TECHNICAL REPORT

STATE-OF-THE-ART STUDY: BEST ESTIMATES FOR EMISSION FACTORS AND CARBON STOCKS FOR SURINAME

FEBRUARY 2017

Zorg voor het Bos en het Bos zorgt voor ons

WE ZIJN HET BOS

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FEBRUARY 2017

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National Institute for Environment and Development in Suriname (NIMOS)
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A special thanks to Alejandra Ospina Pedraza from CATIE, who continued to provide feedback in forestry statistics.

FOREWORD

Suriname is the only country in the world that is over 90% covered with forest (93% in 2016). These magnificent forests are part of the Amazon region and the unique ecosystem of the Guiana Shield. It is one of the most pristine biodiversity hotspots in the world and an impressive number of endemic animal and plant species exist only in Suriname. It is widely recognized that many tropical forest species are probably not yet discovered, and that is only one example of the need to increase data, research efforts and knowledge about this global treasure. With growing concern for the threats of climate change and the role of tropical forests as carbon sink, the urgent quest for reliable scientific information as basis for policy-making has accelerated.

This *State of the art study: Best estimates for emission factors and carbon stocks for Suriname* provides a small contribution to this global research agenda. While no single study alone is enough to bridge the existing knowledge gap, this study plays a significant role in Suriname. It has succeeded in bringing together data produced by various scientists over different years and in different parts of the Surinamese forest, which was previously scattered without a joint conclusion. With permission from all concerned researchers, a dataset could be compiled containing nationally available forest inventory data, based on which calculations could be made for the best estimates of carbon stocks and emission factors in Suriname. An emission factor is an estimate of the amount of emissions released per area unit in the process of land use change, in this case tonnes of carbon dioxide per hectare of deforestation. National estimates could be produced that are not yet complete, but much more specific and reliable than before.

Suriname is currently in the REDD+ readiness process and will develop a Forest Reference Emissions Level/Forest Reference Level (FREL/FRL). This study provides the best possible estimates for the emission factors based on existing information and on different forest transitions and forest management types, which is an important input to the FREL/FRL. In addition, this study will be a starting point for the design of the multipurpose National Forest Inventory (NFI) for Suriname.

To make this study come true, partnerships were formed with organizations, institutes and persons with matching visions and programs. The Foundation for Forest Management and Production Control (SBB), as a technical work arm of the Ministry of Physical Planning, Forest and Land Management (Min RGB) was responsible for the study and chose to collaborate with the Costa Rican institute Tropical Agricultural Research and Higher Education Center (CATIE) for the estimates of the EF in order to strengthen South-South collaboration. The Centre for Agricultural Research in Suriname (CELOS) and the Anton de Kom University from Suriname (NZCS) also contributed. Capacity building of national institutes was prioritized in this process. We are thankful to all those who shared their data and contributed in different ways to making this study a reality.

Mrs. Roline T. Samsoedien

Minister of Physical Planning, Land- and Forest Management

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ACRONYMS

AFOLU	Agriculture, forestry and other land use
AGB	Aboveground Biomass
BGB	Belowground biomass
BU	Biometric Unit
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza
CCWP	Climate Change and Watershed Programme
CDM	Clean Development Mechanism
CELOS	Center for Agricultural Research in Suriname
CL	Conventional Logging
COP	Conference of the Parties (UNFCCC)
CSNR	Central Suriname Nature Reserve
CTL	Controlled Logging
CTL-FSC	Controlled logging on FSC-concessions
dbh	diameter at breast height
DOM	Dead organic matter
EF	Emission Factors
ELE	Extracted Log Emissions
FAO	Food and Agriculture Organization
FCAM	Forest carbon stock measurements
FCPF	Forest Carbon Partnership Facility
FREL/FRL	Forest Reference (Emissions) Level
FSC	Forest Stewardship Council
GHG	Greenhouse gas
GOFC-GOLD	Global Observation for Forest Cover and Land Dynamics
IPCC	Intergovernmental Panel for Climate Change
IRDf	Institute de Recherche pour le Développement
KCA	Key Category analysis
KfW	German Development Bank
LDF	Logging Damage Factor
LIF	Logging infrastructure factor
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NIMOS	National Institute for Environment and Development in Suriname
NZCS	National Zoological Collection Suriname
PCFP	Production and Conservation in Forests Programme
QA/QC	Quality Assessment/Quality Control
REDD+	Reduced Emissions from Deforestation and Forest Degradation, conservation of forest carbon stocks, enhancement of forest carbon stocks and sustainable
RIL	Reduced Impact Logging
RIL	Reduced Impact Logging
SBB	Foundation for Forest Management and Production Control
SFM	Sustainable Forest Management
SU	Sampling Unit
TEAM	Tropical Ecology Assessment and Monitoring
TEF	Total Emission Factor
UNDP	United Nations Development Programme
UNFCC	United Nations Framework Convention on Climate Change
WWF	World Wildlife Fund

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I. Description of REDD+ context

Suriname is currently in its REDD+ Readiness phase, which means that the institutional frameworks are being strengthened, human capacity is built, and the REDD+ National Strategy is being developed. 2016 is a crucial year within this Readiness phase, where all available baseline data in preparation for the FRL/FREL was collected and analyzed. The submission of the first FRL/FREL to the UNFCCC is planned for January 2018.

For the FRL/FREL, according to Decision 11/CP.19, the historic data on activities and emission factors will be provided by the National Forest Monitoring System (NFMS), including the Measuring, Reporting and Verification (MRV) function, and will be adjusted according to national circumstances. Being a relatively small country with a centralized government, Suriname will report on the national scale. The FRL/FREL will be improved, during subsequent submissions through a stepwise approach as indicated in the relevant UNFCCC COP decisions.

In the national REDD+ project of Suriname, the Foundation for Forest Management and Production Control (SBB) is responsible for the FRL/FREL and design of the NFMS[1] including the National Forest Inventory (NFI). SBB seeks to strengthen its collaboration with regional partners, as this will allow for lessons learned during the REDD+ readiness phase to be exchanged between countries, resulting in a more effective implementation of the REDD+ project. For the *State-of-the-art study: Best estimates for emission factors and carbon stocks for Suriname*, SBB chose to collaborate with the Tropical Agricultural Research and Higher Education Center (CATIE)[2] based in Costa Rica.

The overall objective of the work leading up to this study was to support the enhancement of local capacities in Suriname to establish nationally-appropriate emissions factors and to lay the foundation for the design of a NFI. This study provides the best possible estimates for the Emission Factors based on existing information and on different forest transitions and forest management types. A side product of this study was a well structured and harmonized database with all available forest inventory related data for Suriname. This database can be further extended within the future when more information becomes available.

On August 31st to September 1st of 2016, a national workshop was held to present the results of this study and to gather a better understanding of the stakeholders' expectations and roles within a multipurpose and participatory NFI. The results of this workshop are used within the NFMS-roadmap.

II. Database synthesis

To estimate emission factors, Tiers 1 and 2 approaches were applied, based on the 2006 IPCC guidelines. A workflow starting with establishing the national definitions for forest and forest types, deforestation, forest degradation, SFM and land use categories and land use transitions was completed. SBB and CELOS provided CATIE with all available databases, and worked together to compile those data, perform QA/QC routines, and calculate biomass and carbon stocks. The resulting carbon stock values were combined with the relevant land use transitions to arrive at robust estimates of emissions factors (***Figure 1***). Across this workflow, CATIE worked closely with SBB to ensure full and relevant participation in agreeing upon key definitions, clarify data processing, rules for data synthesis, and summarizing data in relevant and meaningful ways.

[1] SBB (2017). NFMS-roadmap: Status and future plans of the NFMS in Suriname.

[2] Access to CATIE´s website http://catie.ac.cr/en/

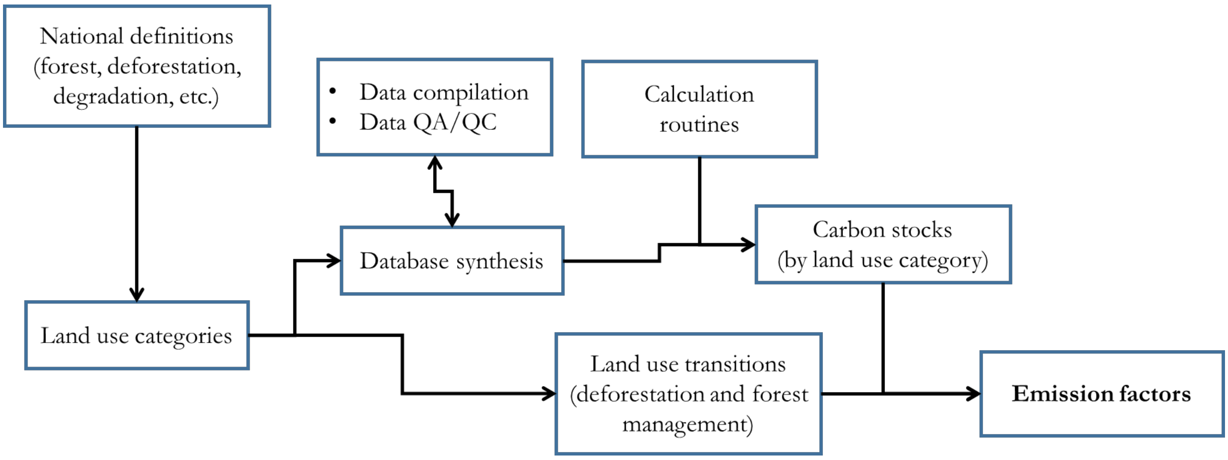


Figure 1 General workflow to estimate emission factors in Suriname.

2.1. Compilation of local existing data from forest inventories and loggings activities

To estimate the emission factors related to the transition from forest to non-forest land and emissions related to logging activities, several databases were provided to CATIE by SBB and CELOS. A total of 11 databases from different forests inventories were compiled and used to estimate forest biomass and emissions due to deforestation. Additionally, SBB provided a database on timber extraction (cq LogPro), including a dataset with logging permissions and a compiled list of tree species, used to estimate the emissions due to logging activities. ***Figure 2*** shows a map with the distribution of the collected field plots and ***Table 1*** summarizes the sources of the plots and describes the related databases. It is important to highlight, that according to field records, even though sampling plots were located within primary forest, some units were subjected to human intervention such as logging. This might affect the carbon content in those forests.

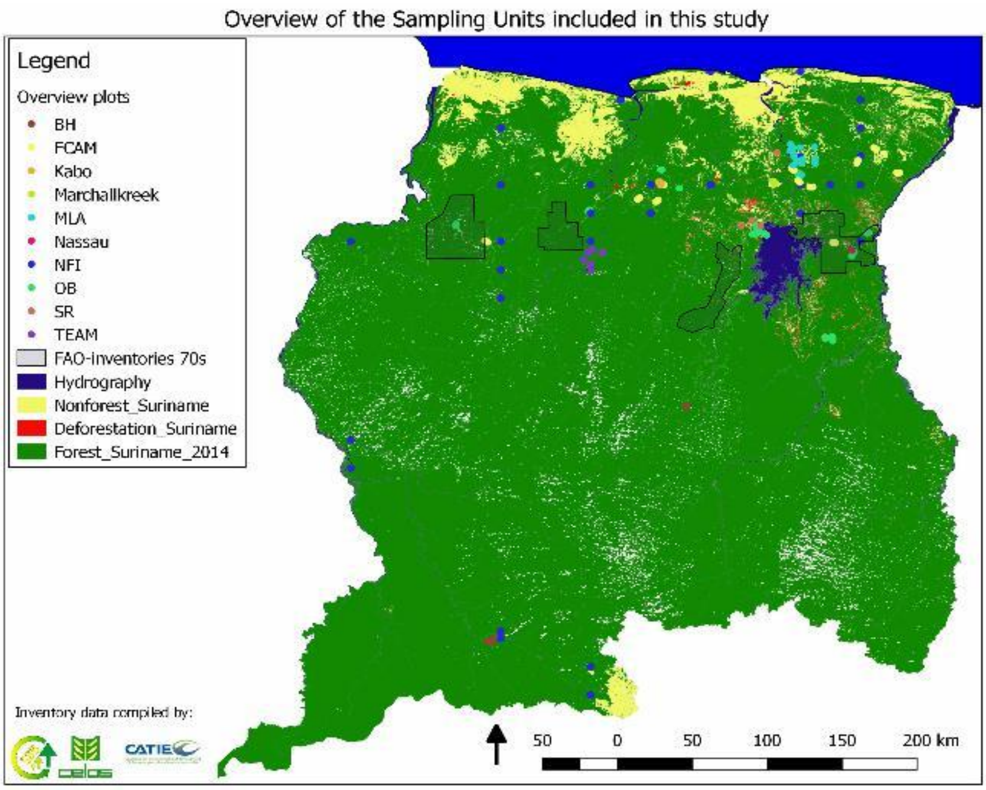


Figure 2. Overview of forest inventory plots used to estimate carbon stocks in forest in Suriname. Source: SBB, 2016.

Table 1. Description of databases used to estimate forest biomass and emissions in Suriname (more details in Annex 1).

Forest component	Source or study were data was collected	Sampling Unit areas (size and shape)	Minimum dbh recorded
Trees (n=104,451)	FAO (1975), provided by SBB	9,039 plots established in 4 areas of the country 0.04 ha circular plots	dbh >= 25 cm
	Study by Sofie Ruysschaert (SR) provided by SBB	4 plots 1 ha, rectangular plots 0.01ha, rectangular plots	dbh>=10cm dbh>=5cm
	Pilot National Forest Inventory (NFI) implemented by SBB	31 Sampling Units (SU), area 1.6ha 32 rectangular plots per SU of 0.01 ha 16 rectangular plots per SU of 0.01 ha	dbh>=20cm dbh>=10cm dbh>= 5cm
	Forest carbon stock measurements (FCAM). Pilot Carbon project implemented by SBB	12 transects, 1.5 ha, transect conformed by three rectangular plots (0.5 ha) Subplots of 0.375	dbh>= 20cm (1.5ha) dbh>= 5cm (0.375ha)
	Olaf Banki (OB) provided by SBB	39 plots, 1 ha varying shape	dbh >= 10cm
	Bruce Hoffman (BH) provided by SBB	5 plots 1 ha (4 plots) rectangular 0.5 ha (1 plot) rectangular	dbh>=10cm
	Kabo, provided by CELOS	30 plots 1 ha square 100x100m	dbh>= 15cm
	MLA, provided by CELOS	18 rectangular transects 40 m per transect, various area size	dbh >=25 cm
	Nassau, provided by CELOS	1 plot 1 ha square 100x100m	dbh>=15 cm
	TEAM (CSN) managed by CELOS and Conservation International	5 plots 1 ha square 100x100m	dbh >10 cm
	Marchall Kreek (MK) provided by CELOS	6 plots 1 ha (3 plots), each 1 ha plot consist of 16 squares of 25m X 25 m 0.2 ha (3 plots), each 0.2 ha plot consist of 5 squares of 25m X 25 m	dbh>=20 cm dbh 5-20 cm
Lianas (n=2,098)	Forest carbon stock measurements (FCAM). Pilot Carbon project implemented by SBB	12 plots 0.375 ha, transect, unknown shape	dbh>= 1cm dbh>= 2 cm

	Pilot National Forest Inventory (NFI) implemented by SBB	31 SU with 8 plots each 0.32 ha, 4 square subplots of 0.01 ha, per plot	dbh>= 5 cm
	TEAM (CSN) managed by CELOS and Conservation International	5 plots 1 ha 100x100m	dbh >10cm
Palms (n=2,600)	Forest carbon stock measurements (FCAM). Pilot Carbon project implemented by SBB	6 transects 0.375 ha, measures in 2 square subplots of 0.125 ha each 0.5 ha 6 transects, measures in all plots 0.375 ha, 5 transects, measures in 2 square subplots of 0.125 ha	dbh 5-20cm dbh >= 20cm Stem H >= 1.3 m
	Pilot National Forest Inventory (NFI) implemented by SBB	31 plots (clusters) 0.01 ha rectangular plots, 4 subplots in each cluster	stem H ≥ 1.3m
	Olaf Banki (OB) provided by SBB	20 plots 1 ha, varyingshape	dbh >= 10cm
	Bruce Hoffman (BH) provided by SBB	3 plots 1 ha rectangular	dbh >= 10cm
	Study by Sofie Ruysschaert (SR) provided by SBB	4 plots 1 ha, unknown shape 1 ha 1 subplots, unknown shape	dbh >= 10cm dbh 0-10 cm
Standing Dead Wood (n=3,173)	Forest carbon stock measurements (FCAM). Pilot Carbon project implemented by SBB	12 plots 0.5 ha, rectangular plots	dbh >= 5cm
	Pilot National Forest Inventory (NFI) implemented by SBB	31 plots 0.02 ha, square plots	dbh >= 10cm
Downed wood (n=642)	Pilot National Forest Inventory (NFI) implemented by SBB	29 plots 0.01 ha, square subplots	dbh >= 10cm
Timber production	LogPro, Wood production 2000-2015. Managed by SBB	Reduced Impact Logging-FSC system: 207 cutting units in 5 concessions Conventional Logging system: 1373 cutting units in 197 forestry licenses Controlled Logging systems: 948 cutting units in 72 forestry licenses	

2.2. Harmonizing national databases

All the databases were compiled and reviewed to determine their design, the variables recorded, the type of forest where the information was collected, and the number, type and sizes of plots used. After this process, the eleven databases collected from forest inventories were merged to create one national database. To complete this task and have common coding, we developed standardized codes to describe the variables of each of the databases, which in turn allowed us to unequivocally identify the measured variables, clusters, sampling units, plots and subplots.

