00
2	0.00003	1.00	1.00	1.00

Table 59. Sample completeness: Priority Landscapes

Diversity Order	Community	s.e.	90% LCL	Estimate	90% UCL
0	Non_Priority	0.045385	0.68	0.75	0.83
0.25	Non_Priority	0.032079	0.76	0.81	0.87
0.5	Non_Priority	0.018722	0.85	0.88	0.91
0.75	Non_Priority	0.008885	0.91	0.93	0.94
1	Non_Priority	0.003474	0.96	0.96	0.97
1.25	Non_Priority	0.001212	0.98	0.98	0.98
1.5	Non_Priority	0.000504	0.99	0.99	0.99
1.75	Non_Priority	0.000284	1	1	1
2	Non_Priority	0.000163	1	1	1

Diversity Order	Community	s.e.	90% LCL	Estimate	90% UCL
0	Northwest_ Priority	0.037394	0.63	0.69	0.75
0.25	Northwest_ Priority	0.027814	0.71	0.76	0.8
0.5	Northwest_ Priority	0.017633	0.8	0.83	0.86
0.75	Northwest_ Priority	0.009272	0.88	0.9	0.91
1	Northwest_ Priority	0.004131	0.94	0.94	0.95
1.25	Northwest_ Priority	0.001751	0.97	0.97	0.98
1.5	Northwest_ Priority	0.000861	0.99	0.99	0.99
1.75	Northwest_ Priority	0.000486	0.99	0.99	1
2	Northwest_ Priority	0.000271	1	1	1
0	SouthEast_ Priority	0.037263	0.72	0.78	0.84
0.25	SouthEast_ Priority	0.024292	0.8	0.84	0.88
0.5	SouthEast_ Priority	0.01301	0.88	0.9	0.92
0.75	SouthEast_ Priority	0.005718	0.94	0.95	0.96
1	SouthEast_ Priority	0.002141	0.97	0.97	0.98
1.25	SouthEast_ Priority	0.000796	0.99	0.99	0.99
1.5	SouthEast_ Priority	0.000387	0.99	0.99	1
1.75	SouthEast_ Priority	0.000224	1	1	1
2	SouthEast_ Priority	0.000125	1	1	1

Table 60. Sample completeness: Counties

Diversity Order	Community	s.e.	90% LCL	Estimate	90% UCL
Priority Landscape 1 (North West)					
0	Bomi	0.108418	0.415418	0.59375	0.772082
0.25	Bomi	0.096727	0.460136	0.619237	0.778338
0.5	Bomi	0.078587	0.521727	0.65099	0.780254
0.75	Bomi	0.056702	0.597678	0.690945	0.784213
1	Bomi	0.036653	0.677155	0.737444	0.797733

Diversity Order	Community	s.e.	90% LCL	Estimate	90% UCL
1.25	Bomi	0.027175	0.742259	0.786958	0.831658
1.5	Bomi	0.0286	0.787946	0.834989	0.882031
1.75	Bomi	0.031325	0.826047	0.877572	0.929097
2	Bomi	0.031676	0.860328	0.91243	0.964533
0	Gbarpolu	0.047566	0.669812	0.748052	0.826292
0.25	Gbarpolu	0.037103	0.723166	0.784194	0.845222
0.5	Gbarpolu	0.025468	0.785038	0.826929	0.868821
0.75	Gbarpolu	0.015111	0.847727	0.872582	0.897437
1	Gbarpolu	0.007771	0.901686	0.914469	0.927252
1.25	Gbarpolu	0.003759	0.941225	0.947408	0.953592
1.5	Gbarpolu	0.002103	0.966525	0.969983	0.973442
1.75	Gbarpolu	0.001416	0.98151	0.983839	0.986169
2	Gbarpolu	0.000966	0.990084	0.991672	0.99326
0	Grand_Cape_Mount	0.064039	0.517854	0.623188	0.728523
0.25	Grand_Cape_Mount	0.054604	0.566969	0.656785	0.746601
0.5	Grand_Cape_Mount	0.042496	0.628423	0.698323	0.768223
0.75	Grand_Cape_Mount	0.02967	0.699253	0.748056	0.796859
1	Grand_Cape_Mount	0.018964	0.770428	0.80162	0.832813
1.25	Grand_Cape_Mount	0.012892	0.831853	0.853059	0.874265
1.5	Grand_Cape_Mount	0.010898	0.87929	0.897215	0.91514
1.75	Grand_Cape_Mount	0.009926	0.91521	0.931536	0.947862
2	Grand_Cape_Mount	0.008575	0.942038	0.956143	0.970247
0	Lofa	0.056261	0.458077	0.550617	0.643158
0.25	Lofa	0.047251	0.534182	0.611903	0.689624
0.5	Lofa	0.034641	0.636145	0.693124	0.750104
0.75	Lofa	0.021382	0.748146	0.783317	0.818488
1	Lofa	0.011256	0.845992	0.864507	0.883021
1.25	Lofa	0.005863	0.91441	0.924055	0.933699
1.5	Lofa	0.003637	0.954952	0.960934	0.966916
1.75	Lofa	0.002438	0.977113	0.981123	0.985134
2	Lofa	0.00156	0.988715	0.991281	0.993847
Non-PriorityLandscape					
0	Bong	0.065017	0.644438	0.751381	0.858325
0.25	Bong	0.053255	0.69605	0.783648	0.871245

Diversity Order	Community	s.e.	90% LCL	Estimate	90% UCL
0.5	Bong	0.038874	0.756049	0.819991	0.883932
0.75	Bong	0.025004	0.818273	0.8594	0.900528
1	Bong	0.014135	0.874178	0.897429	0.920679
1.25	Bong	0.00745	0.917755	0.930009	0.942263
1.5	Bong	0.004411	0.947765	0.955021	0.962276
1.75	Bong	0.003228	0.967208	0.972517	0.977827
2	Bong	0.002475	0.979812	0.983883	0.987955
0	Grand_Bassa	0.070509	0.491865	0.607843	0.723821
0.25	Grand_Bassa	0.056701	0.587041	0.680306	0.773571
0.5	Grand_Bassa	0.039449	0.694245	0.759132	0.82402
0.75	Grand_Bassa	0.023182	0.796567	0.834698	0.87283
1	Grand_Bassa	0.011679	0.877026	0.896236	0.915446
1.25	Grand_Bassa	0.006075	0.929653	0.939646	0.949639
1.5	Grand_Bassa	0.004275	0.959937	0.966968	0.973999
1.75	Grand_Bassa	0.003344	0.977259	0.98276	0.988261
2	Grand_Bassa	0.002446	0.987308	0.991332	0.995356
0	Margibi	0.127375	0.197894	0.407407	0.61692
0.25	Margibi	0.118587	0.252538	0.447597	0.642656
0.5	Margibi	0.100444	0.341021	0.506237	0.671453
0.75	Margibi	0.073658	0.466538	0.587695	0.708853
1	Margibi	0.046576	0.609168	0.685779	0.76239
1.25	Margibi	0.034002	0.728689	0.784616	0.840544
1.5	Margibi	0.032689	0.813231	0.866999	0.920768
1.75	Margibi	0.030135	0.875231	0.924798	0.974366
2	Margibi	0.024833	0.919347	0.960194	1
0	Maryland	0.067769	0.499269	0.610738	0.722208
0.25	Maryland	0.063255	0.525399	0.629445	0.733491
0.5	Maryland	0.056036	0.558179	0.65035	0.742522
0.75	Maryland	0.04728	0.598911	0.676679	0.754448
1	Maryland	0.037945	0.645808	0.708222	0.770636
1.25	Maryland	0.029696	0.695097	0.743942	0.792788
1.5	Maryland	0.024274	0.742091	0.782018	0.821946
1.75	Maryland	0.021982	0.784012	0.820169	0.856326
2	Maryland	0.021224	0.82125	0.85616	0.89107
0	Montserrado	0.157978	0.16872	0.428571	0.688423
0.25	Montserrado	0.144838	0.254215	0.492452	0.73069
0.5	Montserrado	0.116186	0.391727	0.582837	0.773946
0.75	Montserrado	0.075904	0.565686	0.690537	0.815388
1	Montserrado	0.038599	0.731592	0.795082	0.858572
1.25	Montserrado	0.019337	0.845985	0.877792	0.909598
1.5	Montserrado	0.015202	0.907902	0.932907	0.957913

