Guyana Forestry Commission

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Long Term Measurement and Monitoring Plan for Guyana's REDD+ Forest Carbon Monitoring System: Version 2

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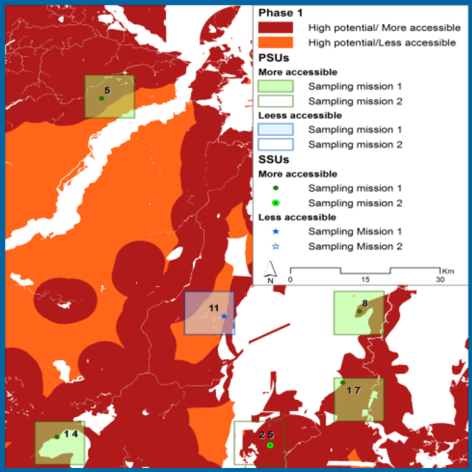

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1.0 BACKGROUND

The Monitoring, Reporting, and Verification System (MRVS) being developed by Guyana will allow the country to determine greenhouse gas emissions and removals resulting from deforestation and forest degradation, and to identify any changes in business as usual (BAU) emissions as a result of implementation of REDD+ activities. The Forest Carbon Monitoring System (FCMS) is a critical element of the MRVS as it details the methods required to quantify the forest carbon stocks in Guyana, develop driver-specific emission factors by forest strata, and monitor emissions from land cover / land use change over time based on a variety of management activities.

This Version 2 report details the long-term measurement and monitoring plan to be implemented under the FCMS. The plan is closely aligned with the Sampling Design (Brown *et al*. 2014), and allows for validation of existing data, reduction in uncertainty, and revision of the emissions factors as needed.

Ongoing monitoring of activity data is being conducted by GFC with the assistance of Indufor. These monitoring activities are described in further detail in GFC and Indufor (2013).

In this report, we briefly summarize work completed to date, and describe the next steps that need to be completed in sampling and developing emission factors for the low potential for change more and less accessible strata and for the other causes of degradation. The final section will describe the plan of proposed steps needed to ensure the emission factors remain current over the medium term of about 10 years.

2.0 WORK COMPLETED TO DATE

Work on developing emission factors (EFs) for deforestation activities and timber harvest in the high and medium potential for change (PFC) strata has been completed. For details on all work to date, refer to the following reports submitted by Winrock to the GFC:

- Petrova S., K. Goslee, N. Harris, and S. Brown. 2013. Spatial Analysis for Forest Carbon Stratification and Sample Design for Guyana's FCMS: Version 2;
- Brown, S., K. Goslee, F. Casarim, N. L. Harris, and S. Petrova. 2014. Sampling Design and Implementation Plan for Guyana's REDD+ Forest Carbon Monitoring System (FCMS): Version 2; and
- Goslee, K., S. Brown, and F. Casarim, 2014. Forest Carbon Monitoring System: Emission Factors, Version 2.

2.1 Deforestation

The carbon stocks for each pool and stratum sampled to date are given in Table 1. The precision target of a 95% CI of ±<15% of mean was achieved for each stratum. The soil pool was also measured and EFs for this pool were estimated using the IPCC 2006 Guidelines.

Table 1. Carbon stocks by pool for the high (HPfC) and medium (MPfC) potential for change strata. MA=more accessible and LA =less accessible.

Stratum	AG Tree (t C/ha)	BG Tree (t C/ha)	Saplings (t C/ha)	Standing Dead Wood (t C/ha)	Lying Dead Wood (tC/ha)	Litter (tC/ha)	**Sum Carbon Pools (t C/ha)**	number of plots	95% CI as a % of mean
HPfC MA	193.6	45.5	4.2	2.0	11.1	3.3	259.8	26	7.8%
HPfC LA	267.6	62.9	4.1	2.0	8.8	5.6	351.0	16	10.1%
MPfC	231.1	54.3	3.5	2.3	5.6	3.2	300.0	24	12.1%

In sum, robust EFs for each driver of deforestation for the HPfC and MPfC strata have been developed with high precision (Table 2).

Table 2. Emission Factors for drivers of deforestation in areas of high (HPfC) and medium (MPfC) potential for change. These EFs assume all the carbon in vegetation is emitted to the atmosphere at the time of the event. MA=more accessible and LA=less accessible.