As an example, the NFI database came from a cluster design, in which 31 sampling units or clusters were established, with 8 plots per cluster, while the SR-database is based on a simpler plot design, in which 4 plots of 1 ha each were established (see Annex 2). Differences in sampling designs of both studies generated the need for biomass estimates at the sub-plot, plot and sampling unit level. Although the two studies used the plot as a unit of measurement, the plot is not necessarily the sampling unit in both studies. Additionally, conversions for numeric variables were performed, defining a single unit of measurement for the diameter at breast height (cm) and height (m).

Furthermore, categorical variables were created to facilitate handling of data during the debugging process and carbon estimation. These variables were:

- ID: code that identifies the study or source database
- SU: code that identifies the sampling unit. It can refer to the same plot code, the cluster code or the transect.
- Plot: code of the measurement plot. It is the same as the SU when sampling design was based on the sampling unit.
- Subplot: code of the measurement subplot
- Component: measurement component referred to trees from 0–5 cm, 5-10 cm, 10-20 cm and >20 cm dbh.

2.3. Quality assurance/quality control procedures

To ensure the quality of the data used for the carbon estimates, we conducted a quality control process of the databases to identify outliers in the data, and thus reduce the uncertainty associated with the results. The descriptive statistics used were the average, maximum, minimum, median, quantiles and coefficient of variation. We used the INFOSTAT software (Di Rienzo *et al* 2016) for all data QA/QC and statistical analyses. An installer of this software was provided by CATIE to the Suriname staff involved in this consultancy.

The first step in performing data quality control was to unify criteria for identifying and standardizing of categorical and numerical variables. This included unifying the names of the variables, encoding variables and converting the numerical value of dbh and height to the same measurement units (cm and m, respectively). Subsequently, the following protocol for data analysis was established:

- Detection of outliers using minimum and maximum function. This activity was performed using the dbh variable component, and identifying the maximum and minimum values. For example, if a specific study indicated that the minimum dbh value of the forest component under consideration was 25 cm, then that should be the minimum value in the datasets. Trees with values lower than 25 cm were considered as outliers.

- Identification of a unique scientific name for each species. All scientific names were reviewed to identify synonyms and inaccurate writing, for which the software F-Diversity (Casanoves *et al.,* 2010) was used.

- Identification of outliers through standardization. When the databases had several species, the identification of outliers has to be performed for each species. This was done because it is possible to identify normal high values in dbh (for example, for the genus *Ceiba* sp.), which are not necessarily normal to other species. In order for standardization to correctly identify unusual values, the species in question must have a considerable number of individuals. The equation used in this study to standardize the data sets was:

$$Z = \frac{X - \mu}{\sigma} N(0; 1)$$

Where:

x the value of the response variable,

μ the overall mean of that variable in one species,

σ the square root of the variance of the variable within a species.

By applying this, dbh records of each species were standardized, and values > 3.5 standard deviations and <-3.5, were considered outliers. These atypical values were revised and then corrected or discarded by the experts of SBB and CELOS.

To debug the logging database (LogPro, Log Tracking database - including timber production), the procedures explained above (sections 2.2 and 2.3) were also applied. Additionally, the measures of the large-end and the small-end diameters of the log were revised to ensure that small ends were not larger than large-ends. To do this, the difference between them was calculated. Negative values were excluded of the analysis as outliers. The positive values resulting from this process were standardized to identify outliers following the same process explained above.

III. An assessment of options to choose the most suitable emissions factor that can be used for Suriname to develop a forest reference level/forest reference emission level (FRL/FREL)

3.1 Scope of the emission factors

Definitions

Definitions of forest and REDD+ activities are provided in ***Table 2***. National discussions were held while this report was being prepared to validate these definitions. The definitions might subsequently change during future discussions.

Table 2 National definitions to be considered to estimate forest emissions factors

Definition	Description	Source and comments, according to SBB
Forest	Land mainly covered by trees which might contain shrubs, palms, bamboo, grass and vines, in which tree cover predominates with a minimum canopy density of 30%, a minimum canopy height (in situ) of 5 m at the time of identification, and a minimum area of 1.0 ha.	Based on national discussions. This definition is in line with the criteria defined by the UNFCCC in decision 11/CP.7, and has been used within the legends of the set of subsequently produced Forest Cover Maps. For the 3rd National Communication on the inventory of GHG, Suriname will align the definition.
Primary forest	The term primary forest is commonly perceived to be the naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed (FAO 2010). Also perceived to be "climax forest type" for a given region and environment, and considered relatively stable.	Atmopawiro (work in progress)
Deforestation	Defined as the direct and/or induced conversion of forest cover to another type of land cover in a given timeframe.	GOFC-GOLD 2015 Note that UNFCC decision 16/CMP.1 defines deforestation as: "...the direct, human-induced conversion of forested land to non-forested land."
Forest degradation	Human-induced or natural loss of the goods and services, provided by the forest land, in particular the forest carbon stocks, not qualifying as deforestation, over a determined period of time	Definition still under discussion at the moment this report was finished. cfr. NFMS-roadmap

Forest managed for logging	These are forest lands remaining as forest lands that are being managed for logging purposes. Logging in Suriname may be classified in 3 main categories, according to logging practices and concession types: 1. Conventional logging (extensive management): Primarily conventional logging practices; no planning of skid trails, no pre-harvest inventories, no directional felling, harvest quotas/intensity, buffer zones set by SBB. 2. Controlled logging (intensive management): Harvest plans are submitted to SBB for approval for 100 ha blocks (Kapvak). Logging practices can vary from both conventional with some level of planning for approval from SBB to potentially complete compliance to the Suriname code of practice for logging, including the application of Reduced Impact Logging (RIL). 3. Controlled – FSC: Same as intensively managed category but with third party sustainable forest management certification. These concessions are most likely in compliance to the Suriname code of practice for logging, with additional sustainable criteria based on the ecology of the forests, social issues and economic viability of the logging operations.	Conclusion of internal discussions at SBB. Based on 'Background study for REDD+ in Suriname: Multiperspective analysis of drivers of deforestation, forest degradation and barriers to REDD+ activities'.

Clarify land use categories and transitions

Suriname is still developing a classification of forest types. So far, the country works with a forest classification proposal that is under discussion among experts of different institutions. This classification separates national forest into mesophytic, hydrophytic and xerophytic (***Table 3***). This study estimates carbon stocks in 15 forest types, as a way to provide inputs that can support the construction of a future national forest inventory sampling.

Table 3. Example of forest types that may be used to classify forest cover in Suriname and report carbon stocks and changes (based on article in press of Atmopawiro, work in progress).

Forest types	Characteristics
Moist Evergreen forest (High Dryland Forest)	A closed three or four-layer forest with emergent trees up to 45 m. The lower layer reaches 25 to 30 m. The undergrowth consists of small trees and poles. Some tree species shed all their leaves during dry season.
Montane forest	Generally, 3-layered, few buttresses. Closed, upper layer of large trees with a lower more extensive occurrence of epiphytes.
Dry Montane forest	Similar to Montane forest, but lower. Sometimes comprises of sclerophytic tree species.
High Montane forest*	
Mangrove forest	One layer and closed forest. The undergrowth is restricted to ferns. Two types are distinguished i.e., *Avicennia nitida* along the coast, and *Rizophora mangle* along major rivers with patches of *Laguncularia.*
High Swamp forest	These forests are marked by very wet conditions all year round. The shorter the inundation period the more it resembles the rain forest. Is at least 20 m high with two stories and is fairly closed.

Peat swamp*	Stilted water table with a peat layer between 0.5 to over 20 m thick. Less species with trees with lower diameter towards the center.
Periodic swamp forest	This forest is characterized by insufficient drain moisture conditions from very dry to very wet.
Riparian forest	Periodic swamp forest along river banks.
Creek forest	Periodic swamp forest along fringes of creeks.
Low swamp forest	This forest is marked by very wet conditions all year around. The shorter the inundation time the more it resembles the rainforest. Varies in physiognomy from open scrub to a low closed forest. Palms and epiphytes are rare. This forest does not have big trees and is poor in species. Low swamp forest, which varies from open woodland, to a single layer 10 to 15 m high forest can be found in permanently, inundated terrain.
High Savanna forest	A two layers forest with a closed canopy reaching heights of 25-30 m. Large trees are scarce. Palms are few and small. Dominant species are the same as in the rainforest. It occurs on deep white sand.
Low Savanna forest	This forest does not show any layers. Height varies from 10-20 m. This type of forest is very dense and closed and more homogenous than the previous ones.
Open Savanna forest*	Grass, shrub and orchard savanna.
Secondary forest	Forests regenerating largely through natural processes after significant human and/or natural disturbance of the original forest vegetation at a single point in time or over an extended period, and displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests on similar sites (Chokkalingam and De Jong, 2001).

* Plots for this forest type were not identified

However, for the purposes of this study, the carbon stock values used to estimate emission factors were the mean of all forest types combined and the mean of carbon per forest strata. This was done according to how Suriname could be planning to design their future national forest inventory (***Figure 3***), which includes the cost of establishing plots and the location of the forest. The strata under this potential classification are Mangrove forest (stratum 1), Young coastal plain (stratum 2 that goes from mangroves to forest belt), Forest belt (stratum 3), and Forest in the interior (stratum 4). For details on how this classification was performed, see Annex 3.

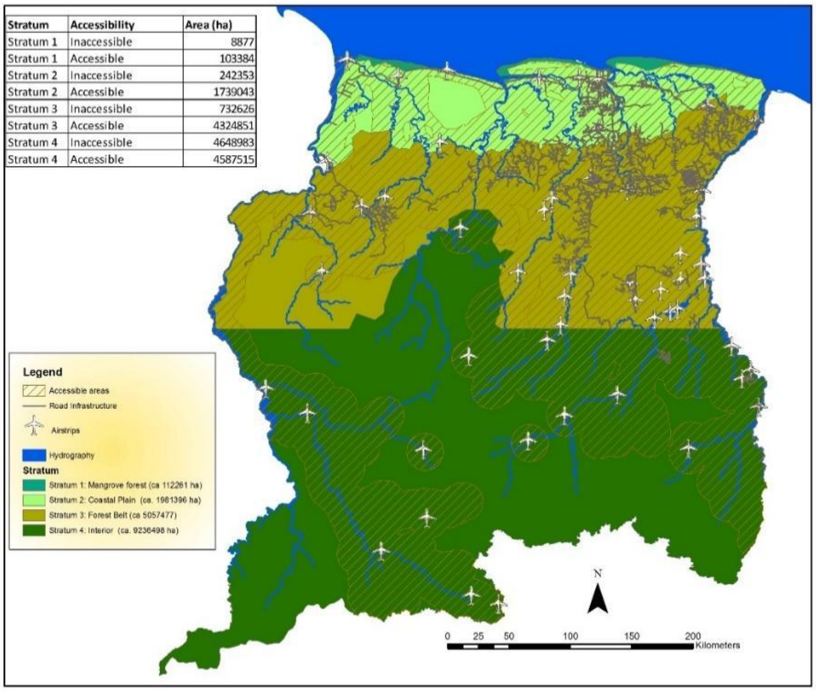


Figure 3 Forest strata based on accessibility and overview of forest inventory plots used to estimate carbon stocks in forest in Suriname. Source: SBB 2016.

Another possible approach could be the stratification based on geomorphological landscape units (Figure 4). This is analogue to the approach used in French Guiana (Guitet *et al.,* 2015). Because this approach is still being tested and improved for Suriname in a close collaboration with IRD, NIMOS and the consultancy agency Kapplan, it will not be included further within this report. Nevertheless, the approach seems promising, and it might be necessary when establishing the final NFI design to recalculate the carbon stocks within the different geomorphological landscape units.

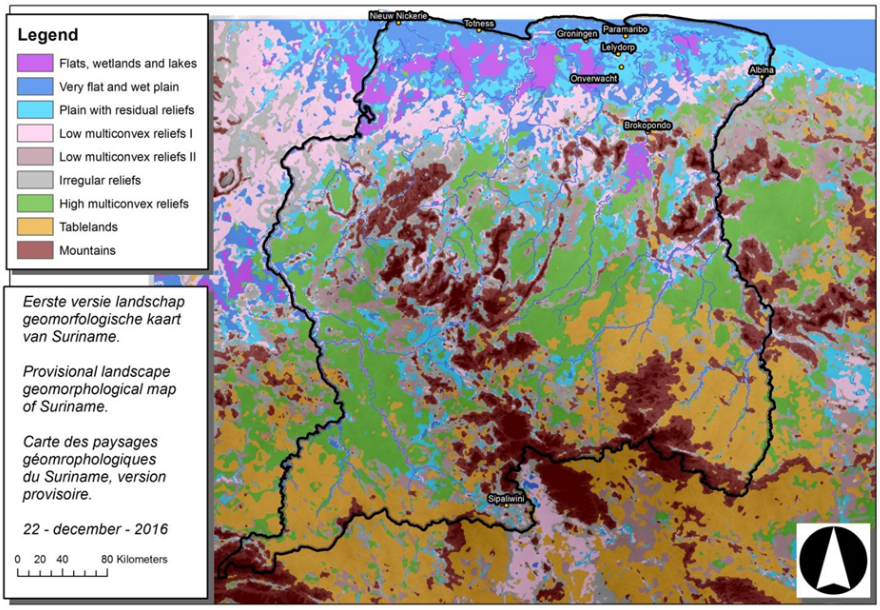


Figure 4. Provisional geomorphological characteristics of Suriname. Source: SBB 2016.

Land use transitions: forest land conversion

Once a forest classification is defined, land use transitions after converting forest land to other lands have to be identified. We used the IPCC approach where land use is classified into 6 categories, and forest can be converted to any of those of those (***Table 4***).

Table 4 Land-use categories for greenhouse gas inventory reporting according to IPCC guidelines.