Diversity Order	Community	s.e.	90% LCL	Estimate	90% UCL
1.75	Montserrado	0.013035	0.943863	0.965304	0.986745
2	Montserrado	0.010105	0.96618	0.9828	0.999421
0	Nimba	0.067678	0.600122	0.711443	0.822763
0.25	Nimba	0.05431	0.665192	0.754524	0.843856
0.5	Nimba	0.037975	0.741743	0.804207	0.866671
0.75	Nimba	0.02257	0.818773	0.855898	0.893022
1	Nimba	0.01158	0.883476	0.902523	0.92157
1.25	Nimba	0.005941	0.92927	0.939042	0.948814
1.5	Nimba	0.003871	0.957947	0.964313	0.97068
1.75	Nimba	0.00289	0.975407	0.980161	0.984915
2	Nimba	0.002083	0.985969	0.989395	0.992821
Priority Landscape 2 (South East)					
0	Grand_Gedeh	0.046502	0.686222	0.762712	0.839201
0.25	Grand_Gedeh	0.034477	0.755826	0.812536	0.869246
0.5	Grand_Gedeh	0.022399	0.826295	0.863139	0.899982
0.75	Grand_Gedeh	0.012707	0.887515	0.908416	0.929317
1	Grand_Gedeh	0.006399	0.932991	0.943516	0.954041
1.25	Grand_Gedeh	0.00312	0.962374	0.967506	0.972638
1.5	Grand_Gedeh	0.001765	0.979419	0.982323	0.985227
1.75	Grand_Gedeh	0.001188	0.988839	0.990793	0.992747
2	Grand_Gedeh	0.000817	0.994019	0.995364	0.996708
0	Grand_Kru	0.064961	0.687041	0.793893	0.900745
0.25	Grand_Kru	0.053017	0.725001	0.812206	0.89941
0.5	Grand_Kru	0.039361	0.767593	0.832336	0.897079
0.75	Grand_Kru	0.026494	0.811158	0.854737	0.898315
1	Grand_Kru	0.016332	0.851291	0.878156	0.90502
1.25	Grand_Kru	0.010208	0.88432	0.90111	0.917901
1.5	Grand_Kru	0.007992	0.909092	0.922238	0.935383
1.75	Grand_Kru	0.007485	0.928277	0.940588	0.952899
2	Grand_Kru	0.006955	0.944295	0.955735	0.967174
0	River_Gee	0.073271	0.616066	0.736585	0.857105
0.25	River_Gee	0.05901	0.676616	0.773679	0.870741
0.5	River_Gee	0.042373	0.742314	0.812011	0.881708
0.75	River_Gee	0.026458	0.807851	0.85137	0.894889
1	River_Gee	0.014255	0.864723	0.888171	0.911619
1.25	River_Gee	0.007567	0.907193	0.91964	0.932087
1.5	River_Gee	0.005839	0.934902	0.944507	0.954111
1.75	River_Gee	0.005569	0.953753	0.962913	0.972074
2	River_Gee	0.004983	0.967657	0.975854	0.98405
0	Rivercess	0.048928	0.713171	0.793651	0.874131
0.25	Rivercess	0.036367	0.775015	0.834833	0.894652

Diversity Order	Community	s.e.	90% LCL	Estimate	90% UCL
0.5	Rivercess	0.023775	0.835382	0.874488	0.913594
0.75	Rivercess	0.013665	0.888636	0.911113	0.93359
1	Rivercess	0.007012	0.929581	0.941115	0.952649
1.25	Rivercess	0.003501	0.957426	0.963184	0.968943
1.5	Rivercess	0.00207	0.974637	0.978042	0.981447
1.75	Rivercess	0.001495	0.984919	0.987379	0.989839
2	Rivercess	0.001112	0.991122	0.99295	0.994779

Diversity Profile Data

The columns contain the following data

Diversity Order: The sample completeness order of q between 0 and 2 in increments of 0.25. The diversity order is reported using Hill numbers, which generalize diversity measures at rational orders.

Target: The target statistic chosen could be either entropy or diversity. Liberia made use of the diversity measure, as it is more useful to understand the diversity dynamics present in the country.

s.e: Standard error of the diversity measure.

Estimate: Estimated diversity measure using the Chao and Jost (2015) method

LCL, UCL: The bootstrap lower and upper confidence limits for diversity order q at the specified level (with a default value of 0.95).

Table 61. Diversity profile data: Liberia

Diversity Order	Target	s.e.	90% LCL	Empirical	90% UCL
0	Diversity	9.88	493.53	511.00	526.73
0.25	Diversity	6.51	375.06	386.55	396.29
0.5	Diversity	4.42	288.45	296.36	303.14
0.75	Diversity	3.26	229.00	234.22	239.87
1	Diversity	2.64	188.12	192.16	196.32
1.25	Diversity	2.32	159.96	163.35	166.84
1.5	Diversity	2.13	140.07	143.04	146.24
1.75	Diversity	2.02	125.23	128.19	130.98
2	Diversity	1.96	113.80	116.97	119.57

Table 62. Diversity profile data: Priority Landscapes

Diversity Order	Target	s.e.	90% LCL	Empirical	90% UCL	Community
0	Diversity	5.78	277.15	286.00	294.70	Non_Priority
0.25	Diversity	4.44	228.38	235.06	241.67	Non_Priority
0.5	Diversity	3.56	187.79	193.50	198.87	Non_Priority

Diversity Order	Target	s.e.	90% LCL	Empirical	90% UCL	Community
0.75	Diversity	3.08	156.19	160.93	165.34	Non_Priority
1	Diversity	2.85	131.34	136.03	139.62	Non_Priority
1.25	Diversity	2.74	112.50	117.18	121.06	Non_Priority
1.5	Diversity	2.69	98.25	102.86	106.96	Non_Priority
1.75	Diversity	2.65	87.32	91.86	96.09	Non_Priority
2	Diversity	2.61	79.06	83.28	87.55	Non_Priority
0	Diversity	8.89	380.09	392.00	408.74	Northwest_Priority
0.25	Diversity	6.95	316.47	325.61	339.07	Northwest_Priority
0.5	Diversity	5.43	261.82	269.03	280.78	Northwest_Priority
0.75	Diversity	4.44	217.17	223.13	232.04	Northwest_Priority
1	Diversity	3.91	181.55	187.34	193.44	Northwest_Priority
1.25	Diversity	3.67	154.25	160.09	165.07	Northwest_Priority
1.5	Diversity	3.59	134.08	139.52	145.30	Northwest_Priority
1.75	Diversity	3.56	118.87	123.92	129.89	Northwest_Priority
2	Diversity	3.54	107.17	111.94	117.44	Northwest_Priority
0	Diversity	6.53	307.60	318.00	329.15	SouthEast_Priority
0.25	Diversity	4.92	253.19	260.80	268.47	SouthEast_Priority
0.5	Diversity	3.97	210.12	216.00	222.30	SouthEast_Priority
0.75	Diversity	3.41	176.75	182.11	187.95	SouthEast_Priority
1	Diversity	3.03	151.89	156.88	162.26	SouthEast_Priority
1.25	Diversity	2.76	134.03	138.08	142.94	SouthEast_Priority
1.5	Diversity	2.56	120.34	123.88	128.39	SouthEast_Priority
1.75	Diversity	2.42	109.48	112.95	117.27	SouthEast_Priority
2	Diversity	2.33	101.16	104.36	108.49	SouthEast_Priority