Stratum	Drivers	Biomass carbon (t C ha^{-1})	Change in soil carbon (t C ha^{-1})	EF (t CO_2e ha^{-1})
HPfC MA	Forestry infrastructure (roads and decks)	259.8	24.4	1,042.0
	Agriculture	259.8	51.6	1,141.9
	Mining (medium and large scale)	259.8	24.4	1,042.0
	Mining infrastructure	259.8	24.4	1,042.0
	Infrastructure (other roads)	259.8	24.4	1,0420
	Fire-Biomass burning	NA	0	775.4
HPfC LA	Forestry infrastructure (roads and decks)	351.0	19.7	1,359.5
	Agriculture	351.0	41.8	1,440.2
	Mining (medium and large scale)	351.0	19.7	1,359.5
	Mining infrastructure	351.0	19.7	1,359.2
	Infrastructure (other roads)	351.0	19.7	1,359.5
	Fire-Biomass burning	NA	0	1,042.6
MPfC (and LPfC)	Forestry infrastructure (roads and decks)	300.0	23.7	1,186.9
	Agriculture	300.0	50.2	1,284.0
	Mining (medium and large scale)	300.0	23.7	1,186.9
	Mining infrastructure	300.0	23.7	1,186.9
	Infrastructure (other roads)	300.0	23.7	1,186.9
	Fire-Biomass burning	NA	0	889.0

2.2 Degradation

Implementation of the first phase of the sampling design for degradation focused on timber harvesting in concessions of various sizes and using different extraction rates specified in Guyana's code of practice. A total of 184 plots were established in logging concessions where timber had recently been extracted. The detailed methods described in the sampling plan design were used to estimate the impact of timber extraction on forest carbon stocks and the resulting emission factors are given in Table 3 (see Brown et al. 2014 and Goslee et al. 2014 for further details).

Table 3. Emission Factors, and their uncertainties, used for estimating total emissions for degradation due to timber harvest. LDF – logging damage factor; LIF – logging infrastructure damage factor (skid trails), and C_{LTP} – fraction of a given product class that goes into long term storage.

Driver	Emission Factors		Uncertainty
	Unit	t CO_2	% of mean
LDF	per m^3	3.85	9.4
Wood Density of Timber Harvested	per m^3	1.47	1.0
LIF (Skid Trails)	per km	171.8	14.6
C_{LTP}	Fraction		Not available
Sawnwood		0.06	
Woodbase panels		0.01	
Other industrial roundwood		0.00	

2.3 Other Causes of Degradation

Carbon stock assessment has not been completed for shifting cultivation. The main reason for this is the lack of detailed knowledge on the extent of the activity, the length of the fallow/crop cycles, and the extent of any changes in the dynamics of the practice across Guyana. Two surveys that have been conducted in many communities where shifting cultivated is practiced have improved the knowledge and understanding of the typical practices employed by the communities. However, it is difficult at present to design a forest carbon measurement system until further details on the extent and dynamics of this practice are available across Guyana — such data will be forthcoming in future work on analysis of remote sensing imagery. Once such data are routinely monitored it will be possible to design and implement a system to measure and monitor this practice and to develop emission factors.

Small scale mining has been considered to be forest degradation rather than deforestation because the area typically cleared is less than 1 ha. However given the current use of higher resolution remote sensing imagery and the fact that small scale mines often coalesce, it is suggested that small scale mining be included with medium and large scale mining and be considered deforestation. Even if a small scale mine was detected and found to have cleared only 0.5 ha, the EF for deforestation by medium and large scale mining would still be appropriate — the emissions would be the product of the mined area and EF, whether the area is a clearing of multiple hectares or a fraction of one hectare.

Work on quantifying emission factors for other causes of degradation, such as in the buffers around mines or roads, is in planning stages, building on preliminary work done to date. Preliminary factors have been developed to assist GFC in reporting on the interim measures to Government of Norway, but further work is needed. Once again, the design of such a forest carbon monitoring system is closely linked to the activity data produced by the remote sensing team. The sampling system for the forest carbon component for monitoring these other causes of degradation will be developed when progress on monitoring the associated activity data has advanced.

2.4 Steps to Reduce Uncertainties

Several steps are needed to reduce uncertainties is the existing data set used to estimate emission factors. With the implementation of these tasks, all sources of uncertainties will better quantified and higher confidence in the emission factors will be attained.

2.4.1 Aboveground biomass estimation from allometric equations

Destructive sampling was conducted, as described in the Sampling Design, to verify the appropriateness of an existing allometric equation for estimating aboveground tree biomass. Four trees were sampled, providing sufficient data to confirm that the equation for moist forests developed by Chave et al (2005) appears to be appropriate for use in Guyana. Additional data would be valuable to add to the overall database and thoroughly confirm the appropriateness of the equation. Two to three large trees (dbh > 70 cm) should be destructively sampled and added to the data base to reconfirm the use of this equation. The sampled trees (those sampled in 2010 and additional ones) can be added to the data base and the regression model re-run. If resources permit, this step could be repeated each year over the next 5 years, including smaller diameter trees (40-70 cm dbh). If, over time, there is found to be a significant discrepancy between sampled and model estimated biomass, an adjustment will need to be made to the Chave equation used to estimate aboveground tree biomass in Guyana.