Types	Description
(i) Forest Land	This category includes all land with woody vegetation consistent with thresholds used to define Forest Land in the national GHG inventory. It also includes systems with a vegetation structure that currently fall below, but *in situ* could potentially reach the threshold values used by a country to define the Forest Land category.
(ii) Cropland	This category includes cropped land, including rice fields, and agro-forestry systems where the vegetation structure falls below the thresholds used for the Forest Land category.
(iii) Grassland	This category includes rangelands and pasture land that are not considered Cropland. It also includes systems with woody vegetation and other non-grass vegetation such as herbs and brushes that fall below the threshold values used in the Forest Land category. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvo-pastoral systems, consistent with national definitions.
(iv) Wetlands	This category includes areas of peat extraction and land that is covered or saturated by water for all or part of the year (e.g., peatlands) and that does not fall into the Forest Land, Cropland, Grassland or Settlements categories. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.
(v) Settlements	This category includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories. This should be consistent with national definitions.
(vi) Other Land	This category includes bare soil, rock, ice, and all land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available. If data are available, countries are encouraged to classify unmanaged lands by the above land-use categories (e.g., into Unmanaged Forest Land, Unmanaged Grassland, and Unmanaged Wetlands). This will improve transparency and enhance the ability to track land-use conversions from specific types of unmanaged lands into the categories above.

The main drivers of deforestation in Suriname are mining, settlements (including infrastructure), and the conversion of forest to agriculture/crops and pasture land and grasslands (***Table 5***).

Table 5 Land use transition matrix proposed for Suriname.

IPCC categories	From	To	Level of probability for these changes to happen (preliminary KCA)	Comments and assumptions
Forest Land Remaining Forest Land	Primary forest	Primary forest	High	
	Primary undisturbed forest	Conventional logging	High	
	Convention al logging	Conventional logging 2nd cycle	Medium	Emission factor will be the same as when forest is logged for the first time.
	Primary forest	Reduced impact logging	Medium	
	Primary forest	Controlled logging	High	
	Primary forest	Shifting cultivation	Low/Medium	It is assumed that all biomass was emitted the first year of the conversion
Forest Land Converted to Cropland	Forest land	Cropland	Low	Since data does not exist, default values provided by IPCC were used. If forest is converted to crop land, the common agricultural systems are rice, sugar, or home gardens.
Forest Land Converted to Grassland	Forest land	Pasture	Low	Since data on EF does not exist, default value provided by literature were used. The assumption is that there are some forest remnant trees on the grasslands lands.
Forest to other lands	Forest land	Mining	High	It is assumed that all the biomass carbon is emitted in the year of the event.
Forest to wetland	Forest land	Managed wetland	Low?	Planned construction of hydropower lakes
Forest to Settlements	Forest	Roads, cities, etc.	Low	It is assume that all of the biomass carbon is emitted in the first year after conversion
Land Converted to Forest Land	Crops	Forest	Low	It is assumed that crops and grasslands converted to forest are secondary young forest younger than 20 years.
	Grasslands	Forest	Low	

Land use transitions: forest land remaining forest land

For the purposes of this study, we considered the following transitions of forest land remaining forest land, which are consistent with the most recent country discussions related to its NFI and other FREL/FRL elements. Also, we are considering the following logging types:

- CTL-FSC (Controlled logging on FSC-concessions)
- CTL (Controlled Logging)
- CL (Conventional Logging)

Carbon pools and gases

The IPCC divides the components of terrestrial ecosystems in 3 main categories (***Table 6***).

Table 6 Definitions for Carbon Pools Used in AFOLU for each Land-Use category[3]

Pool	Description	
Biomass	Aboveground biomass	All biomass of living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds, and foliage. Where forest understory is a relatively small component of the aboveground biomass carbon pool, it is acceptable for the methodologies and associated data used in some tiers to exclude it, provided the tiers are used in a consistent manner throughout the inventory time series.
	Belowground biomass	All biomass of live roots. Fine roots of less than (suggested) 2 mm in diameter are often excluded because these often cannot be distinguished empirically from soil organic matter or litter.
Dead organic matter (DOM)	Dead wood	Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps, larger than or equal to 10 cm in diameter (or the diameter specified by the country).
	Litter	Includes all non-living biomass with a size greater than the limit for soil organic matter (suggested 2 mm) and less than the minimum diameter chosen for dead wood (*e.g.* 10 cm), lying dead, in various states of decomposition above or within the mineral or organic soil. This includes the litter layer as usually defined in soil typologies. Live fine roots above the mineral or organic soil (of less than the minimum diameter limit chosen for below-ground biomass) are included in litter where they cannot be distinguished from it empirically.
Soil	Soil organic matter[4]	Includes organic carbon in mineral soils to a specified depth chosen by the country and applied consistently through the time series[5]. Live and dead fine roots and DOM within the soil that are less than the minimum diameter limit (suggested 2 mm) for roots and DOM, are included with soil organic matter where they cannot be distinguished from it empirically. The default for soil depth is 30 cm and guidance on determining country-specific depths is given in Chapter 2.3.3.1.

Based on existing data and on the impact of the drivers of deforestation and forest degradation on carbon pools, Suriname selected the carbon pools as shown on ***Table 7***.

[3] Source: IPCC 2006, Chapter 1, table 1.1.

[4] Includes organic material (living and non-living) within the soil matrix, operationally defined as a specific size fraction (e.g., all matter passing through a 2 mm sieve). Soil C stock estimates may also include soil inorganic C if using a Tier 3 method. CO2 emissions from liming and urea applications to soils are estimated as fluxes using Tier 1 or Tier 2 method

[5] Carbon stocks in organic soils are not explicitly computed using Tier 1 or Tier 2 method, (which estimate only annual C flux from organic soils), but C stocks in organic soils can be estimated in a Tier 3 method. Definition of organic soils for classification purposes is provided in Chapter 3.

Table 7 Definitions for carbon pools used in the AFOLU sector in Suriname.

Activity	Pool					
	Aboveground biomass	**Belowground biomass**	**Dead wood**	**Litter**	**Soil carbon**	**Harvested wood production**
Deforestation	Yes Trees and lianas	Yes	Yes	No	No	No
Degradation from shifting cultivation	Yes	Yes	Yes	No	No	No
Carbon lost due to logging	Yes Trees	No	No	No	No	Yes

3.2 Procedures to estimate carbon in biomass in the different components of the forest

The available country data allowed us to estimate carbon in the biomass of standing trees and palms, standing dead trees, roots, lying dead wood and lianas in all management types, and carbon in standing trees in logged forests.

Estimation of aboveground biomass

To determine the carbon in the biomass of living trees, all individuals with a dbh > 5 cm were first selected. For each individual tree, the dry biomass was estimated using allometric equations. Subsequently, the biomass of all individuals belonging to the same plot was summarized and, from this, the average biomass per sampling unit, and per forest type was calculated.

Since Suriname has not established specific allometric equations by forest type yet, pantropical equations that use dbh, height and wood density as explanatory variables (Chave *et al.* 2005 and Pearson *et al*. 2005) were tested for estimating biomass. Chave *et al*. 2005, in particular, developed eight equations for four forest types based on respective climatic conditions (annual rainfall and number of dry months) and demonstrated that including wood density improves biomass estimation. The allometric equation that best fits the requirements of this study, corresponds to humid forest (rainfall between 1500 and 3500 mm/year, with 1-5 dry months) according to Chave *et al.* 2005 (***Table 8***). The selection of the equation was confirmed based on information provided by the national experts, which indicated that forests in the country are mostly found in areas where annual rainfall ranges between 1400 and 2900 mm/year, as indicated by WorldClim (Hijmans *et al*. 2005).

Table 8 Allometric equation used for estimating forest biomass in Suriname.

Allometric equation	Source
Biomass = (ρ*exp(-1,499+(2,148*Ln(DBH))+(0,207*(Ln(DBH))^2)-0,0281*(Ln(DBH))^3))	Chave *et al*. 2005

The selected equations used dbh values in cm and wood density values (ρ) in g/cm^3. Wood density was obtained from Zanne *et al*. 2009. For most forest inventories included in the dataset, tree species identification was done based on the vernacular name. This name was linked in the best possible way, using compiled lists of tree species with corresponding vernacular names, to the species, genus or family name.

When the species of an individual tree was known, a specific wood density value was given (66,813 individuals). For individuals with unknown species, a *ρ* value was given by calculating a genus average value (28,090 individuals); for individuals with unknown genus and family, a *ρ* value was given by calculating a family average value (5,893 individuals); and for individuals with unknown information about it species; genus or family (3,571 individuals), a *ρ* value of 0,68 g/cm^{-3} was given, which was calculated from the average mean of *ρ* values and abundance of species with a previously assigned valued.

For estimating aboveground biomass of palms, four specific genus equations and one general family equation were used, according to Goodman *et al*. 2013 (***Table 9***). Because the information on palms came from different studies, different equations were used. In cases were the height of the individual was not measured, but its dbh was, an equation to estimate biomass for family of palms was applied, since this equation just required the dbh of an individual to estimate the biomass. This equation was also used for those individuals of palm trees with unknown genus. Of a total of 2600 palms recorded by all the studies, 281 were individuals with unknown species or individuals with missing data of height or dbh, so the biomass of these palms could not be estimated.

Table 9 Allometric equation used to estimate biomass in palms

Gender	Equation
Astrocaryum	AGB= 21,302*Hc
Attalea	Ln(AGB)= 3,2579+1,1249*Ln(Hc+1)
Euterpe	AGB= -108,81+13,598*Hc
Oenocarpus	Ln(AGB)=4,5496+0,1387*Hc
Family Arecaceae	Ln(AGB)= -3,3488+2,7483*Ln(dbh)

AGB: aboveground biomass, dbh: diameter at breast height, Hc: commercial height

Estimation of belowground biomass (roots)

To obtain the belowground biomass value, aboveground biomass values were multiplied by the 0.24 factor for tropical rainforests (Cairns 1997), as recommended by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). To estimate the belowground biomass value for palms, the general equation for estimating biomass in roots developed by Goodman *et al* 2013 was used (***Table 10***).

Table 10 Allometric equation used for estimating belowground biomass in palms in Suriname.

Allometric equation
Ln(BGB)= -0,3688+2,0106*Ln(Hc)

BGB: below ground biomass, Hc: height

Estimation of biomass in standing dead trees and downed wood

Biomass in standing dead trees was estimated using the Chave *et al*. 2005 equation used for estimating biomass in living trees. After this, it was assumed that all standing dead trees were decomposing, thus a biomass reduction factor representing 75% of the individual total weight was applied to each individual, as suggested by Brown *et al.* 1992 and Saldarriaga *et al.* 1998, cited by Sarmiento *et al.* 2005.
Biomass in downed wood was estimated from the volume of the tree using Smalian's formula (***Table 11***) and a biomass reduction factor approach suggested by Harmon and Sexton 1996 for the AR-TOOL12 methodological tool for CDM projects. Factors used depended on the decomposition state of the tree. For solid wood the factor used was 0.46, for wood in advanced state of decomposition it was 0.40 and for decayed wood we used 0.34 (Cifuentes, 2010).

Table 11 Smalian's formula used for estimating wood volume in lying trees.

V: volume of the log in m^3, A_1: area of the small end of the log in m^2, A_2: area of the large end of the log in m^2, L: length of the log in m

Formule
$V = \frac{A1 + A^2}{2} * L$

Estimation of biomass in lianas

Biomass in lianas was estimated using Schnitzer *et al*. 2006 equations (***Table 12***).

Table 12 Allometric equation used for estimating biomass in lianas in Suriname.

Allometric equation
AGB (kg) = exp(-1,484 + 2,6557(Ln(dbh))

AGB: aboveground biomass
dbh: diameter at breast height

Carbon in harvested wood

For estimating the harvested timber biomass, data on the length and diameter of the logs harvested were used. As a first step, dbh estimated using the log length and diameter values at the ends of the log. Subsequently, the increment in diameter per m in length of the log was estimated, and this value was subtracted from the diameter of the base of the log, assuming that all logs leave a stump height of 30 cm. In addition, the extracted biomass was estimated using the cylinder formula for calculating the timber volume, and then this was multiplied by the corresponding species' wood density value as explained above for living trees.

3.3 Procedures for calculating emission factors

Emission factors were estimated for deforestation and logging, based on the land use change transitions and on the impact of the practices during logging activities.

Deforestation

For deforestation, emission factors were calculated as the difference between carbon stocks in forest land and the remaining carbon in the land use existing after the forest conversion. To be consistent with data available for other land uses in the literature and to be conservative with the reporting of the emissions, we estimated the emissions factor only for the aboveground biomass in trees, as shown in formula below. When better information is available in the future, the formula in Annex 5 can be used.

$$EF_{deforestation} = \{(C_{TABG}) - (C_{OT})\} * 44 / 12$$

Where:

$EF_{deforestation}$ =Emission factor for deforestation (Mg CO_2 ha^{-1})

C_{TABG} =carbon in above ground biomass in living trees (Mg CO_2 ha^{-1})

C_{OT} =carbon in other land uses (Mg CO_2 ha^{-1})

Since no detailed national data exists on the different carbon stock in the land uses after forest conversion, literature default values and expert assumptions were applied. We assumed that after forest loss due to mining, human settlements, and infrastructure, carbon stocks were zero, and that forest lands converted to "shifting cultivation" have an estimated average carbon stock of 52.2 Mg C ha^{-1} (data from tropical forest in Panama, Petellier *et al.* 2012), which is consistent with findings in Brazil from D'Oliveira *et al.* (2011)). Pastureland with trees were assumed to have an amount of carbon of 25,06 Mg C ha^{-1} (data from pasture in Para, Brazil according to Kauffman *et al.* (1998)) and cropland an amount of 1,7 Mg ha^{-1} the first year after the conversion (based on a study on the Peruvian Amazon by Lapeyre *et al.*, 2004).

Logging

Since the IPCC guidelines do not provide enough details on how to estimate emissions from logging activities, the methodology developed by Pearson *et al.* 2014 and tested by Haas 2015 was applied. This methodology suggests applying the IPCC gain–loss approach, because it fits Suriname's national circumstances. The approach focuses on the direct losses in live biomass caused by the felled trees, incidental damage to other trees caused by the tree felling, and related logging infrastructure, and the gains from regrowth in and around the gaps caused by the felled and damaged trees and infrastructure. It is thus more appropriate to estimate the change in live and dead biomass pools due to logging impacts directly in the harvested areas as opposed to estimating the difference in the carbon stocks of the pre- and post-logged forest (Pearson *et al.* 2013). The following criteria were used for the calculations:

- All wood extracted is emitted at the time of the event, according to IPCC Tier 1
- Biomass was estimated using Chave *et al*. (2005)
- Emissions due to illegal logging is unknown, so it was not considered in this study
- Since there is no information about number of gaps per concessions, we assumed that every log represents a single gap
- Missing data was filled in from default factors provided by Pearson *et al*. 2014.

When logging occurs, harvested wood products may also be considered as part of the carbon fluxes. The inclusion or exclusion of one or any of these pools depends on their magnitude and potential for change over time and, especially, when these are due to project activities. Whenever a pool is excluded from the accounting, adequate reasoning and evidence must be supplied to justify the decision. Based on Tier 1 guidance[6] we considered litter, necromass (both standing and CWD) and soil carbon stocks are in equilibrium and, thus, not included in the emissions accounting (***Table 13***). Furthermore, carbon emissions from soils were not included, as selective logging has been shown to have no impact on soil carbon over large concessions because of the relatively small area impacted, the short duration of the impact and the retention of vegetation cover (Johnson and Curtis 2001). Finally, because any of the previous pools may potentially be significant sinks/sources of emissions, they are an open area for further technical improvement within the FREL/FRL.