Table 63. Diversity profile data: Counties

Diversity Order	Target	s.e.	90% LCL	Empirical	90% UCL	Community
Priority Landscape 1						
0	Diversity	4.12	50.88	57.00	63.43	Bomi
0.25	Diversity	4.01	48.40	53.92	60.42	Bomi
0.5	Diversity	3.91	44.90	50.85	57.46	Bomi
0.75	Diversity	3.83	41.92	47.83	54.66	Bomi
1	Diversity	3.78	38.99	44.92	51.65	Bomi
1.25	Diversity	3.75	36.22	42.18	49.01	Bomi
1.5	Diversity	3.75	33.62	39.65	46.57	Bomi
1.75	Diversity	3.76	31.23	37.34	44.34	Bomi
2	Diversity	3.78	29.17	35.27	42.08	Bomi
0	Diversity	6.89	277.49	288.00	298.04	Gbarpolu
0.25	Diversity	5.89	241.13	250.36	259.21	Gbarpolu
0.5	Diversity	5.15	206.87	216.11	224.39	Gbarpolu

Diversity Order	Target	s.e.	90% LCL	Empirical	90% UCL	Community
0.75	Diversity	4.70	179.25	186.24	193.48	Gbarpolu
1	Diversity	4.45	154.85	161.18	167.77	Gbarpolu
1.25	Diversity	4.32	134.05	140.81	146.81	Gbarpolu
1.5	Diversity	4.23	117.27	124.59	130.26	Gbarpolu
1.75	Diversity	4.15	104.13	111.78	117.18	Gbarpolu
2	Diversity	4.07	94.16	101.67	107.07	Gbarpolu
0	Diversity	5.14	120.34	129.00	136.44	Grand_ Cape_Mount
0.25	Diversity	4.80	110.96	119.50	126.27	Grand_ Cape_Mount
0.5	Diversity	4.56	102.28	110.23	116.48	Grand_ Cape_Mount
0.75	Diversity	4.41	93.83	101.43	107.37	Grand_ Cape_Mount
1	Diversity	4.33	85.88	93.28	99.27	Grand_ Cape_Mount
1.25	Diversity	4.26	78.61	85.91	92.10	Grand_ Cape_Mount
1.5	Diversity	4.19	72.34	79.39	85.71	Grand_ Cape_Mount
1.75	Diversity	4.11	67.09	73.70	79.85	Grand_ Cape_Mount
2	Diversity	4.03	62.62	68.79	74.91	Grand_ Cape_Mount
0	Diversity	6.90	211.23	223.00	232.78	Lofa
0.25	Diversity	6.13	183.91	194.47	203.71	Lofa
0.5	Diversity	5.47	159.41	168.16	176.66	Lofa
0.75	Diversity	4.92	137.82	144.97	153.19	Lofa
1	Diversity	4.50	118.87	125.41	133.06	Lofa
1.25	Diversity	4.17	104.42	109.46	116.48	Lofa
1.5	Diversity	3.93	92.08	96.71	102.80	Lofa
1.75	Diversity	3.76	81.61	86.62	92.44	Lofa
2	Diversity	3.64	73.29	78.60	84.60	Lofa
Non-PriorityLandscape						
0	Diversity	5.69	127.12	136.00	147.22	Bong
0.25	Diversity	5.14	114.57	122.11	132.15	Bong
0.5	Diversity	4.67	102.70	109.23	117.62	Bong
0.75	Diversity	4.29	91.76	97.66	104.80	Bong
1	Diversity	4.01	81.72	87.53	93.72	Bong
1.25	Diversity	3.80	73.38	78.86	84.39	Bong
1.5	Diversity	3.66	66.12	71.55	76.85	Bong
1.75	Diversity	3.56	60.11	65.42	70.43	Bong
2	Diversity	3.50	55.02	60.29	65.21	Bong

Diversity Order	Target	s.e.	90% LCL	Empirical	90% UCL	Community
0	Diversity	6.13	113.89	124.00	132.44	Grand_ Bassa
0.25	Diversity	5.38	102.33	111.26	119.30	Grand_ Bassa
0.5	Diversity	4.69	92.01	99.67	106.83	Grand_ Bassa
0.75	Diversity	4.09	82.53	89.40	95.58	Grand_ Bassa
1	Diversity	3.61	74.72	80.50	85.78	Grand_ Bassa
1.25	Diversity	3.24	67.99	72.92	77.44	Grand_ Bassa
1.5	Diversity	2.98	62.03	66.53	70.78	Grand_ Bassa
1.75	Diversity	2.82	56.70	61.16	65.14	Grand_ Bassa
2	Diversity	2.72	52.35	56.65	60.74	Grand_ Bassa
0	Diversity	4.91	36.12	44.00	51.12	Margibi
0.25	Diversity	4.78	32.90	40.86	47.82	Margibi
0.5	Diversity	4.66	29.91	37.58	44.59	Margibi
0.75	Diversity	4.53	27.07	34.23	41.36	Margibi
1	Diversity	4.39	23.90	30.93	38.06	Margibi
1.25	Diversity	4.23	21.02	27.79	34.32	Margibi
1.5	Diversity	4.03	18.51	24.93	30.76	Margibi
1.75	Diversity	3.82	16.38	22.41	27.66	Margibi
2	Diversity	3.59	14.84	20.27	25.58	Margibi
0	Diversity	5.13	82.87	91.00	99.07	Maryland
0.25	Diversity	4.95	79.43	87.26	95.10	Maryland
0.5	Diversity	4.81	75.95	83.48	91.11	Maryland
0.75	Diversity	4.70	72.47	79.72	87.15	Maryland
1	Diversity	4.64	68.60	76.03	83.31	Maryland
1.25	Diversity	4.63	64.76	72.44	80.05	Maryland
1.5	Diversity	4.67	61.42	68.99	76.67	Maryland
1.75	Diversity	4.73	58.37	65.71	73.27	Maryland
2	Diversity	4.82	55.50	62.63	70.71	Maryland
0	Diversity	3.38	30.45	36.00	41.10	Montserrado
0.25	Diversity	3.11	27.58	32.75	37.83	Montserrado
0.5	Diversity	2.84	25.03	29.63	34.45	Montserrado
0.75	Diversity	2.58	22.86	26.74	31.16	Montserrado
1	Diversity	2.35	20.69	24.14	28.12	Montserrado
1.25	Diversity	2.15	18.73	21.86	25.60	Montserrado
1.5	Diversity	1.98	16.92	19.91	23.14	Montserrado