Recently Chave et al[1] published a new paper that includes new allometric equations for tropical forests. Chave et al compiled a larger data base (1,481 trees in 2005 and 4,004 trees in 2014) that ranged from 5-212 cm diameter. The best equation includes three parameters of DBH, total tree height, and species-specific wood density. If height data are not available an alternative equation is presented. Chave et al. 2014 propose that the new equations are an improvement over the 2005 versions. Further work is recommended in addition to the above (harvest of some additional trees) to see if the new equation by Chave et al 2014 produces more accurate estimates for Guyana’s trees. It is recommended that the equation (4) be used from Chave et al 2014 be tested and also to improve it develop a local dbh-ht relationship (as recommended by Chave et al.) by taking new measurements of a range of sizes of trees (at least 30 trees), making sure to include tallest trees.

Belowground tree biomass is estimated using an established root to shoot ratio (Mokany et al 2006), which is accepted under IPCC 2006 standards. Because this ratio has been found to be sufficient for tropical forests, and because destructive sampling of belowground biomass is highly intensive and extremely expensive, this ratio is appropriate for use in the FCMS.

2.4.2 Updating more and less accessible strata

As has been found to date in the remote sensing component of the MRVS, forestry infrastructure (logging roads and decks) and other roads are expanding in the areas of high and medium potential for change. This will influence the sampling plan in relation to the more and less accessible zones; areas that are currently considered less accessible may become more accessible. To account for this, accessibility should be reassessed following these changes in road development (forestry and other). Specifically, the development of any new roads will require a reassessment of accessibility by building buffers around these new roads in the GIS layer and updating the sampling of more and less accessible zones (see sampling plan by Goslee et al. 2012 and below for more description of the work needed).

2.4.3 Skid trails in logged areas

The two largest sources of error in the emission factors for logging are skid trails (12.4% of mean) and wood products (factors assumed to be 20% uncertain). Efforts in the next 6 months or so should be made to reduce the uncertainties related to skid trails; the uncertainty around wood products is assumed and there is no work that can be done by GFC to reduce this uncertainty at present.

For **skid trails**, reductions in the uncertainty can be achieved through more detail measurements of the actual damaged trees along lengths of skid trail (this would need to take place on skid trails recently formed using actual measurements of damaged trees). At present the C stock of damaged trees is based on an assumption that all non-commercial trees below a certain size would be killed in addition to any trees alongside the skid trail that are snapped or uprooted. This assumption needs to be confirmed with further investigation, e.g. by talking with the logging concessionaires and through site visits to active concessions to assess the damage along skid trails

[1] Chave, J. plus 23 other authors, 2014. Improved allometric models to estimate the aboveground biomass of tropical trees. Global Change Biology doi: 10.1111/gcb.12629.

immediately after the logs have been skidded out (using the log extraction SOP). Such work could be done during the next time period of active logging.

2.4.4 Complete uncertainty analysis for emission factors

At present the uncertainty analysis only includes the uncertainty due to the sampling error, however there are other sources of error such as measurement error (errors in collecting data from the plots), and the error due to the use of models such as the allometric equations, soil factors, and wood product factors.

Limited data are available at present with which an estimate of measurement error can be assessed. A SOP for doing measurement error assessment is available and this needs to be completed. Given the accessibility issue for reaching the location specific PSU/SSUs, this SOP may need to be revised. For example, for every fifth cluster plot, two field teams need to go to the same plot with each team measuring two subplots, and then when complete the teams switch and re-measure each other's plots. Further discussions are needed to finalize a plan to develop the magnitude of this error that is both effective and efficient.

The IPCC GPG 2003 recommends that the best way to estimate total uncertainty with multiple sources of error is through a Monte Carlo type of analysis. It is proposed that this be done for the emission factors when all the above recommendations for new field data collection have been implemented. (Winrock has recently acquired a program to perform such an analysis that is an add-on module to Excel and is currently developing expertise in its use. GFC staff have received introductory training on this program and at the appropriate time GFC should arrange for staff to receive further training — a plan should be made to do this late-2014.)