The total emission factor (TEF) from selective logging is estimated as the sum of three factors: (1) emissions relative to extracted volume; (2) damaged biomass in the process of logging; and (3) damaged biomass resulting from logging infrastructure (Haas 2015, Pearson *et al* 2014, Brown *et al* 2014), following the equation (Pearson *et al.* 2014):

a) TEF = (ELE + LDF + LIF)

Where:

TEF = the total emission factor resulting from timber harvest (Mg C m^{-3})

ELE = the extracted log emissions (Mg C m^{-3} extracted) or carbon losses from the extracted biomass in commercial logs.

6 This approach it also being follow by Malaysia's previous reference level submissions to the UNFCCC (Ministry of Natural Resources and Environment, Malaysia 2005)

To estimate ELE, the carbon per trees was calculated by estimating the volume of the tree extracted and defining its wood density (Zanne *et al*. 2009). To calculate the carbon content from biomass, a factor of 0.47 was used according to IPCC 2006. The amount of carbon per tree was summarized per cutting unit, to have a total of the carbon extracted per cutting unit. This total amount of carbon per cutting unit was divided by the total timber volume (m^3) extracted per cutting unit. Once the ELE was estimated at the cutting unit level, the values were averaged to estimate one value per terrain and then per type of concession.

LDF = the logging damage factor— dead biomass carbon left behind in the gap from the felled tree and incidental damage (Mg C m^{-3} extracted) or carbon losses from the damage caused by logging activities. It is calculated as follows:

$$DW = \left\{ \sum_{Gaps} ([f\ (\mathrm{dbh}) - (\mathrm{GAPVol} \times \mathrm{WD} \times \mathrm{CF}) + (\mathrm{BI} \times \mathrm{CF}))]/\mathrm{GAPVo}l) \right\} \{\text{Number of gaps}\}^{-1}$$

Where:

DW = the dead wood carbon stock (Mg C m^{-3})
f(dbh) = the allometric function for calculating tree biomass based on diameter at breast height - dbh) and species specific wood density (Mg biomass)
GAPVol = the volume of timber over bark extracted in gap (m^3 gap^{-1})
WD = the wood density of felled trees (Mg m^{-3})
CF = the carbon fraction
BI = the biomass of incidentally killed/damaged trees (Mg C gap^{-1})
Number of Gaps = the total number of gaps inventoried

To estimate LDF, a damage factor value was generated for each tree, assuming that each tree creates a gap. To estimate the LDF, four values were required: the total carbon of the tree, the extracted carbon (commercial log), the carbon of the damages caused by the fall of the tree and the volume of wood extracted per tree. Then, the total carbon per tree was calculated using an allometric equation (Chave *et al.* 2005), and the extracted carbon was estimated based on the volume extracted, the wood density and the carbon factor of 0.47. While assessing the biomass damage due to the falling of the trees, a gap damage factor developed for Guyana was used (Pearson *et al.* 2014). With these three values, the residual carbon and extraction damage were calculated and divided by the volume of wood extracted to obtain a value of Mg C per m^3. The DW was then calculated by summarizing the carbon per m^3 obtained at the cutting unit level and divided by the number of trees used in each cutting unit. Once the DW was estimated at the cutting unit level, the values were averaged to estimate one value per terrain and then per type of concession.

To estimate the ELE and LDF at the country level, a mean of all the factors was estimated considering all the terrains, but not the type of concession.

Logging infrastructure factor (LIF): the logging infrastructure factor - dead biomass carbon caused by construction of infrastructure (Mg C m^{-3}) or carbon losses from the extraction of trees due to construction of skid trails

$$LIF = \frac{\left((RF \times RL) + (DF \times \#D) + (SF \times SL)\right)}{TotSampleVol}$$

Where:
LIF = the logging infrastructure factor - dead biomass carbon caused by construction of infrastructure (Mg C m^{-3})
RF = the road factor - emissions per km of road construction (Mg C km^{-3}), RL is the road length (km),
DF = the decks factor - emissions per deck constructed (Mg C $deck^{-1}$)
#D = is the number of decks
SF = the skid trail factor - emissions per km of trail (Mg C km^{-1})
SL = is the skid length (km)
TotSampleVol = the total extracted volume across the area sampled for infrastructure (m^3)

Table 13 Variables and metrics needed to estimate emissions due to forest logging in Suriname.

Source of emission and emission factor	Description	Variables needed for the estimations	Value used	Source of information
Extracted log emissions (ELE)	Emissions from biomass in extracted commercial logs	Volume log extracted (m^3/per log)	SBB data	Local logging volume records from SBB, and conversion to biomass customary factors. It is assumed that each log is a tree.
		Biomass log extracted (Mg C/per log)	SBB data	SBB data and Biomass calculated using allometric equations Chave *et al* 2005, wood density based on FAO(Zanne *et al.*, 2009)
Logging damage factor (LDF)	Emissions from decomposition of dead wood from the felled trees (crown-, bole-, stump-, not including below-ground biomass)	**f(dbh)** = Biomass left in gaps (Mg C/tree)	SBB data	SBB data and Biomass calculated using allometric equations Chave *et al* 2005
	Emissions from gaps at the location where the specific tree(s) are felled.	**GAPVol** = the volume of timber over bark extracted in gap G (m^3 gap^{-1})	SBB data	SBB data and assuming each tree leaves a gap
	Emissions from gaps at the location where the specific tree(s) are felled.	**WD=** wood density of felled trees (Mg m^{-3})	FAO	FAO (Zanne *et al.*, 2009)
		CF= Carbon fraction (Mg C·in Mg dry mass**)**	0.47	IPCC 2006
		BI = the biomass of incidentally killed/damaged trees (Mg C gap^{-1})	3.1	Ruthers 2016 BI=0.68*(0.4+1+3.7+4.7)*0.47 We only selected logs between 1.6-12.7 m^{-3})
		Number of gaps = the total number of gaps inventoried	SBB data	SBB data and assuming each tree leaves a gap
Logging infrastructure factor (LIF):	Logging infrastructure emissions including emissions resulting from the creation of logging roads, skid trails and logging decks	**RF**= road factor—emissions per km of road construction (Mg C km^{-1}).	0.98	Pearson *et al* 2014, value for Guyana, see table 4. Default value used, since the country does not have completed data on logging infrastructure yet.
		RL = is the road length (km),		
		DF = decks factor—emissions per deck constructed (Mg C $deck^{-1}$)		
		#D = number of decks		
		SF = skid trail factor—emissions per km of trail (Mg C km^{-1})		
		SL = skid length (km)		

3.4 Emission factors for deforestation

Total carbon stocks in forest biomass per strata

Total carbon stocks in mangrove forest biomass were estimated as 57.93 Mg C ha^{-1} aboveground, while tropical forest can store up to 225.85 Mg C ha^{-1} (***Table 14***).

It is important to highlight that mangrove carbon stocks found, seem to be low, when compared to other studies in the Amazon, which suggests that the plots were probably established in young forest, or in forest modified by humans or natural factors, as suggested by other studies ranging from 8.3 Mg C ha^{-1} to 313.2 Mg C ha^{-1}(Rovai *et al.* 2015). A similar trend was found in French Guyana, carbon stocks have been reported to reach 157.5 Mg C ha^{-1}, with lower values of 15.5 Mg C ha^{-1} in young mangroves (Fromard *et al.* 1998). To obtain better estimates, more plots will need to be established in the mangrove forest.

The amount of carbon in AGB found in forest ecosystems, both by stratum (***Table 14***) or by forest types (Table 15), is similar to the amounts reported by other studies in the Amazon region, which show that carbon in the AGB can range from 47.5 to 206.5 Mg C ha^{-1} (Houghton *et al.* 2001, Nascimento and Laurance 2002, Sist *et al.* 2014). The IPCC 2006, suggests default values for carbon in AGB tropical forest that range from 60 to 200 Mg C ha^{-1} (Goslee *et al.* 2014).

Table 14 Carbon stocks (Mg C ha^{-1} and %) by pool in forest strata in Suriname.

Stratum	Aboveground biomass										Belowground biomass		Total	
	Living trees (dbh >5 cm)		Palms		Lianas		Downed wood		Standing dead wood*		Roots*			
	Mg C ha-1	%	Mg C ha-1	%	Mg C ha-1	%	Mg C ha-1	%	Mg C ha-1	%	Mg C ha-1	%	Mg C ha-1	%
Mangrove forest	44.41	76.60	0.00	0.00	0.00	0.00	0.79	1.37	2.11	3.65	10.66	18.38	57.97	100.00
Young coastal Plain	149.62	76.42	5.08	2.59	0.64	0.33	3.23	1.65	1.31	0.67	35.91	18.34	195.78	100.00
Forest belt	176.10	74.33	1.06	0.45	2.83	1.19	11.54	4.87	3.14	1.32	42.26	17.84	236.93	100.00
Interior	164.99	76.51	2.26	1.05	2.38	1.10	4.50	2.09	1.92	0.89	39.60	18.36	215.65	100.00

*Carbon in below ground biomass does not include the carbon stored in palm roots. For trees, carbon in roots was estimated by applying a root-to-shoot ratio factor of 0.24, based on IPCC 2006 default values for tropical forest.

** See Annex 6 and 7 for details on uncertainties.

Carbon stocks in living trees by forest ecosystem type

The mean values for carbon stocks in living trees by forest type are found in table 15. These results are also similar to what has been found in other countries with similar forest types. Alder and Kuijk 2009 (cited by Cedergren 2009) reported for the Guiana Shield AGB carbon stocks of 152 Mg C ha^{-1}, while ter Steege 2001 found in Guyana carbon stocks between 111.5 and 146.5 Mg C ha^{-1}. Furthermore, Arets *et al* 2011 reports AGB carbon stocks range in Suriname from 121 to 265 Mg C ha^{-1}. They base their estimates on a review of several published documents and on different allometric equations and thus provide an overall estimation of the country's carbon densities, with which this study is also consistent.

Table 15. Aboveground carbon (trees >5 cm dbh, Mg C ha^{-1}) by forest type in Suriname.

Forest Type	Mean	S.E.	n	LL(95%)	UL(95%)	Uncertainties
All forest	157.38	3.23	349.00	151.03	163.72	4.03
Creek forest	139.51	7.37	64.00	124.78	154.23	10.55
Dry montane forest	202.26	0.00	1.00			
Forest plantation	210.12	77.87	2.00			
High Savanna forest	159.05	12.39	29.00	133.67	184.43	15.96
High swamp forest	109.93	9.42	5.00	83.77	136.08	23.79
Low Savanna forest	117.52	34.82	7.00	32.31	202.72	72.50
Low swamp forest	122.29	12.12	3.00	70.16	174.42	42.63
Mangrove	44.41	17.15	2.00			
Moist Evergreen forest	161.75	4.57	144.00	152.71	170.78	5.59
Montane forest	198.11	15.53	13.00	164.27	231.96	17.08
Periodic swamp forest	165.47	13.15	8.00	134.38	196.55	18.79
Riparian forest	112.88	0.00	1.00			
Savanna forest	210.87	17.24	13.00	173.32	248.43	17.81
Secondary forest	113.81	33.94	7.00	30.76	196.87	72.97
Swamp forest	127.47	31.33	7.00	50.81	204.14	60.14
Unknown	167.43	6.40	43.00	154.52	180.34	7.71

Empty cells mean that confidence limits could **not** be estimated due to a small numbers of data (n)
(S.E. = standard error, n=number of plots, LL=lower limit, UP=upper limit)

The amount of carbon found in the other components of the forest in Suriname (***Table 16***), seems to be consistent with what is reported in other Amazon forests. ABG biomass for palms in an Amazon forest in Peru ranges between 2.5 to 21.2 Mg C ha^{-1}, and in Brazil from 0 to 10.6 Mg C ha^{-1} (de Castilho *et al.* 2006). Other authors have also reported carbon stocks this range (Cummings *et al.* 2002, Nascimento and Laurance 2002). AGB Carbon in lianas in Amazon forests can range from 1.86 Mg C ha^{-1} (Laurence *et al.* 2001) to 21.5 Mg C ha^{-1} **(**Gerwing and Farias 2000). In the forest of French Guyana, carbon stocks for lianas with diameter ≥ 0.5 cm can range between 5.05-6.8 Mg C ha^{-1} (Schnitzer *et al.* 2006).

Our results for dead matter are consistent with reports from other Amazon forests. For example, Nascimento and Laurance 2002, found that downed wood carbon stocks range between 5.9 to 18.07 Mg C ha^{-1}, while standing dead wood ranged between 5.9 to 18.07 Mg C ha^{-1}. Delaney *et al.* 1998 found values between 0 to 13.1 Mg C ha^{-1} in the forest of Venezuela.

Table 16. Aboveground carbon (Mg C ha^{-1}) by carbon pool in forest type in Suriname[7].

Type of forest	Palms	Lianas	Downed wood	Standing dead wood
Creek forest	3.48	3.62	6.67	1.82
Dry Montane forest	0.11	4.56	3.02	1.78
High savanna forest	0.06	2.47	11.92	3.33
Low Savanna forest	9.95	8.30		1.09
Low Swamp forest	2.30		3.40	2.34
Mangrove	2.30		0.79	2.28
Moist evergreen forest	1.69	3.03	9.93	3.13
Periodic swamp forest	5.14	3.44	12.84	3.19
Riparian forest	0.58	0.82	3.70	2.20
Secondary forest	2.96	3.67	22.89	4.42
Swamp forest	6.57	1.62	3.86	2.13
High swamp forest		1.47		2.07
Montane forest	0.05	1.57		

Empty cells mean that there were no data linked to this type of forest in the available databases.

**See Annex 6 and 7 for details on uncertainties

Emission factors for deforestation

Emission factors for deforestation were estimated based on the results from harmonizing the several databases used in this study and complementing them with default values found in technical and scientific literature. ***Table 17*** shows emission factors only for aboveground biomass in trees, as explained in section 3.3, and only for the forest stratification based on accessibility.

Table 17. Emission factors for drivers of deforestation per accessibly forest stratum in Suriname.

Forest type or stratum	CO_2 Store in forest (Mg ha^{-1})	Emission factors (Mg CO_2 ha^{-1})			
		Shifting cultivation	Pasturelands with trees	Agriculture	Mining
Mangrove forest†	162.98	-28.59	71.01	156.75	162.98
Young coastal plain	549.11	357.53	457.14	542.87	549.11
Forest belt	646.29	454.71	554.32	640.05	646.29
Interior	605.51	413.94	513.54	605.51	605.51

† Carbon stored in mangroves may be higher.

*Carbon stocks in forest are found in Table 14

**Carbon stocks in other land uses: shifting cultivation-young forest= 52.2 Mg C ha^{-1}; pasturelands with trees: 25.06 Mg C ha^{-1}; agriculture/ cropland= 1.7 Mg C ha^{-1} the first year after the conversion; mining= 0 Mg C ha^{-1}

3.4 Emissions factors due to logging activities

Emission factors due to logging are shown in Tables 18, 19 and 20. Since there were few publications available, we used work done by Pearson *et al.* 2014 and Haas (2015) to compare the results of this study, which seem to be consistent with those publications as shown in ***Table 21***.

[7] Annex 6, shows individual table for each pool, including confidential limits and uncertainties.

Table 18. Summary of information on logging concession used to estimate emissions factors in Suriname.

Type of logging system	Number of concessions	Number of cutting units	Area of cutting units (ha)		
			Mean	Min.	Max.
CL	197	1373	121.05	5.25	1472.66
CTL	72	948	101.52	9.69	895.81
CTL-FSC	5	207	96.68	32.20	182.52

Table 19. Summary of variables, tree variables and estimates of the extracted log emissions (ELE) factor (with 90% CI)

Types of logging	DBH (cm)			Length (m)			Volume extracted per gap (m^3)	Biomass extracted per gap (Mg C)	Residual Biomass per gap (Mg C)
	Mean	Min	Max	Mean	Min	Max			
CL	48.13	11.00	146.25	12.93	2.00	29.90	2.66	1.68	1.23
CTL	53.11	14.25	145.00	14.27	1.30	29.70	3.46	2.24	1.41
CTL-FSC	53.99	13.00	138.25	14.92	3.20	29.40	3.75	2.44	1.35
All concessions	50.08	11.00	146.25	13.48	1.30	29.90	2.98	1.91	1.30

Table 20. Mean estimates (with 90% CI) for the amount of damage and dead biomass produced per gap and the resulting logging damage factor (LDF).