Diversity Order	Target	s.e.	90% LCL	Empirical	90% UCL	Community
1.75	Diversity	1.85	15.35	18.26	21.07	Montserrado
2	Diversity	1.76	14.01	16.88	19.43	Montserrado
0	Diversity	5.85	133.38	143.00	151.03	Nimba
0.25	Diversity	5.24	117.18	126.44	133.83	Nimba
0.5	Diversity	4.72	102.96	111.28	118.60	Nimba
0.75	Diversity	4.29	90.62	97.91	105.41	Nimba
1	Diversity	3.93	80.14	86.53	93.36	Nimba
1.25	Diversity	3.64	71.18	77.10	83.16	Nimba
1.5	Diversity	3.40	63.87	69.42	75.12	Nimba
1.75	Diversity	3.20	58.03	63.21	68.85	Nimba
2	Diversity	3.04	53.42	58.18	63.43	Nimba
Priority Landscape 2						
0	Diversity	5.13	216.84	225.00	232.94	Grand_ Gedeh
0.25	Diversity	4.41	190.41	196.79	202.71	Grand_ Gedeh
0.5	Diversity	3.92	167.30	172.35	177.63	Grand_ Gedeh
0.75	Diversity	3.62	146.76	151.79	156.74	Grand_ Gedeh
1	Diversity	3.47	129.98	134.90	140.00	Grand_ Gedeh
1.25	Diversity	3.41	116.31	121.19	126.53	Grand_ Gedeh
1.5	Diversity	3.39	105.23	110.12	115.58	Grand_ Gedeh
1.75	Diversity	3.38	96.26	101.17	106.72	Grand_ Gedeh
2	Diversity	3.38	88.90	93.88	99.44	Grand_ Gedeh
0	Diversity	3.91	96.55	104.00	109.10	Grand_Kru
0.25	Diversity	3.58	90.19	97.36	101.90	Grand_Kru
0.5	Diversity	3.34	84.62	91.11	95.28	Grand_Kru
0.75	Diversity	3.20	78.86	85.32	89.27	Grand_Kru
1	Diversity	3.16	73.49	80.04	83.79	Grand_Kru
1.25	Diversity	3.18	69.00	75.29	78.85	Grand_Kru
1.5	Diversity	3.26	64.68	71.04	74.62	Grand_Kru
1.75	Diversity	3.37	60.66	67.28	71.17	Grand_Kru
2	Diversity	3.49	57.49	63.94	68.10	Grand_Kru
0	Diversity	5.33	143.24	151.00	159.24	River_Gee
0.25	Diversity	4.77	132.75	139.33	146.67	River_Gee
0.5	Diversity	4.32	122.51	128.56	135.47	River_Gee
0.75	Diversity	4.00	112.99	118.85	125.54	River_Gee

Diversity Order	Target	s.e.	90% LCL	Empirical	90% UCL	Community
1	Diversity	3.79	104.44	110.24	116.54	River_Gee
1.25	Diversity	3.66	96.82	102.73	108.42	River_Gee
1.5	Diversity	3.60	90.13	96.23	101.32	River_Gee
1.75	Diversity	3.58	84.46	90.63	95.85	River_Gee
2	Diversity	3.59	79.67	85.81	91.17	River_Gee
0	Diversity	5.49	143.03	150.00	159.33	Rivercess
0.25	Diversity	4.72	126.66	133.48	141.96	Rivercess
0.5	Diversity	4.11	112.54	119.06	125.52	Rivercess
0.75	Diversity	3.69	101.05	106.81	111.79	Rivercess
1	Diversity	3.40	91.23	96.62	101.11	Rivercess
1.25	Diversity	3.22	82.94	88.24	92.68	Rivercess
1.5	Diversity	3.11	76.14	81.38	86.20	Rivercess
1.75	Diversity	3.05	70.75	75.76	80.94	Rivercess
2	Diversity	3.01	66.28	71.12	76.14	Rivercess

Annex V. Field Forms – Biophysical Survey

Form F1. Access to cluster plot

Cluster Plot Form | Plot

1. Cluster Plot number
Start access date ___/___/___
Start access time ___:___

End access date ___/___/___
End access time ___:___

Team

Team number ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6
Team Leader

Cluster Plot description

Cluster Plot remarks

Settlement

District

Access route

Description	Coordinates SRS	GPS Y	GPS X	Access photo code	Bearing
	EPSG:4326				
	EPSG:4326				
	EPSG:4326				
	EPSG:4326				
	EPSG:4326				
	EPSG:4326				
	EPSG:4326				
	EPSG:4326				
	EPSG:4326				
	EPSG:4326				