Types of logging	LDF (Mg C m^{-3})					ELE (Mg C m^{-3})				
	Mean	S.E.	n	LL(95%)	UL(95%)	Mean	S.E.	n	LL(95%)	UL(95%)
CL	0.683	0.017	197.000	0.650	0.716	0.297	0.002	197.000	0.293	0.301
CTL	0.588	0.037	72.000	0.514	0.662	0.298	0.002	72.000	0.293	0.303
CTL-FSC	0.484	0.037	5.000	0.381	0.587	0.304	0.007	5.000	0.286	0.323
All concessions	0.655	0.016	274	0.624	0.686	0.298	0.002	274	0.294	0.301

S.E.: standard error; LL: lower limit of confidence interval; UL: upper limit of confidence interval

Table 21. Comparison of logging emission factors (Mg C m^{-3}) in Suriname and other countries.

Country and type of logging system	ELE	LDF	LIF	TEF	Source
Suriname					This study
All licenses	0.30	0.65	NA		
CL	0.30	0.683	NA		
CTL	0.30	0.588	NA		
CTL-FSC	0.30	0.484	NA		
Guyana	0.36	0.99	0.98	2.33	Pearson *et al* 2014
Republic of Congo	0.25	0.50	0.24	0.99	
Indonesia	0.25	0.57	0.67	1.49	
Belize	0.28	1.26	NA		
Bolivia	0.30	1.23	NA		
Brazil	0.38	0.71	NA		
Fiji	0.57-0.69	0.10-0.15	NA		Haas 2015

IV. Recommendations for future emissions factor estimations and preliminary recommendations to lay the foundation for designing a National Forest Inventory for Suriname.

4.1 Improving future emission factor estimations

Since reporting emissions and removals of GHG is a key element of REDD+ MRV systems and national reference levels, it will be important for the country to set up a roadmap to improve accuracy and reduce uncertainties, while generating information that allows the country to estimate emissions by applying a Tier 2, and progressively, Tier 3 approaches. While the specifics of the roadmap are beyond the scope of our work, the information we generated may be used to support its development.

Selection of carbon pools and setting up a baseline

To gather information that will allow the country to estimate emission factors under a Tier 3 approach, a complete forest carbon inventory baseline is needed. Even though some of the studies used to prepare this report estimate carbon in dead wood, litter, soil carbon and lianas, this information was not enough to represent the forest of the country as a whole, since there were not enough plots in all forest types. A process to decide which carbon pools to measure in this baseline and which pools to monitor in the future should be undertaken, and it should include the participation of relevant country partners. The IPCC special report (2000), can provide guidance during this decision making process[8].

Estimation of carbon stock in forests and other land uses

Special attention should be paid to mangroves, a fragile and important ecosystem, because their capacity to store considerably higher amounts of carbon than terrestrial forests (Donato *et al.* 2011), and where little information exists for the country. Mangroves are also key landscape elements that can help coastal areas adapt to extreme events (Mitra 2013) and to protect the coastline. Starting with the GCCA+ project, Suriname will establish more field plots within the mangrove forest during 2017 and 2018. This will provide more insights on mangrove carbon stocks.

[8] See section 5.4.1.1 in IPCC 2000 http://www.ipcc.ch/ipccreports/sres/land_use/index.php?idp=271

Forest management for timber purposes in Suriname is well known as a successful proof that logging practices, when well implemented, can ensure the sustainability of forest resources for the future (Werger, 2011). But, under the increment of CO_2 in the atmosphere due to human practices, sustainable forest management systems also needs to show that its practices have little impact on greenhouse gas emissions.

Three types of forest management are in place in Suriname, namely: (1) conventional logging, (2) controlled logging and (3) controlled logging with an external audit (FSC-concessions). Determining carbon emissions from logging more precisely (preferably integrated in the operational field check procedures) can support the notion that the logging industry can produce sustainable timber while supporting climate change mitigation through reduced carbon emissions. During the first semester of 2017, field measurements will be done within the forest belt, collecting data for all three management types based on the method of Griscom *et al.* 2014. This will provide better insights in the national emissions due to logging, and in the differences between the different management types.

The experience developed during the preparation of this study can help to develop a more accurate protocol to estimate emissions in each forest concession and to establish a future greenhouse gas emission monitoring system. This could be easy to achieve, since SBB and CELOS have professional expertise on field data collection and database management.

4.2 Inputs to support a sampling design for a national forest inventory for carbon estimation

To improve accuracy and reduce uncertainties, the first step should be validating current proposals for the stratification of the national forest, in a way that can allow the estimation of carbon stocks based on national circumstances. In this sense, inputs provided through this consultancy can be used to define a sampling design for a forest inventory with the specific objective to estimate carbon stocks in aboveground biomass of living trees. This exercise was done only for moist evergreen forest, since it is the type of forest with the best available information across databases used for this report. Other forest ecosystems can be considered later, based on national needs.

Basic statistic considerations for national forest inventories

A national forest inventory may have different objectives and the type of variables and the size, shape and number of plots will be defined based on those. For estimating carbon stock and emission factors, the sampling design can be constructed considering 95% confidence intervals and an uncertainty as low as possible (for example 10%). Uncertainty is defined from confidence intervals as:

$$I = \frac{UL - \hat{\theta}}{\hat{\theta}} 100$$

Where UL is the upper limit obtained from the confidence intervals for the mean or the total:

$$x' \pm Z_{(1-\alpha/2)} \sqrt{N^2 \frac{N-n}{N} \frac{S_x^2}{n}}$$

$$\overline{x} \pm Z_{(1-\alpha/2)} \sqrt{\frac{N-n}{N} \frac{S_x^2}{n}}$$

Where *N* is the total population size, *n* is the sample size.

$$\frac{N-n}{N}$$

The number goes to 1 when the population size *N* goes to infinite.

One of the first steps to set up a national forest inventory, is to determine the type of stratification that best serves national needs. If the strata are not well defined, the variation among strata goes to the estimated variance, increasing the standard error and, consequently, increasing the uncertainty. Errors in carbon pool estimates are additive, so the total uncertainty depends on the uncertainty of each pool. Once the strata are defined, it is possible to calculate the minimum sample size in each stratum to ensure a given uncertainty. To decide the sampling size in each stratum it is important to consider:

- the stratum size
- The stratum variances
- The relative cost to evaluate a sampling unit
- Importance of the stratum in carbon content
- The cluster definition

Clusters are a useful sampling design in forest inventories, but it is critical to consider that they pose some common problems affecting uncertainties:

- Cluster size is not large enough to estimate the variation
- Different plot size according the reservoir
- Some plots cannot be sampled because of physical restrictions (rivers, slop, other land use)
- Some plots are partially evaluated
- Correction for slope is necessary

The cluster definition (*i.e.* cluster size), the cluster shape, the number of subplots in each cluster, and the different nested plot sizes for the different pools depend mainly on the cluster intra-variation. When the variation in a cluster increases, we need more sampling effort to consider that variation. Therefore, when the intra-cluster variation increases, we need to increase the sampling effort in the cluster, increasing the number of subplots.

Evaluating the need for more subplots depends on the variation among clusters and the intra-cluster variation. These variances can be estimated by mean variance components estimation using a General Linear Mixed Model.

Considerations based on the Suriname context

Inputs provided in this section were prepared by:

- Using the information from the different databases (table 1) provided by SBB,
- Considering only data for moist evergreen forest, since it was the type of forest with the best information available across databases,
- Using the sample design used in the project Pilot National Forest Inventory, led by SBB, this study evaluated the variances for cluster and subplot, that consisted in 8 subplots of 100m x 20m), and
- Using forest strata based on accessibility provided by SBB.

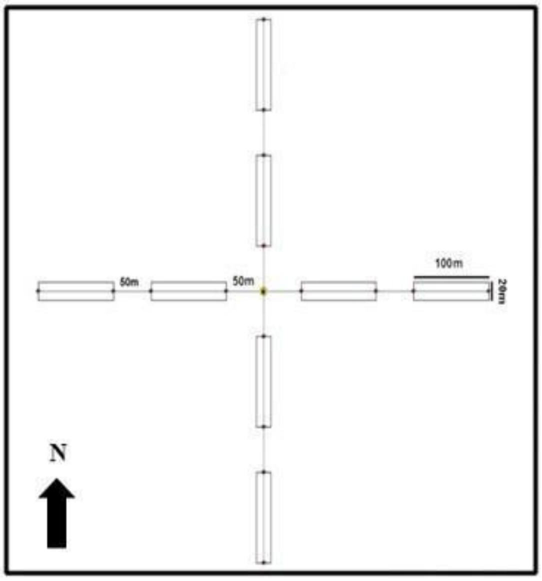


Figure 4 Cluster shape proposed for the NFI. Source: SBB 2016.

Different numbers of subplots were evaluated using statistical simulations. For each simulation we estimated the variance among clusters and among subplots. The simulations were made using the information of moist evergreen forest clusters (8 clusters) and all clusters (31 clusters). We observed a higher variance among the subplots than among clusters. Furthermore, the former does not change significantly when different numbers of subplots are considered. This implies that 8 subplots per cluster are necessary to account for the intra-cluster variability in the moist evergreen forest (***Table 22***).

Table 22. Cluster and subplot variance for moist evergreen forest (n=8)

# subplot	Cluster	Subplot
4	1150.43	3627.60
5	1152.13	3635.26
6	1157.01	3629.23
7	1146.02	3633.48
8	1150.37	3631.70

When estimating component variances using all the information, the intra-cluster variability was similar to the moist evergreen forest, but the variability among clusters was greater than the variability obtained only with evergreen forest. Using the 31 clusters resulted in greater among-cluster variance because in several clusters there are more than one type of forest (strata). Therefore, the variance between strata is confounded with the cluster variance.

In addition, when we used the 31 clusters to perform the simulations, the number of subplots in the clusters ranged between 5 and 11 with a mean of 8.3 (***Table 23*** **Cluster and subplot variance for all forest (n=31)**).

Table 23. Cluster and subplot variance for all forest (n=31)

# subplot	Cluster	Subplot
5-11 (8.3)	2985	3192

Based on the forest strata provided by SBB, confidence intervals for each stratum and current uncertainty were calculated. Additionally, the number of clusters for each stratum was estimated. In the case of mangroves, the information was not enough to perform the calculations (***Table 24***).

Table 24. Living trees aboveground carbon (Mg ha^{-1})

Stratum	Mean	S.E.	n	LL (95%)	UL (95%)	Uncertainty	S.D.	Var	n (10%)
Mangrove forest	44.41	17.15	2.00				24.26	588.43	
Young coastal Plain	149.62	15.34	21.00	117.63	181.61	21.38			82
Forest belt	176.10	3.38	170.00	169.43	182.77	3.79	70.28	4938.59	34
Interior	164.99	9.09	15.00	145.50	184.48	11.81			21

For all the strata, the area, the standard deviation, and the relative cost to establish and collect data in the field by cluster, are shown in ***Table 25***.

Table 25. Data for strata sample size estimation

Stratum	Accessibility	Area (ha)	S.D	Cost (U$/ ha)
Mangrove forest	Inaccessible	8.877,00	24,2	5000
	Accessible	103.384,00	24,2	5000
Young coastal Plain	Inaccessible	242.353,00	66,9	5000
	Accessible	1.739.043,00	66,9	5000
Forest belt	Inaccessible	732.626,00	46,4	20000
	Accessible	4.324.851,00	46,4	5000
Interior	Inaccessible	4.648.983,00	33,3	20000
	Accessible	4.587.515,00	33,3	10000

The optimal sample size calculation in each stratum depends on stratum area and the stratum standard deviation:

$$n_h = \frac{\sigma_h N_h}{\sum_{h=1}^{L} \sigma_h N_h} n$$

However, when the costs are different among strata, then a relative cost can be included into the sample size calculation. There are two ways to consider costs: by considering, a given total n (generally defined for the systematic grid):

$$n_h = \frac{\sigma_h N_h / \sqrt{C_h}}{\sum_{h=1}^{L} \sigma_h N_h / \sqrt{C_h}} n$$

and, an alternative when the funding available for the inventory (fixed total cost) is known:

$$n_h = \frac{\sigma_h N_h / \sqrt{C_h}}{\sum_{h=1}^{L} \sigma_h N_h / \sqrt{C_h}} C$$

For the purposes of this study, the sampling effort for each stratum using the formula for fixed "n" was estimated, with 2 scenarios (200 and 400 total sample size for the inventory, ***Table 26***). For mangrove, the information can be improved with more field information are available.

Table 26 Sample size for stratum considering a fixed n

Stratum		n=200	n=400
Mangrove forest	Inaccessible	0	0
	Accessible	1	2
Young coastal Plain	Inaccessible	6	12
	Accessible	43	86
Forest belt	Inaccessible	6	13
	Accessible	75	149
Interior	Inaccessible	29	58
	Accessible	40	80

References

Arets, E.J.M.M., B. Kruijt, K. Tjon, V.P. Atmopawiro, R.F. van Kanten S. Crabbe, O.S. Bánki and S. Ruysschaert. 2011. Towards a carbon balance for forests in Suriname. Wageningen, Alterra, Alterra report 1977. 42 p.

Atmopawiro, V. 2016. Proposed Structure of Forest Typology 1 V., July 2016. Work in progress.

Banki O.S.. 2009. Does neutral theory explain community composition in the Guiana shield forests? Dissertation. University of Utrecht.

Brown, JK.; Roussopoulos, PJ. 1974. Eliminating biases in the planar intersect method. Forest Science. 20(4): 350-356.

Brown, S.; Goslee, K.; Casarim,F.; Harris, N.; Petrova, S. 2014. Sampling Design and Implementation Plan for Guyana's REDD+ Forest Carbon Monitoring System (FCMS): Version 2. Guyana Forestry Commission GFC, Winrock International.

Brown, I.F.; Nepstad, D.E.; Ires, O.; Luz, L. M., Alechandre, A. Z. 1992. Carbon storage and land use in extractive reserves, Acre, Brazil. Environmental Conservation 19: 307-315.

Cairns, M. A., Brown, S., Helmer, E. H., & Baumgardner, G. A. 1997. Root biomass allocation in the world's upland forests. Oecologia, 111(1): 1-11.

Casanoves F.; Pla L.; Di Rienzo J.A.; Díaz S. 2010. FDiversity: a software package for the integrated analysis of functional diversity. Methods in Ecology & Evolution doi: 10.1111/j.2041-210X.2010.00082)

Cedergren, J. 2009. Measurement and Reporting of Forest Carbon in Guyana: Preparing for REDD Implementation. UN-REDD PROGRAMME. MRV Working Paper 6

Chokkalingam, U.; De Jong, W. 2001. Secondary forest: a working definition and typology. International Forestry Review (Center for International Forestry Research - CIFOR) 3(1).

Chave, J.; Andalo, C.; Brown, S. *et al*. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia. 145:87-99.

Cummings, D.L.; Kauffman, J.B.; Perry, D.A. Hughes, R.F. 2002. Aboveground biomass and structure of rainforests in the southwestern Brazilian Amazon. Forest Ecology and Management, 163(1), pp.293-307.

de Castilho, C.V.; Magnusson, W.E.; de Araújo, R.N.O.; Luizao, R.C.; Luizao, F.J.; Lima, A.P.; Higuchi, N., 2006. Variation in aboveground tree live biomass in a central Amazonian Forest: Effects of soil and topography. Forest ecology and management, 234(1):85-96.

Delaney, M.; Brown, S.; Lugo, A.E.; Torres-Lezama, A.; Quintero, N.B., 1998. The quantity and turnover of dead wood in permanent forest plots in six life zones of Venezuela1. Biotropica, 30(1):2-11.

Di Rienzo J.A.; Casanoves F.; Balzarini M.G.; Gonzalez L.; Tablada M.; Robledo C.W. InfoStat versión 2016. InfoStat Group, Facultad de Ciencias Agropecuarias, Universidad Nacional de Córdoba, Argentina. URL http://www.infostat.com.ar).

Donato, D.; Kauffman, J.B.; Murdiyarso, D.; Kurnianto, S.; Stidham, M.; Kanninen, M. 2011. Mangroves among the most carbon-rich ecosystems in the tropics. Nature Geoscience. 4:293-297. DOI: 10.1038/NGEO1123

D´Oliveira, M.V.N.; Alvarado, E.C.; Santos, J.C.; Carcalho Jr., J.A. 2011. Forest natural regeneration and biomass production after slash and burn in a seasonally dry forest in the Southern Brazilian Amazon. Forest Ecology and Management 261:1490–1498

FAO. Global Forest Resources Assessment 2010: Main report. FAO Forestry Paper 163. FAO. Rome.

Fromard, F.; Puig, H.; Mougin, E.; Marty, G.; Betoulle, J.L. and Cadamuro, L., 1998. Structure, above-ground biomass and dynamics of mangrove ecosystems: new data from French Guiana. Oecologia, 115(1-

2):39-53.

Giri, C.; Ochieng, E.; Tieszen, L.L.; Zhu, Z.; Singh, A.; Loveland, T.; Masek, J.; Duke, N. 2011. Status and distribution of mangrove forests of the world using earth observation satellite data (version 1.3, updated by UNEP-WCMC). Global Ecology and Biogeography 20:154-159. doi: 10.1111/j.1466-8238.2010.00584.x . Data URL: http://data.nep-wcmc.org/datasets/4

Goodman, R.C.; Phillips, O.L.; del Castillo Torres, D.; Freitas, L.; Cortese, S.T.; Monteagudo, A.; Baker, T. R. 2013. Amazon palm biomass and allometry. Forest Ecology and Management. 310:994-1004.

Goslee, K.; Brown, S.; Casarim, F. 2014. Forest Carbon Monitoring System: Emission Factors, Version 2. Submitted by Winrock International to the Guyana Forestry Commission.

Guitet, S.; Brunaux, O.; Richard-Hansen, C.; Gonzalez, S. 2016. Catalogue des habitats forestiers de Guyane, 65p. ISBN : 978-2-84207-384-8

Haas, M. 2015. Carbon Emissions from Forest Degradation caused by Selective Logging in Fiji. Prepared for the international climate initiative regional project: Climate Protection through Forest Conservation in Pacific Island Countries.

Harmon, M.E. Sexton, J. 1996 Guidelines for Measurements of Woody Detritus in Forest Ecosystems. US LTER Publication No. 20. US LTER Network Office, University of Washington, Seattle, WA, USA.

Hendrison, J., 1989. Damage-controlled logging in managed tropical rain forests in Suriname. Doctoral thesis, Wageningen Agricultural University, The Netherlands 204 p.

Hoffman, B. 2009. Drums and Arrows: Ethnobotanical Classification and Use of Tropical Forest Plants by a Maroon and Amerindian Community in Suriname, with Implications for Biocultural Conservation

Hijmans R.J.; Cameron, S.E.; Parra, J.L.; Jones, P.G.; Jarvis, A. 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology. 25:1965-197.

Houghton, R.A.; Lawrence, K.T.; Hackler, J.L.; Brown, S. 2001. The spatial distribution of forest biomass in the Brazilian Amazon: a comparison of estimates. Global Change Biology, 7(7):731-746.

Gerwing, J.J.; Farias, D.L. 2000. Integrating liana abundance and forest stature into an estimate of total aboveground biomass for an eastern Amazonian forest. Journal of tropical ecology, 16(3):327-335.

Government of Guyana. 2015. The Reference Level for Guyana's REDD+ Program. http://redd.unfccc.int/files/guyanas_proposal_for_reference_level_for_redd__-_final_sept_2015.pdf Accessed March 2016

Griscom, B.D.; Ganz, N.; Virgilio, F.; Price, J.; Hayward, R.; Cortez, G.; Dodge, J.; Hurd, F.L.; Lowenstein, B.; Stanley. 2009. The Hidden Frontier of Forest Degradation: A Review of the Science, Policy and Practice of Reducing Degradation Emissions. The Nature Conservancy, Arlington, VA. 76p.

IPCC. 2000. Land Use, Land-Use Change and Forestry. Robert T. Watson, Ian R. Noble, Bert Bolin, N. H. Ravindranath, David J. Verardo and David J. Dokken (Eds.) Cambridge University Press, UK. pp 375 Available from Cambridge University Press, The Edinburgh Building Shaftesbury Road, Cambridge CB2 2RU ENGLAND. http://www.ipcc.ch/ipccreports/sres/land_use/index.php?idp=0

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

Kauffman, J.N.; Cummings, D. L.; Ward, D. E. 1998. Fire in the Brazilian Amazon 2. Biomass, nutrient pools and losses in cattle pastures. Oecologia 113(3):415-427.

Lapeyre , T.; Alegre, J.; Arévalo, L. 2004. Determinación de las reservas de carbono de la biomasa aérea en diferentes sistemas de uso de la tierra en San Martín, Perú. Ecología Aplicada, 3(1,2). http://www.lamolina.edu.pe/ecolapl/Articulo6vol3.pdf

Laurance, W.F.; Pérez-Salicrup, D.; Delamônica, P.; Fearnside, P.M.; D'Angelo, S.; Jerozolinski, A.; Pohl, L.; Lovejoy, T.E., 2001. Rain forest fragmentation and the structure of Amazonian liana communities.

Ecology. 82(1):105-116.

Pearson, T.; Brown, S.; Casarim, F. 2014. Carbon emissions from tropical forest degradation caused by logging. Environ. Res. Lett.

Pelletier, J.; Codjia, C.; Potvin, C. 2012. Traditional shifting agriculture: tracking forest carbonstock and biodiversity through time in western Panama. Global Change Biology. doi: 10.1111/j.1365-2486.2012.02788.x

Nascimento, H.E.; Laurance, W.F. 2002. Total aboveground biomass in central Amazonian rainforests: a landscape-scale study. Forest Ecology and Management, 168(1):311-321.

MAE. 2012. Evaluación Nacional Forestal, Manual de Campo. Quito, Ecuador.

CDM. 2012. Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities. Version 3.0 http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-12-v1.1.0.pdf/history_viewn Accessed August 2016

Ministry of Natural Resources and Environment, Malaysia. 2005. Malaysia's Submission on Reference Levels for REDD+ Results Based Payments under UNFCCC http://redd.unfccc.int/files/modified_submission_malaysia_frel_final.pdf Accessed July 2016

Mitra, A. 2013. Sensitivity of mangrove ecosystem to changing climate. Springer, India. 323 p.

Rovai, A.S.; Riul, P.; Twilley, R.R.; Castañeda-Moya, E.; Rivera-Monroy, V.H.; Williams, A.A.; Simard, M.; Cifuentes-Jara, M.; Lewis, R.R.; Crooks, S. and Horta, P.A., 2016. Scaling mangrove aboveground biomass from site-level to continental-scale. Global Ecology and Biogeography, 25(3), pp.286-298.

Rüters, M. 2016. Logging residues in tropical forest operations –High potential for increasing resource efficiency? A case study from Suriname. Master of Science (M.Sc.) At the University of Hamburg. Faculty of Mathematics, Informatics and Natural Science Department Biology Study programme "wood science".62 p.

Saldarriaga, J. G.; West, D. C.; Tharp, M. L.; Uhl, C. 1988. Long-term chronosequence of forest succession in the upper Rio Negro of Colombia and Venezuela. Journal of Ecology 76:938-958.

SBB. 2017. NFMS-roadmap: Status and plans for the National Forest Monitoring System of Suriname.

Schnitzer, S. A.; DeWalt, S.J.; Chave, J. 2006. Censusing and measuring lianas: a quantitative comparison of the common methods. Biotropica 38(5):581-591.

Sist, P.; Mazzei, L.; Blanc, L.; Rutishauser, E. 2014. Large trees as key elements of carbon storage and dynamics after selective logging in the Eastern Amazon. Forest Ecology and Management. 318:103-109.

Ter Steege, H. 2001. Biomass estimates for forests in Guyana and their use in carbon offsets. Georgetown, Guyana, Iwokrama International Centre for Rain Forest Conservation and Development/UNDP, 44 p.

Van der Hout, P.; Van Leersum, G.J.R. 1998. Reduced impact logging: a global panacea? Comparison of two logging studies. Logging, Damage and Efficiency: A Study on the Feasibility of Reduced Impact Logging in Cameroon, 8 p.

Werger, M. J.A (ed.). 2011. Sustainable management of tropical rain forest: the CELOS Management System. Tropenbos International, Paramaribo, Suriname. 282 p.

V. Annex

Annex 1. Summary of tree and palms databases analyzed to be used to estimate carbon in forest in Suriname

ID	Name of database	Institution responsible of data base and main contact	Short description	Total of records	Total number of plots	Main variables	Documents linked to this database AND Information gaps
BH	data_ BH	Bruce Hoffman SBB Research & Development Unit Sewdien,A artiesewdien@gmail.com +597 8765695 Location of the database: SBB server http://sbbsur.com/	"Inventories done in non- fl ooded "upland forest" (UP), "seasonally fl ooded or lowland forest" (LO), and fallow forest of greater than 15 years of age (FA) in two areas: Kwamalasemtu (3plots) and Stonhuku (2 plots) for trees >= 10cm"	Trees: 1932 palms: 72	0.5ha (1plot) rectangular 1 ha (4 plots) rectangular	Tree species, DBH	http://content.alterra.wur.nl/Webdocs/PDFFiles/Alterrarapporten/AlterraRapport1977.pdf
CMS	Kabo	Verginia Wortel, CELOS, Forest Management department; wortelv@gmail.com; +5978578135	Permanent sample plots established in 1978-1979, to determine which combination of silvicultural treatment and exploitation level is optimal, considering silvicultural and economical aspects.	8191	1 ha (30 plots), unknown shape	Tree species, DBH	
CSN	TEAM	Verginia Wortel, CELOS, Forest Management department; wortelv@gmail.com; +5978578134	Permanent sample plots established in 2013. Permanent sample plots established in 2013 to monitor changes in aboveground	2440 trees, including palms	1 ha (5 of the 6 plots), unknown shape	Tree species, Liana, DBH	

			biomass in tropical forests (IPCC 2006). In addition it is to measure the effects of climate change on forest growth, mortality and function.				
FAO	Data_FAO	SBB Research & Development Unit Sewdien,A artiesewdien@gmail.com +597 8765695 Location of the database: SBB server http://sbbsur.com/	Inventory carried out in 4 areas: Pokigron, Fallawatra, Nassau and Kabalebo. The purpose was to assess the potential of the accessible resources. Inventoried was the DBH of all trees with a DBH >=25 cm	Trees: 43582	0.04ha (9,039 circular plot) Plots were stablished in 4 areas of the country	forest_type slope soil type family-genus-treespecies dbh (cm) wood density (g/cm^{-3})	No exact geographical locations; tree identification done by a trees potter
FCAM	Data_FCAM	SBB Research & Development Unit Sewdien,A artiesewdien@gmail.com +597 8765695 Location of the database: SBB server http://sbbsur.com/	forest carbon stock measurements were carried out in the period 2010-2011 on 12 locations spread over the forest belt. At every location a transect (1.5ha) was established. Each transect is composed of three measurement plots (0.5ha) spaced apart one km from each other.	Trees: 7054 Standing dead wood: 1081 Lianas: 1231 Coarse Litter (Lying Dead Wood): Soil data: Palms: 615	1.5 ha, transect conformed by three rectangular plots (0.5 ha) and subplots of 0.375	Tree species, DBH, Stem height (palms)	
MK	Marchall kreek	CELOS, M.Playfair, mplayfair@gmail.com	these plots were established to determine 1) the forest sturcture of a degraded	1537	6 (three 1 hectare and three 0.2 hectare	Tree species, DBH	

			community forest, 2) the forest potential for Non Timber Forest Products (NTFPs)		plots)		
MLA	MLA	CELOS, Verginia Wortel, wortelv@gmail.com	The Multiple Landscape Assessment (MLA) method is a quick method, used to obtain information that can determine which (from the perspective of local communities) areas of the studied habitat are important for the local communities. The assessment should provide information that can be used in further discussions with local communities regarding the planning of land use and to formulate policy proposals for development and protection of their area. These transects were established in 2010.	708	40 m transect, various area size (18 transects), unknown shape	Tree species, DBH, Total and commercial height	
Nassau	Nassau	CELOS, Verginia Wortel, wortelv@gmail.com	Conduct a forest inventory in the Nassau area where bauxite mining activities of the Suriname Aluminum Company	373	1	Tree species, DBH	

			(SURALCO) are proposed. The inventory (2012) was to provide an estimate of the volume of the wood lost in the clearing of the Field Trial area and to identify the species that might endure water logging in the area.				
NFI	Data_NFI	SBB Research & Development Unit Sewdien,A artiesewdien@gmail.com +597 8765695 Location of the database: SBB server http://sbbsur.com/	inventory carried out for pilot national inventory. "Pilot National Forest Inventory - sample size: 31 sampling units (SU's). Each SU consisted of 8 or more Permanent Sample Plots (PSP's). Each PSP is again subdivided in Main Assessment Plots (MAP's) Measured were the following components: in each PSP (0.2 ha): Trees dbh ≥ 20cm Standing dead wood (diam ≥ 10cm) Terrain characteristics Pictures in 4 MAP's (0.04ha) : Lianas (diam ≥	Trees: 15146 Standing dead wood: 2092 Lying dead wood: 642 Lianas: 821 palms: 1364	1.6 ha (sometimes larger) clusters conformed by 8 rectangular plots of 0.2 ha	dbh diam, total height crown height species local name scientific name family terrain characteristics, descriptive tree quality scores	Tree species identification done by a trees potter Towards a carbon balance for forests in Suriname- Alterra Report 1977 by Arets, et.al, 2011 http://content.alterra.wur.nl/Webdocs/PDFFiles/Alterrarapporten/AlterraRapport1977.pdF Bánki, O.S. (2010). Does Neutral Theory explain Community Composition in the Guiana Shield Forests? Ph.D. Thesis. Utrecht University, Utrecht, The Netherlands. Bánki, O.S., H. ter Steege,

			5cm) Woody Palms (woody stem ≥ 1.3m) in 2 MAP's (0.02 ha): Pole trees (10 cm ≤ dbh < 20cm) Pole trees (5cm ≤ dbh < 20cm) in 2 subplots (0.005ha): Regeneration (stem height ≥ 1.3m and dbh < 5cm) Lying dead wood (diam ≥ 10cm)"				M.J. Jansen-Jacobs and U.P.D. Raghoenandan. (2003). Plant diversity of the Nassau Mountains, Suriname - Report of the 2003 Expedition. NHN-Utrecht Branch, Utrecht University, Utrecht, Utrecht, The Netherlands. Poorter et.al. (2015). Diversity enhances carbon storage in tropical forests. Global Ecology and Biogeography 24:1314-1328.
OB	Data_OB	Olaf Banki & ter Steege SBB Research & Development Unit Sewdien,A artiesewdien@gmail.com +597 8765695 Location of the database: SBB server	"Biodiversity study with 39 x 1 ha plots across different forest and soil types at Brownsberg, Lely Nassau and Zanderij in Northern Suriname. The DBH of all trees > 10 cm DBH was measured"	Trees: 21701 Palms: 370	1 ha (39 plots), unknown shape	Family-species-binomial Forest type, dbh (cm)	Subplot area is unknown. Towards a carbon balance for forests in Suriname-Alterra Report 1977 by Arets, et.al, 2011
SR	Data_SR	Sofie Ruyschaerts SBB Research & Development Unit Sewdien,A artiesewdien@gma	"Biodiversity study including 4 x 1 ha plots of high forest, savanna forest and marsh	Trees: 2551 palms: 195	1 ha, rectangular plots 0.01ha,	bh diam, total height crown height	Only in plot 1 and 2 small trees and shrubs were measured; height was

		il.com +597 8765695 Location of the database: SBB server /	forest at Brownsweg and Powakka). The DBH of all trees >10 cm DBH was measured in the whole plot en in subplots DBH 0-10cm." Measured were: SR_1= trees with DBH >=10 cm in 20mx20m subplots & Trees&Shrubs DBH<10cm / Height>=1,5m in 10x10m subplots SR_2= Herbs: Height <=1.5m in 2m x 2m subplots => only speciesname known		, rectangular plots	species local name scientific name family terrain characteristics, descriptive tree quality scores	not measured, but roughly estimated Towards a carbon balance for forests in Suriname- Alterra Report 1977 by Arets, et.al, 2011 Source: http://content.alterra.wur.nl/Webdocs/PDFFiles/Alterrarapporten/AlterraRapport1977.pdf

Description of available datasets.