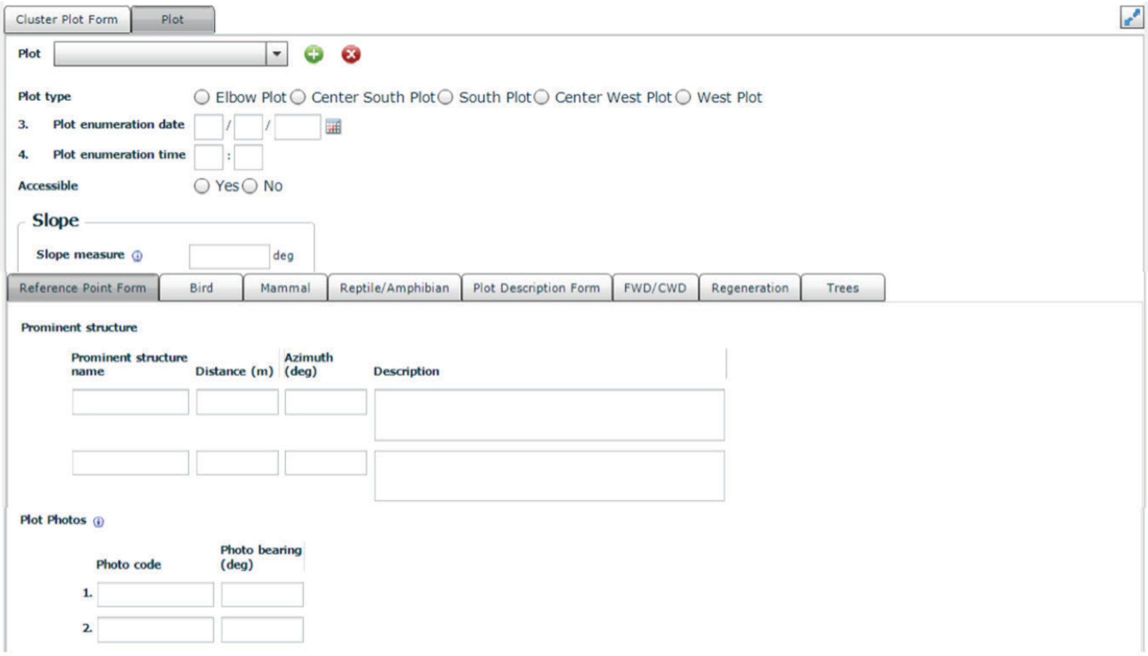
Add

Form F1A. Sketch for access to cluster plot

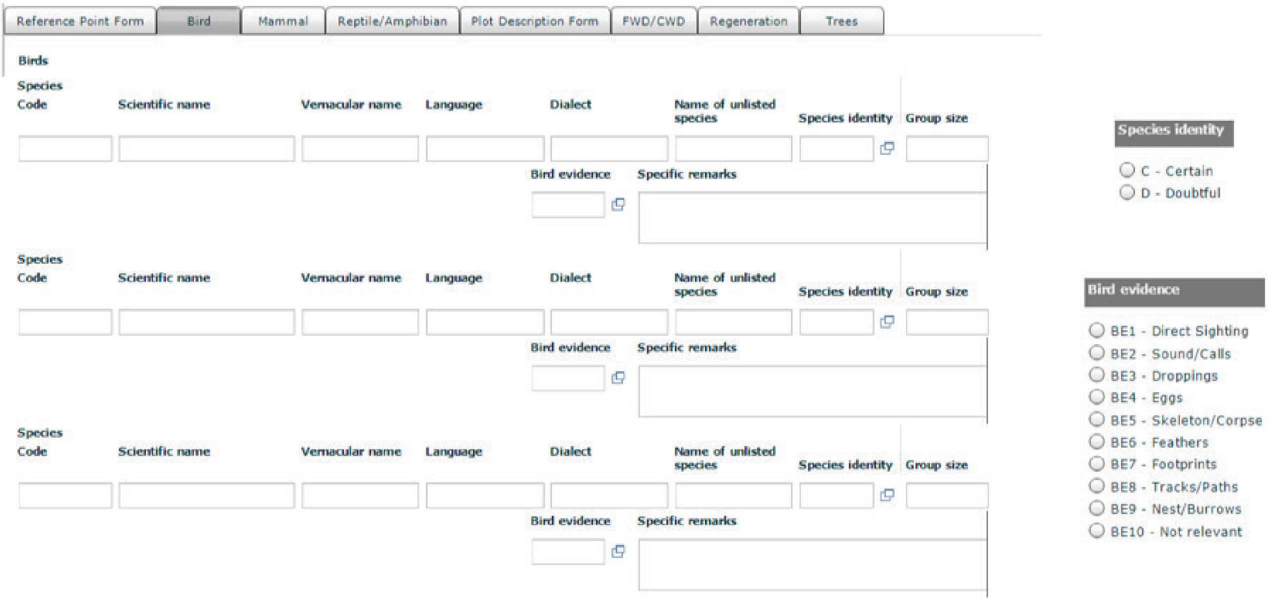
Cluster Plot Form | Plot

1. Cluster Plot number

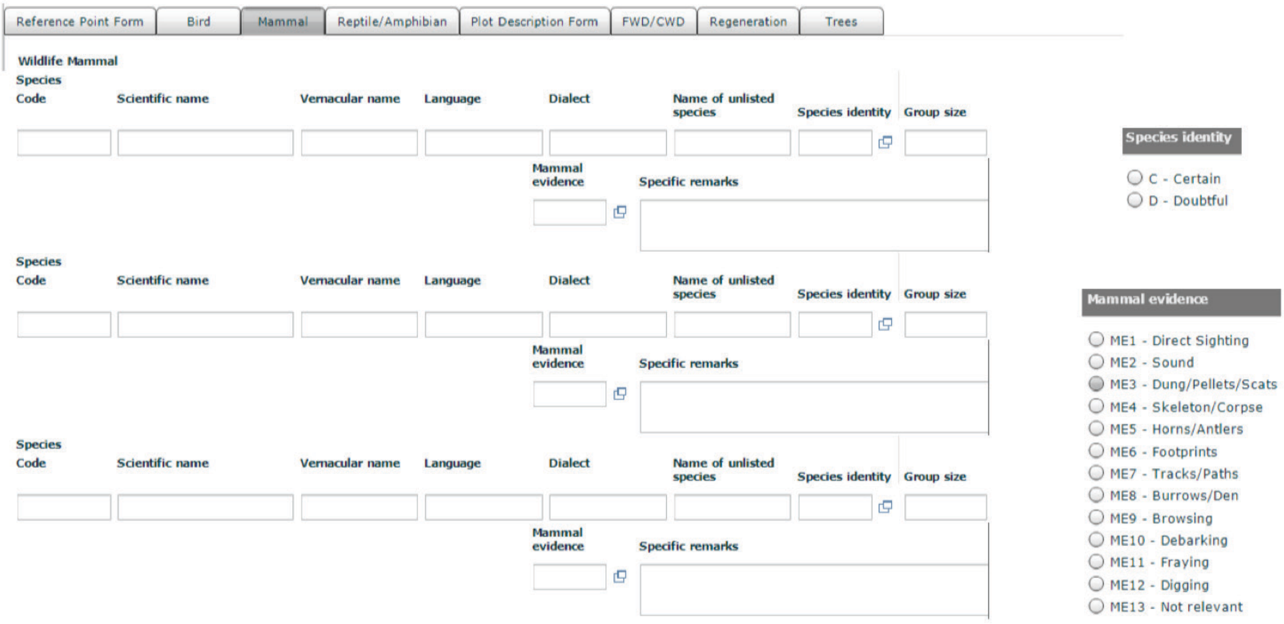
Form F2. Plot identification and Plot Reference Point



Form F3. Bird identification



Form F4. Mammal identification



Reference Point Form | Bird | Mammal | Reptile/Amphibian | Plot Description Form | FWD/CWD | Regeneration | Trees

Wildlife Mammal

Species Code | Scientific name | Vernacular name | Language | Dialect | Name of unlisted species | Species identity | Group size

Mammal evidence | Specific remarks

Species Code | Scientific name | Vernacular name | Language | Dialect | Name of unlisted species | Species identity | Group size

Mammal evidence | Specific remarks

Species Code | Scientific name | Vernacular name | Language | Dialect | Name of unlisted species | Species identity | Group size