FAO

Forest inventory held in 4 areas in the forest belt: Kabalebo (141000 ha.), Fallawatra (70000 ha.), Nassau (123000 ha.) and Pokigron (unknown).

Trees with dbh >25 cm were measured in each plot. In each area, circular plots were set up of each 0.04 ha. The total number of plots in all 4 areas was 9039 plots.

Available variables: dbh (cm) and tree species

Gaps: no location coordinates for the plots & unknown tree species

Bruce Hoffman

Inventories were carried out in "non-flooded upland forest (UP)" using 1 ha plots, in "seasonally flooded or lowland forest (LO)" using 1 ha plots, and in "fallow forest of greater than 15 years of age (FA)" using 0.5ha plots. These were carried out in two areas: Kwamalasemutu and StonHuku.

Trees with dbh > 10 cm were measured in each plot. A total of 5 plots were set up (3 in Kwamalasemutu and 2 in Stonhuku).

Available variables: DBH (cm)

Gaps: not all scientific names are known; only local names.

Olaf Banki

Inventory done for biodiversity purposes across different habitat types in 39 plots of 1 ha.

Trees with dbh > 10 cm were measured in each plot. Total number of 1 ha plots used: 39.

Available variables: dbh (cm) and tree species

Gaps: unknown tree species

Sofie Ruyschaert

Inventory done for biodiversity study purpose across different forest types in 4 plots of 1 ha.

Trees with dbh > 10 cm were measured in each plot. Also, trees with dbh from 0-10cm we measured in 10 m x 10 m (0.01 ha) subplots.

Total number of 1 ha plots: 4

Variables available: dbh (cm) and tree species.

Gaps: unknown tree species

FCAM: Pilot Carbon project

Forest carbon stock measurements were carried out in 12 locations spread out over the forest belt. At every location, a transect (1.5 ha) was established. Each transect was composed of three plots (each 0.5ha) spaced apart 1 km from each other.

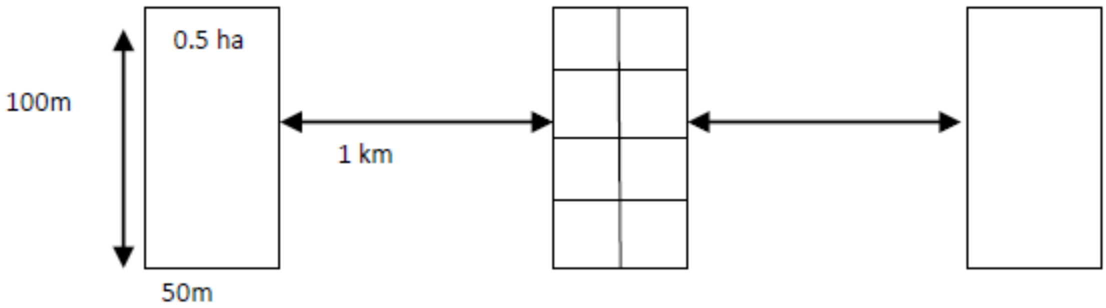


Figure: The FCAM project sampling design consists of a transect with three plots.

In each 0.5 ha plot, trees with a dbh > 20 cm were measured. Also, palms in a transect 2-7 with dbh >20 cm were measured.

In 2 0.125 ha subplots, Trees with dbh 5-20 cm were measured. Palms in transect 2-7 with 5-20 cm dbh were also measured. Palms in transect 8-12 cm with a stem height from 1.3m and up.

Total number of 0.5 ha plots: 36

Variables available for trees: dbh (cm) and species; for palms: dbh (cm) or stem height (m)

Gaps: unknown tree species

<u>NFI</u>

Pilot National Forest Inventory carried out to collect information for multiple purposes for the future National Forest Monitoring System. Measurements were taken in 31 sampling units distributed throughout the country.

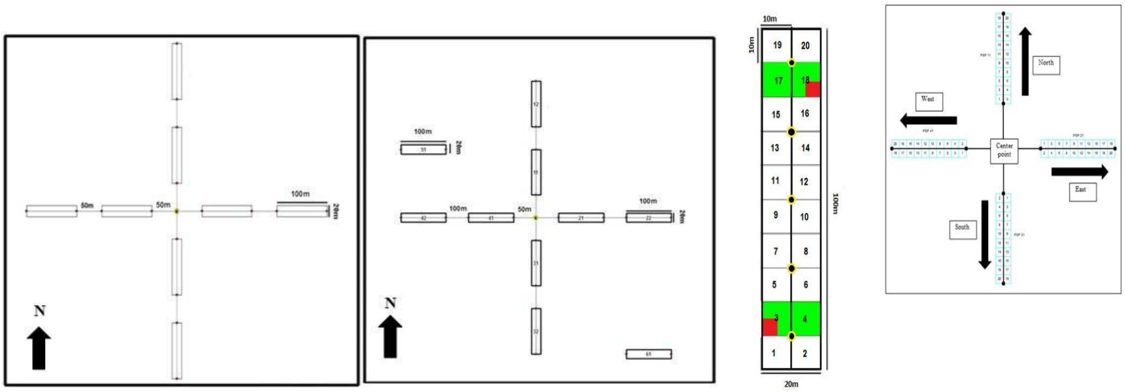


Figure: NFI pilot sampling design consists of 8 permanent sampling plots (0.2 ha). A PSP consist of 20 subplots (Main Assessment Plots-MAP- 0.01 ha)

Total number of 0.2 ha plots: 257

Available Variables: Trees:dbh (cm) and tree species; Palms: stem height (m)

Gaps: Unknown treespecies

Unit	Unit size	Component	Comments
PSP	0.2 ha	Trees dbh ≥ 20 cm Standing dead wood (diameter ≥ 10 cm) Terrain characteristics Pictures	Components to be measured in all MAPs Soil type at the beginning of 2 MAPs At the intersections of 4 MAP's
4 MAPs	0.04 ha	Lianas (diameter ≥ 5 cm) Woody Palms (woody stem ≥ 1.3m)	Components to be measured only in MAPs 3, 4, 17 and 18
2 MAPs	0.02 ha	Pole trees (10 cm ≤ dbh < 20 cm)	Components to be measured only in MAP 4 & 17
2 MAPs	0.02 ha	Pole trees (5 cm ≤ dbh < 20 cm)	Components to be measured only in MAP 3 & 18
2 subplots	0.005 ha	Regeneration (stem height ≥ 1.3 m and dbh < 5 cm) Lying dead wood (diameter ≥ 10cm)	Subplots located only in MAP 3 and 18

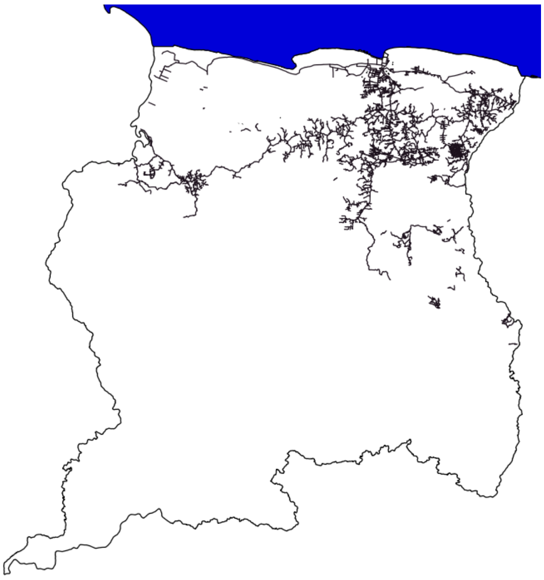
Annex 2. Number of sampling units by carbon pool in Suriname's forests.

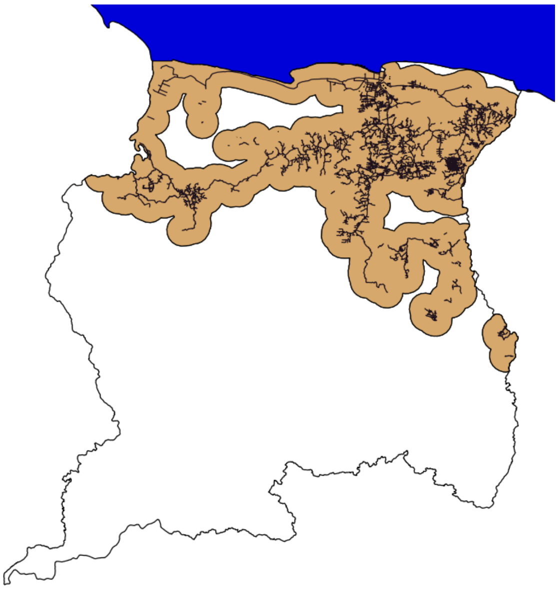
Forest type	Live trees	Lianas	Palms	Downed wood	Standing dead wood
Creek forest	64	5	5	6	7
Dry montane forest	1	1	1	1	1
Forest plantation	2				
High savanna forest	29	6	5	7	7
High swamp forest	5	3	4		4
Low savanna forest	7			1	2
Low swamp forest	3	1	1	1	1
Mangrove	2			2	2
Moist evergreen forest	144	27	49	20	34
Montane forest	13	4	4		
Periodic swamp forest	8	5	7	4	5
Riparian forest	1	1	1	1	1
Savanna forest	13		2		
Secondary forest	7	4	1	4	4
Swamp forest	7	5	7	4	6
Non-forest					1
Unknown	44				

Annex 3. Stratification of accessible areas for Suriname

1. **Roads**

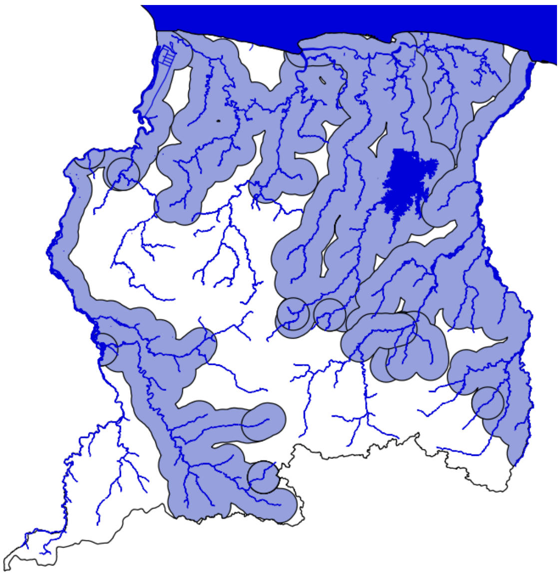
The road layer of 2015 was used. A buffer of 15 km on both sides of the road is classified as "accessible". Roads that are overgrown by vegetation were excluded.





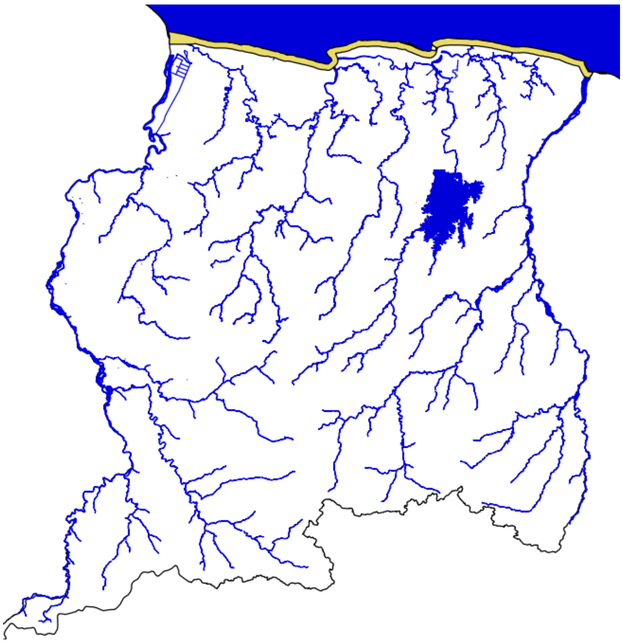
2. **Rivers**

The hydrology layer created using Landsat images was crosschecked with topographic maps. Navigable rivers and very difficult to navigate rivers were distinguished based on field knowledge. A buffer of 15 km was applied to the navigable rivers.



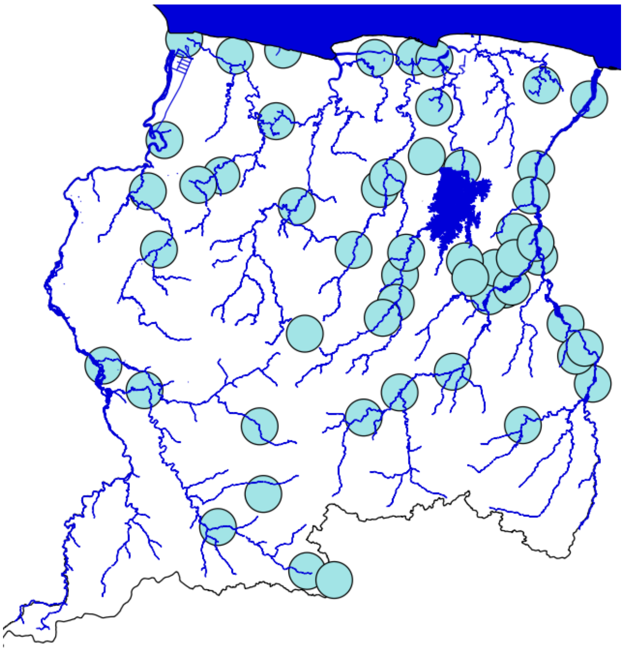
3. **Ocean**

Because the coastal area is mostly difficult to access, a buffer of 5 km was applied.



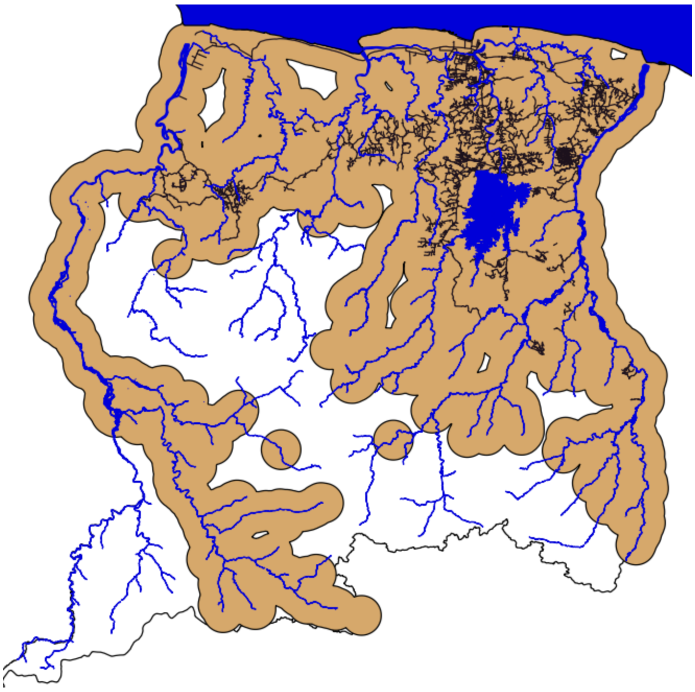
4. **Airstrips**

Based on the aeronautical map the airstrips were also included. A buffer of 15 km was applied to them.

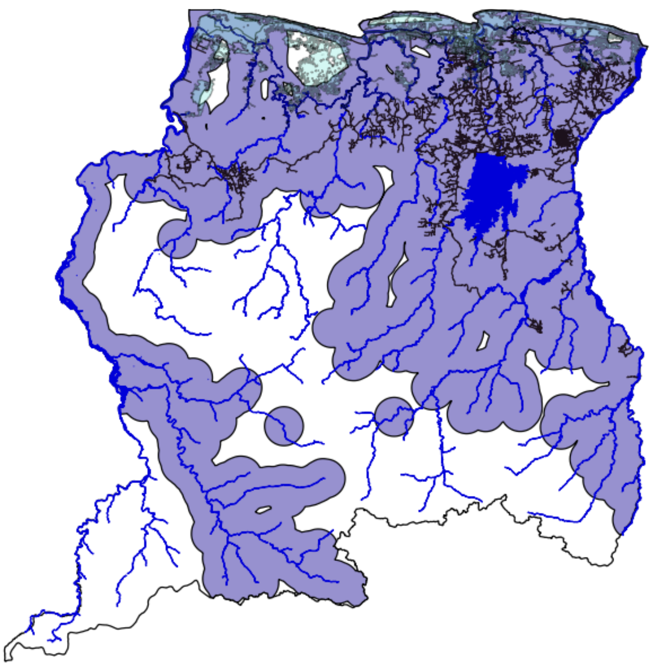


5. **Bringing the information together – including swamps**

When all the above buffers are merged we reach the following result:



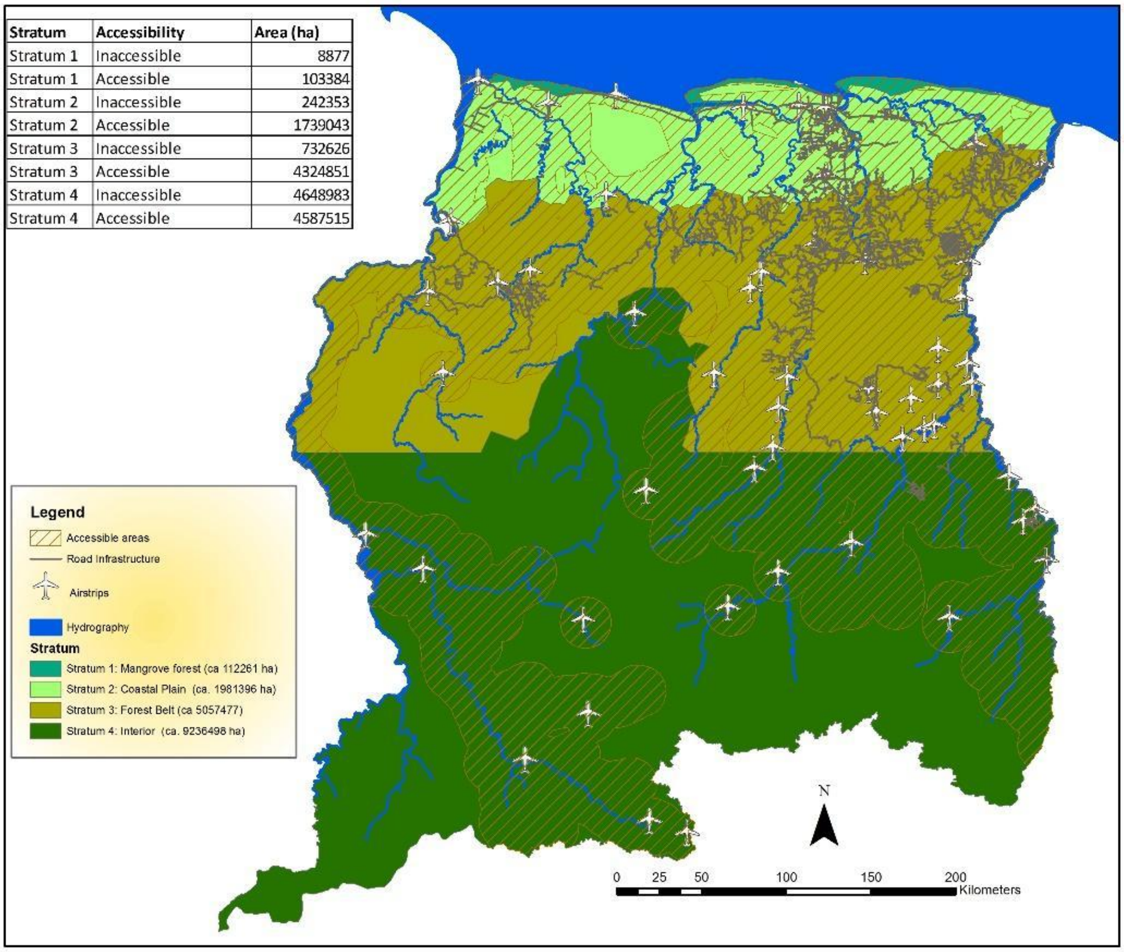
Nevertheless, since it is much more complicated to walk in a swamp then in a high forest, the former need special attention. When we assume that inventory personnel can only walk 5 km within the swamps, we get following result:



Final Areas:

1) **Mangrove forest** (needs to be determined nationally)

2) **Young coastal plain:** From mangroves to forest belt. Most variable area with most human activities and natural variation (swamps, savannah, forest).
3) **Forest belt:** Northern line: based on productive forest occurrence. Southern line: 4º latitude, based on National Forest Policy (2005); no forestry concessions are issued south of this line.
4) **Interior:** south of the 4th latitude, including the whole Central Nature reserve, where no forestry concessions are granted, but gold mining activities occur in the east. This area is very difficult to access due to river rapids and no road infrastructure.



Stratum	Accessibility	Area (ha)
Stratum 1	Inaccessible	8877
Stratum 1	Accessible	103384
Stratum 2	Inaccessible	242353
Stratum 2	Accessible	1739043
Stratum 3	Inaccessible	732626
Stratum 3	Accessible	4324851
Stratum 4	Inaccessible	4648983
Stratum 4	Accessible	4587515

Annex 4. Summary of logging practices in Suriname

As shown in Table 6, Reduced Impact Logging (RIL) is a different forest management category than Conventional Logging (CL) and Conventional Community Logging (CCL). Since RIL is implemented, most of the forest practices due as the FSC requirement and validation process.

Summary of logging practices in Suriname; A = yes; B = sometimes; C/null = no.

Component of logging process	Practices	CTL-FSC	CTL	CL
Pre harvest inventory		A	A	
	Preparation of topographic maps	A	A	
Harvest planning				
	Designation/identification of cutting blocks	A	A	A
	Designation buffer zones	B	B	
	Inventory of the trees per cutting block	A	A	
	Tree selection system	A	A	
	Seed trees	B	B	
	Layout of a detailed transportation and extraction system;	B	B	
	Planning of skid trails and landings	B	B	
	Manpower-machine input	A	A	A
	Skid rail alignment	A	B	
	Scheduling of operations to accommodate the timing of, for example, the rainy season	A	B	
	Implementation and control of harvesting operations	B	B	
	Planning of felling patterns	B	B	
	Assessment and communication of results between planners and operators	B	B	
	A competent and properly motivated workforce	B	B	
Felling				
	Reduction of damage to potential crop trees	A	B	
	Facilitation of skidding	A	B	
	Reduction of damage to the felled trunk	A	B	
	Creation of multiple tree gaps	C	A	A
Skidding				
	Detailed planning of the skid trails on the map;	A	B	
	Detailed alignment of the skid trails in the forest;	B	B	
	Log winching to the skid trails.	B	B	

Source: Adapted from Van der Hout & Van Leersum 1998

Annex 5. Alternative approach to estimate emission factor for deforestation

$$EF_{deforestation} = \{(C_{TABG} + C_{PAGB} + C_{TBGB} + C_{Lianas}) - (C_{OT})\} * 44 / 12$$

Where:

$EF_{deforestation}$ =Emission factor for deforestation (Mg CO_2 ha^{-1})

C_{TABG} =carbon in above ground biomass in living trees (Mg CO_2 ha^{-1})

C_{PAGB} =carbon in above ground biomass in palms (Mg CO_2 ha^{-1})

C_{TBBG} =carbon in below ground biomass in roots of living trees (Mg CO_2 ha^{-1})

C_{lianas} =carbon in lianas (Mg CO_2 ha^{-1})

C_{OT} =carbon in other land uses (Mg CO_2 ha^{-1})

Annex 6. Aboveground carbon (Mg C ha^{-1}) in Suriname (S.E.=standard error, N=number of plots, LL=lower limit, UP=upper limit) per Study

Study	Mean	S.E.	N	LL (95%)	UL (95%)	Uncertainties
BH	170.92	14.37	5	131.03	210.81	23.34
CSN	179.29	22.76	4	106.86	251.72	40.40
FAO	161.06	4.33	61	152.41	169.71	5.37
FCAM	136.68	7.63	12	119.88	153.48	12.29
KABO	199.03	4.91	30	188.99	209.06	5.04
MK	160.82	7.63	3	128.00	193.64	20.41
MLA	158.50	17.41	18	121.77	195.23	23.17
NASSAU	286.50		1			
NFI	150.06	10.36	31	128.89	171.23	14.11
OB	196.82	7.76	39	181.11	212.52	7.98
SR	171.46	11	4	136.45	206.47	20.42

Annex 7. Carbon stocks (Mg C ha^{-1}) by carbon pool in Suriname. (S.E.=standard error, N=number of plots, LL=lower limit, UP=upper limit).

Empty cells mean that confidence limits could be estimated due to a small numbers of data (n)

Carbon stock in living trees per stratum

Stratum	Mean	S.E.	n	LL (95%)	UL (95%)	Uncertainties
1	44.41	17.15	2.00			
2	149.62	15.34	21.00	117.63	181.61	21.38
3	176.10	3.38	170.00	169.43	182.77	3.79
4	164.99	9.09	15.00	145.50	184.48	11.81
All	171.36	3.38	208.00	164.70	178.02	3.89

Carbon in lianas per accessibility strata

Stratum	Mean	S.E.	n	LL(95%)	UL(95%)	Uncertainties
1	0	0	2			
2	0.64	0.42	5			
3	2.83	0.24	23	2.32	3.33	17.97
4	2.38	0.46	8	1.28	3.48	46.13
All	2.30	0.23	38	1.82	2.77	20.43

Carbon in lianas per study

ID	Mean	S.E.	n	LL(95%)	UL(95%)	Uncertainties
CSN	1.57	0.41	4	0.26	2.87	83.57
FCAM	2.6	0.39	5	1.52	3.68	41.53
NFI	3.06	0.24	29	2.58	3.54	15.72

Carbon in lianas per forest type

Forest type	Mean	S.E.	n	LL(95%)	UL(95%)	Uncertainties
Creek forest	3.01	0.66	16.00	1.60	4.43	47.18
Dry montane forest	4.56	1.13	7.00	1.80	7.32	60.53
High Savanna forest	1.06	0.40	25.00	0.23	1.88	77.36
High swamp forest	2.66	0.61	4.00	0.70	4.61	73.31
Low savanna forest	0.00	0.00	1.00	0.00	0.00	
Low swamp forest	8.30	6.03	2.00			
Mangrove	0.00	0.00	16.00	0.00	0.00	
Moist Evergreen forest	2.99	0.26	126.00	2.47	3.51	17.39
Montane forest	1.57	0.41	4.00	0.26	2.87	82.80
non-forest	0.00	0.00	5.00	0.00	0.00	
Periodic swamp forest	3.59	0.67	13.00	2.14	5.04	40.39

Carbon in standing dead wood per accessibility strata

Stratum	Mean	S.E.	n	LL(95%)	UL(95%)	Uncertainties
1	2.11	0.7	2.00			
2	1.31	0.59	5.00			
3	3.14	0.32	30.00	2.49	3.78	20.62
4	1.92	0.51	6.00	0.61	3.23	68.21
All	2.71	0.26	43.00	2.18	3.23	19.18

Carbon in standing dead wood per study

ID	Mean	SE	n	LL (95%)	UL (95%)	Uncertainties
FCAM	2.98	0.44	12.00	2	3.96	32.83
NFI	2.60	0.32	31.00	1.95	3.26	25.12

Carbon in standing dead wood per forest type

Forest type	Mean	S.E.	n	LL(95%)	UL(95%)	Uncertainties
Creek forest	1.35	0.35	17.00	0.61	2.09	54.81
Dry montane forest	1.65	0.41	7.00	0.64	2.65	60.61
High Savanna forest	4.65	0.87	25.00	2.86	6.44	38.49
High swamp forest	1.90	0.67	6.00	0.19	3.61	90.00
Low Savanna forest	0.99	0.95	2.00			
Low swamp forest	2.17	0.95	2.00			
Mangrove	2.11	0.63	16.00	0.76	3.47	64.45
Moist Evergreen forest	2.97	0.21	152.00	2.54	3.39	14.14
Periodic swamp forest	2.77	0.55	13.00	1.57	3.97	43.32
Riparian forest	2.04	0.43	8.00	1.02	3.06	50.00
Secondary forest	4.09	1.79	4.00			
Swamp forest	1.13	0.31	27.00	0.50	1.77	56.64

Carbon in downed dead wood per study

ID	Mean	S.E.	n	LL(95%)	UL(95%)	Uncertainties
NFI	8.39	1.63	29	5.05	11.74	39.93

Carbon in downed dead wood per accessibility strata

Stratum	Mean	S.E.	n	LL(95%)	UL(95%)	Uncertainties
1	0.79	0.12	2			
2	3.23	1.59	5			
3	11.54	2.29	18	6.7	16.37	41.89
4	4.5	1.34	4	0.25	8.76	94.47
All	8.39	1.63	29	5.05	11.74	39.93

Carbon in downed dead wood per forest type

Forest type	Mean	S.E.	n	LL(95%)	UL(95%)	Uncertainties
Creek forest	6.29	2.06	16.00	1.89	10.69	69.95
Dry montane forest	3.02	2.13	7.00			
High Savanna forest	14.91	3.65	25.00	7.39	22.44	50.50
Low savanna forest	0.00	0.00	1.00			
Low swamp forest	3.40	2.43	2.00			
Mangrove	0.79	0.38	16.00			
Moist evergreen forest	9.81	1.88	115.00	6.08	13.54	38.02
Periodic swamp forest	6.29	3.09	13.00			
Riparian forest	3.70	1.31	8.00	0.59	6.81	84.05
Secondary forest	22.89	20.79	4.00			
Swamp forest	4.81	1.72	20.00	1.20	8.42	75.05

Carbon in palms per study

ID	Mean	S.E.	n	LL(95%)	UL(95%)	Uncertainties
BH	2.29	0.77	3			
FCAM	3.61	1.51	12	0.28	6.94	92.345
NFI	1.73	0.51	33	0.69	2.76	59.789
OB	0.25	0.08	39	0.1	0.41	61.796
SR	3.12	2.4	4			

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