Mammal evidence | Specific remarks

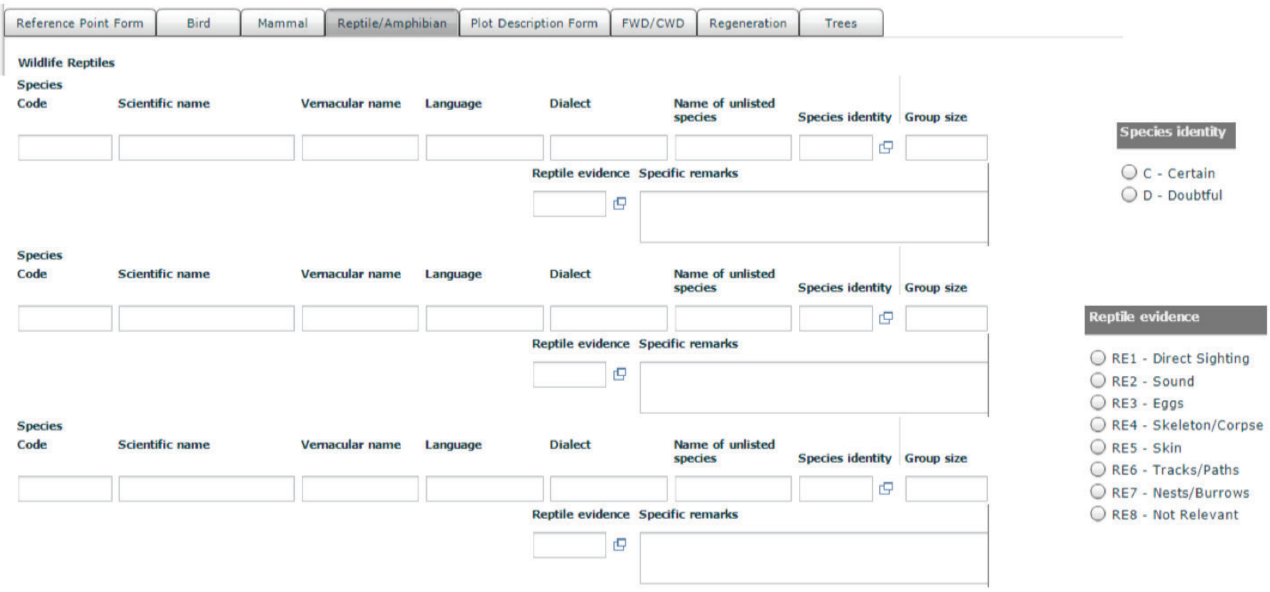
Species identity

- C - Certain
- D - Doubtful

Mammal evidence

- ME1 - Direct Sighting
- ME2 - Sound
- ME3 - Dung/Pellets/Scats
- ME4 - Skeleton/Corpse
- ME5 - Horns/Antlers
- ME6 - Footprints
- ME7 - Tracks/Paths
- ME8 - Burrows/Den
- ME9 - Browsing
- ME10 - Debarking
- ME11 - Fraying
- ME12 - Digging
- ME13 - Not relevant

Form F5. Reptile identification



Reference Point Form | Bird | Mammal | Reptile/Amphibian | Plot Description Form | FWD/CWD | Regeneration | Trees

Wildlife Reptiles

Species Code | Scientific name | Vernacular name | Language | Dialect | Name of unlisted species | Species identity | Group size

Reptile evidence | Specific remarks

Species Code | Scientific name | Vernacular name | Language | Dialect | Name of unlisted species | Species identity | Group size

Reptile evidence | Specific remarks

Species Code | Scientific name | Vernacular name | Language | Dialect | Name of unlisted species | Species identity | Group size

Reptile evidence | Specific remarks

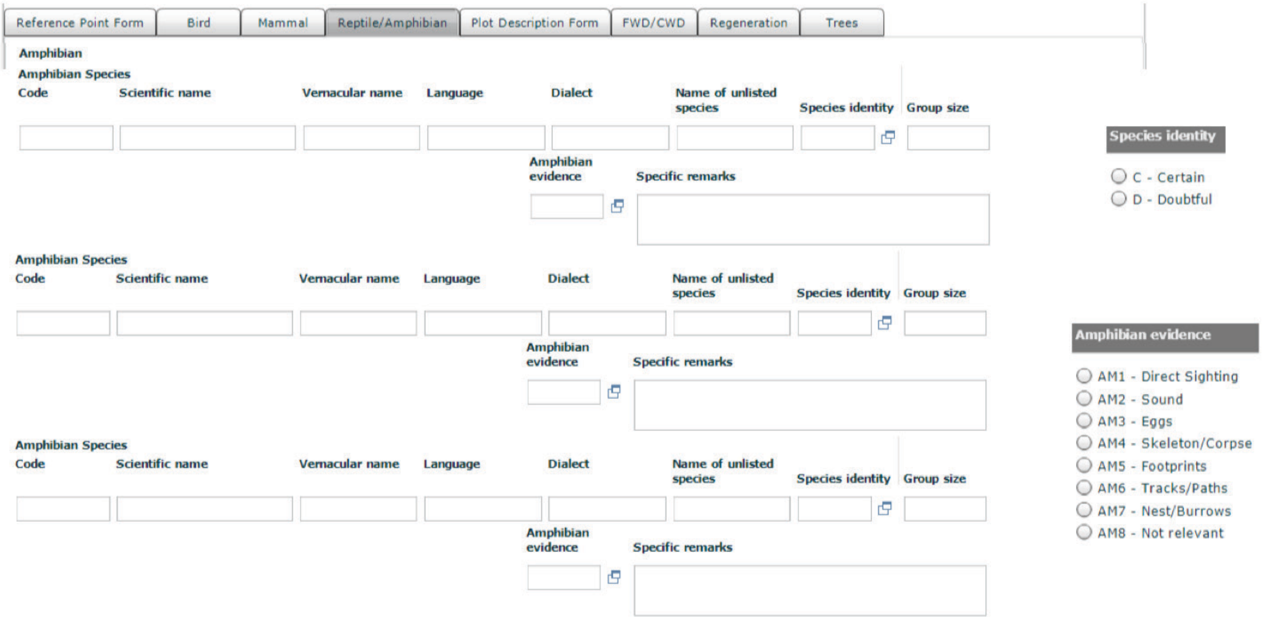
Species identity

- C - Certain
- D - Doubtful

Reptile evidence

- RE1 - Direct Sighting
- RE2 - Sound
- RE3 - Eggs
- RE4 - Skeleton/Corpse
- RE5 - Skin
- RE6 - Tracks/Paths
- RE7 - Nests/Burrows
- RE8 - Not Relevant

Form F6. Amphibian identification


Reference Point Form | Bird | Mammal | Reptile/Amphibian | Plot Description Form | FWD/CWD | Regeneration | Trees

Amphibian

Amphibian Species

Code | Scientific name | Vernacular name | Language | Dialect | Name of unlisted species | Species identity | Group size

Amphibian evidence | Specific remarks

Amphibian Species

Code | Scientific name | Vernacular name | Language | Dialect | Name of unlisted species | Species identity | Group size

Amphibian evidence | Specific remarks

Amphibian Species

Code | Scientific name | Vernacular name | Language | Dialect | Name of unlisted species | Species identity | Group size

Amphibian evidence | Specific remarks

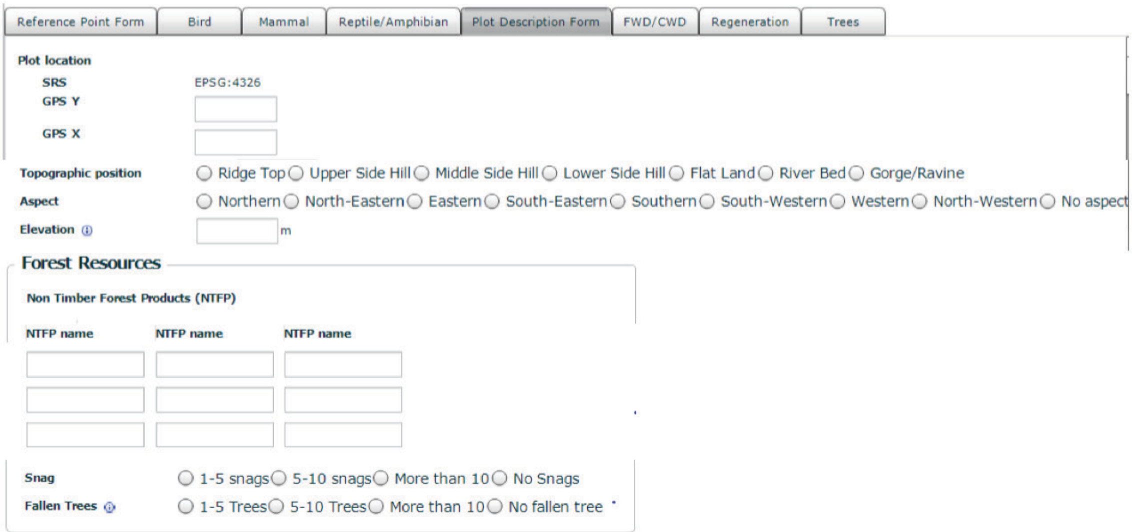
Species identity

- C - Certain
- D - Doubtful

Amphibian evidence

- AM1 - Direct Sighting
- AM2 - Sound
- AM3 - Eggs
- AM4 - Skeleton/Corpse
- AM5 - Footprints
- AM6 - Tracks/Paths
- AM7 - Nest/Burrows
- AM8 - Not relevant

Form F7. Plot Description. Forest Resources


Reference Point Form | Bird | Mammal | Reptile/Amphibian | Plot Description Form | FWD/CWD | Regeneration | Trees

Plot location

SRS: EPSG:4326

GPS Y

GPS X

Topographic position: Ridge Top, Upper Side Hill, Middle Side Hill, Lower Side Hill, Flat Land, River Bed, Gorge/Ravine

Aspect: Northern, North-Eastern, Eastern, South-Eastern, Southern, South-Western, Western, North-Western, No aspect

Elevation: m

Forest Resources

Non Timber Forest Products (NTFP)

NTFP name | NTFP name | NTFP name

Snag: 1-5 snags, 5-10 snags, More than 10, No Snags

Fallen Trees: 1-5 Trees, 5-10 Trees, More than 10, No fallen tree

Form F8. Plot Description. Stand description, main understory type and disturbances

Stand description

Land ownership	◯ Private ◯ Protected ◯ Communal ◯ Sacred ◯ Don't know
Land ownership note	
Land Use class	◯ Forest ◯ Cropland ◯ Wetland ◯ Grassland ◯ Settlement ◯ Shrubland/Woodland ◯ Water ◯ Rocky outcrop ◯ Other land

If Forest

Land Use subdivision ⓘ	◯ Forest protected area ◯ Forest/Timber extraction ◯ Community forest ◯ Mangroves ◯ Forest plantation
Successional status	◯ Primary forest (old growth) ◯ Secondary forest young ⓘ ◯ Secondary forest old ⓘ
Forest type	◯ Not sure ◯ Savannah ◯ Mangrove ◯ Mountain ◯ Plantation ◯ Semidecideous ◯ Evergreen

If Cropland

Land Use subdivision ⓘ	◯ Cropland rubber ◯ Cropland oil palm ◯ Cropland cocoa ◯ Cropland coffee ◯ Cropland annual ◯ Cropland fallow ◯ Cropland mixed ⓘ ◯ Cropland unknown

Main understorey type

Moss	☐
Grass	☐
Herbs	☐
Bamboo	☐
Shrubs	☐
Lianas	☐
Palms	☐
Others	☐
If other understorey, specify	

Disturbance

Forest fire extent	◯ Heavy Fire ◯ Moderate Fire ◯ Light Fire ◯ No Fire
Fire type	◯ Surface ◯ Crown ◯ Not Sure ◯ No fire signs
Grazing evidence	☐
Grazing incidence	◯ Slight ◯ Moderate ◯ Severe ◯ None
Timber extraction	◯ Yes, Clear Cutting ◯ Yes, Selective Felling ◯ Yes, Group Felling ◯ Others ◯ No Felling
Mining	◯ Yes, Surface Collection ◯ Yes Quarry ◯ No

Form F9. Plot Description. Health, litter/fuelbed, soil and canopy cover

Forest Health

Pest and disease evidence	☐
Other forest health issues ⓘ	

Duff, litter and fuelbed

Litter depth value ⓘ		cm
Humus depth value ⓘ		cm
Fuelbed depth value ⓘ		cm
Bare soil cover percent ⓘ		%

Soil

Stoniness	◯ None ◯ Rare >10% ◯ Few, 10-20% ◯ Common, 20-30% ◯ Many, 30-60% ◯ Abundant, >60%
Soil Drainage	◯ Poorly Drained ◯ Moderately Drained ◯ Well Drained
Top soil colour	◯ Dark ◯ Reddish ◯ Yellowish ◯ Others
Top soil texture	◯ Sand ◯ Loam ◯ Silt ◯ Clay ◯ Others
Evidence gully	☐
Evidence erosion	☐

Water bodies	◯ Stream/River ◯ Wetland/marshy area ◯ Lake ◯ Pond ◯ No Water bodies

Canopy cover

	Canopy cover measurement position	Number of shaded squares
1.		
2.		
3.		
4.		

Canopy cover

◯ N - North
◯ E - East
◯ S - South
◯ W - West

Form F10. FWD/CWD. Fine woody debris

Reference Point Form | Bird | Mammal | Reptile/Amphibian | Plot Description Form | FWD/CWD | Regeneration | Trees

Fine woody debris

Diameter at intersection (cm)	FWD decomposition status	Diameter at intersection (cm)	FWD decomposition status	Diameter at intersection (cm)	FWD decomposition status	Diameter at intersection (cm)	FWD decomposition status	Diameter at intersection (cm)	FWD decomposition status

FWD general plot remarks

FWD decomposition status

- V - Very decomposed
- H - Half decomposed
- N - Not decomposed

Form F11. FWD/CWD. Coarse woody debris

Reference Point Form | Bird | Mammal | Reptile/Amphibian | Plot Description Form | FWD/CWD | Regeneration | Trees

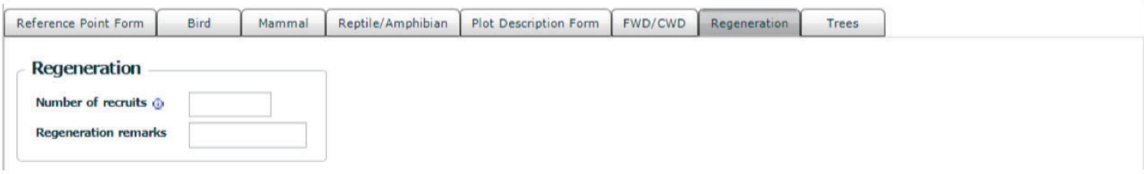
Coarse woody debris

Diameter large end (cm)	Diameter small end (cm)	CWD length (m)	CWD decomposition status	Remarks

FWD decomposition status

- V - Very decomposed
- H - Half decomposed
- N - Not decomposed

Form F12. FWD/CWD. Regeneration



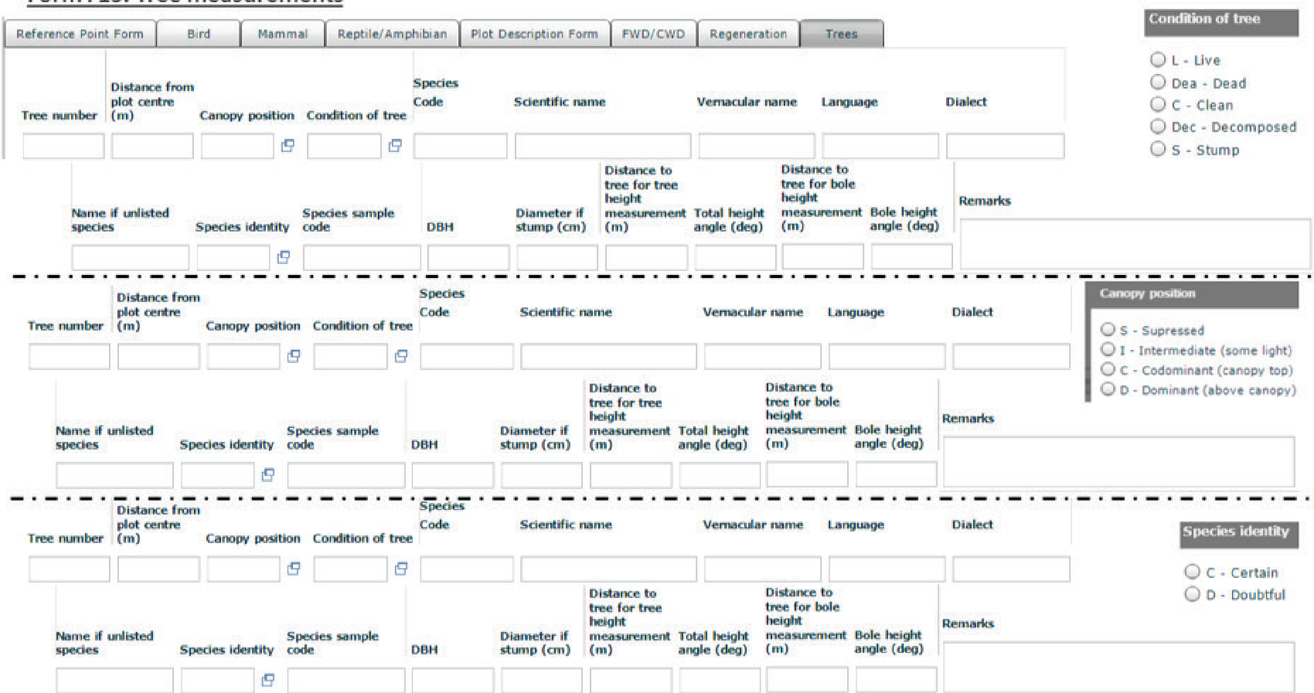
Reference Point Form | Bird | Mammal | Reptile/Amphibian | Plot Description Form | FWD/CWD | Regeneration | Trees

Regeneration

Number of recruits

Regeneration remarks

Form F13. Tree measurements



Reference Point Form | Bird | Mammal | Reptile/Amphibian | Plot Description Form | FWD/CWD | Regeneration | Trees

Tree number | Distance from plot centre (m) | Canopy position | Condition of tree | Species Code | Scientific name | Vernacular name | Language | Dialect

Name if unlisted species | Species identity | Species sample code | DBH | Diameter if stump (cm) | Distance to tree for tree height measurement (m) | Total height angle (deg) | Distance to tree for bole height measurement (m) | Bole height angle (deg) | Remarks

Tree number | Distance from plot centre (m) | Canopy position | Condition of tree | Species Code | Scientific name | Vernacular name | Language | Dialect

Name if unlisted species | Species identity | Species sample code | DBH | Diameter if stump (cm) | Distance to tree for tree height measurement (m) | Total height angle (deg) | Distance to tree for bole height measurement (m) | Bole height angle (deg) | Remarks

Tree number | Distance from plot centre (m) | Canopy position | Condition of tree | Species Code | Scientific name | Vernacular name | Language | Dialect

Name if unlisted species | Species identity | Species sample code | DBH | Diameter if stump (cm) | Distance to tree for tree height measurement (m) | Total height angle (deg) | Distance to tree for bole height measurement (m) | Bole height angle (deg) | Remarks

Condition of tree

- L - Live
- Dea - Dead
- C - Clean
- Dec - Decomposed
- S - Stump

Canopy position

- S - Supressed
- I - Intermediate (some light)
- C - Codominant (canopy top)
- D - Dominant (above canopy)

Species identity

- C - Certain
- D - Doubtful

Annex VI. Terms of reference for field team members

The composition of a NFI field team can vary from five to six members. An additional two local community members should be employed to act as guides and assistants throughout the enumeration process. The team should also include at least one person specialized in each of the relevant key disciplines, depending on the type of information to be collected.

In addition, the inclusion of a student from an appropriate discipline (forestry, agriculture, environment, ecology) is strongly recommended for capacity building. Additional persons may be included to improve performance of the field teams when conditions require greater resources.

Team members must be experienced in tree, shrub and herbaceous species identification (using local and/or scientific names). It is also recommended that some of the team members speak the local language.

The tasks and responsibilities of the team members must be clearly defined, and include the following:

The TEAM LEADER is responsible for organizing all the phases of the fieldwork, from the preparation to data collection. He/she has the responsibility of contacting and maintaining good relationships with the community and the informants and monitoring and ensuring timely progress in the fieldwork. He/she will specifically:

- Prepare the fieldwork: ensure that all bibliographic research is undertaken and all secondary data, field forms and maps (at appropriate scales) are assembled into field packs;
- Plan the work for the team;
- Following sensitisation activities undertaken by the supervisory team, the team leader will establish contact with local authorities, local technical officers (forestry, agriculture, land, community development), and share with them the proposed inventory activities planned for their areas;
- Lead on community engagement stakeholder meetings and ensure field activities are well explained to local authorities and dwellers;
- Administer the location and access of SUs and plots;
- Take care of team logistics: obtain information and organize accommodation facilities and food (meals; cooking facilities);
- Plan/organize the interviews together with those team members assigned to undertake interviews;
- Ensure accurate completion/filling of field forms and taking notes and applying cross-checking procedures to insure reliable data;
- Organize daily meetings after fieldwork in order to sum up the day's activities and plan the next day;
- Make a report of the SU summarizing the data collection process;
- Take necessary measurements and observations and carry out interviews;
- Ensure collected data have been correctly stored in the tablet;
- Organize and ensure fieldwork safety (first aid kit, support of local authority/armed guards if required, reduce risk from wildlife);
- Maintain good team spirit among others.

The ASSISTANT TEAM LEADER will:

- Help the team leader to carry out his/her tasks;
- In consultation with the team leader, manage all field related finance such as fuel, maintenance and community consultation meetings.
- Ensure easy access to the SU with a guide very familiar with the area;
- Take necessary measurements and observations and carry out interviews;
- Make sure that the equipment of the team is always complete and operational;
- Supervise and orient the temporary assistants;
- Assist the team leader in the making of the SU report;
- Take over if the team leader falls sick.

The Data entrant will:

- Enter field data directly into the tablet or paper form;
- Ensure data collection follows the field manual to avoid data entry errors;
- Ensure the storage of data and its security;
- Manage tablet or paper form and ensure that the tablet is fully charged;
- Assist in collection of coordinates for access locations and plots and bearings for photos;
- Regularly review/edit field data collected in the plot before leaving it or at the end of the day to ensure and correct errors or enter data from the paper forms into the tablet;
- Regularly export individual plot data in the survey to avoid losing data if there is any incident with the tablet;
- At the end of the field work, do a general export in the survey and attach the download and send via email to the data management team or via specified email address;

The technical FIELD TEAM MEMBERS / enumerators will carry out the field measurements and interviews.

Each team must have a taxonomist for tree species identification.

The TEMPORARY ASSISTANTS, who are recruited locally, should be assigned the following tasks, according to their skills and knowledge of local species, language and practices:

- Help to measure distances;
- Provide the common/local name of tree, plants, and wildlife species;
- Inform about access to the SU;
- Open ways to facilitate access and visibility to technicians;
- Provide information about the various natural resources, their uses and management (forest, soil, water, crops, livestock etc.);

Field teams will receive theoretical and practical training on inventory methodology prior to the commencement of the fieldwork, through an initial pilot test; during which techniques of different forest/land measurements, data tallying and interview techniques (if socio-economic assessment is to be done).