3.0 FUTURE MONITORING FOR THE FCMS

3.2 Phase III Measurements

The next steps in the implementation of a national sampling design are data collection under Phase III, in the low PFC stratum, and subsequent calculation of the carbon stocks and emission factors for this stratum. However, in the low PFC stratum (Phase III), very little deforestation has occurred in 2010-1012. Thus in the near term (5 years), field data collection in this stratum could be initiated to obtain preliminary data on the variability and comparability of the C stocks in these forests with the those in the high and medium PFC strata.

These steps are described in more detail in the Spatial Techniques Version 2 report (Petrova et al. 2013) and the Sampling Design Version 2 (Brown et al, 2014). The specific methods used for data collection are described in detail in the Standard Operating Procedures (Casarim et al. 2014).

3.3 Longer Term Monitoring

3.3.1 Deforestation

Monitoring must be conducted at regular intervals to update carbon stocks and emissions factors due to changes that result from growth, mortality, management activities, land use, or other factors. For this reason, it is necessary to update forest biomass and carbon stocks on a regular basis. Every five years a complete forest biomass inventory should be conducted for each Phase. These inventories can be conducted on a rolling basis by strata, as follows (Table 4):

Table 4. Timeline for 5-year re-measurement of forest strata based on potential for change in Guyana. "X" indicates year in which measurements will be conducted in each stratum.

Year	Stratum					
	High potential		Medium potential		Low potential	
	More accessible	Less accessible	More accessible	Less accessible	More accessible	Less accessible
2014						
2015					X[1]	X[1]
2016						
2017	X	X				
2018			X	X		
2019						
2020					X	X
2021						
2022	X	X				
2023			X	X		

[1] Feld data could start being collected in these strata even if deforestation has not increased—this would start to provide information as to how the C stocks of this forests may or may not be too different from those in the other strata.

Because Guyana's FCMS does not use permanent plots, for each new inventory, new PSUs will need to be randomly chosen and SSUs randomly located within the PSUs. If time and resources allow, however, GFC is encouraged to establish five permanently monumented plots in the more accessible zone of the high PFC stratum so that through time a dataset can be developed to assist in the establishment of typical growth rates and mortality and likely changes due to climate change. The SOP for establishing and measuring trees in permanent plots should be used.

In addition, ongoing efforts to coordinate with the RAINFOR program should be continued and efforts should be made to obtain summaries of the findings for each plot as they are re-measured. The RAINFOR project has established a series of 12 permanent plots in Guyana, located in the forest reserves of Mabura Hill, Iwokrama, and Pibiri. The Pibiri and Mabura plots have been measured over multiple years since 1993 and the Iwokrama plots were measured since 2002 to 2008.The latest measurements for all plots were taken in 2012. The mean rate of C accumulation in above and below ground biomass[2] of existing trees and ingrowth was 5.2 ± 1.76 t C ha^{-1} (±95% confidence interval equivalent to 34% of the mean value). The summaries would include change in biomass stocks (biomass estimated using the Chave et al. equation), ingrowth, and mortality.

Establishment of plot locations should follow Petrova *et al*. (2013) and plot design and data collection should follow Brown *et al.* (2014) and Casarim *et al.* (2014).

3.3.2 Degradation

Separate monitoring is needed to update emission factors for degradation from selective logging and other drivers of degradation as these are included in the forest cover monitoring system. Unless the forest code of practice changes there is no need to collect additional data for the logging damage factor (LDF) in the high PFC stratum.

[2] RAINFOR did not include roots but they are included here based on same root shoot ratio as used in all GFC work.

3.3.3 Steps for long-term monitoring for the FCMS

Table 5 summarizes the steps that need to be taken to implement the long term monitoring plan for the FCMS to arrive at updated estimates of the emission factors that are used with the activity data from the remote sensing work.

Table 5. Summary of steps included in long-term monitoring for the Forest Carbon Monitoring System (FCMS).

Task	Description	Time frame	Notes
Phase III	Establish some plots and conduct measurements in the LPfC strata	By end of 2016	Use same design as for Phase I and II; collect data to compare to data from Phase II (MPfC strata)
Update emission factors for deforestation	Complete field measurements using methods in Sampling Plan Version 2; update accessibility strata in the HPfC, MPfC, and LPfC strata	Every 5 years as shown in Table 4	
Update emission factors from degradation from selective logging	Conduct measurements of logging activity in: HPfC stratum if changes in logging practices occur, and in areas of MPfC if logging occurs in this stratum	When new areas are opened to logging or where this activity is found to occur in the MPfC stratum	
Establish permanently monumented plots	Establish 5 permanent cluster plots in the HPfC more accessible stratum	Re-measure every 2-3 year using SOPs for permeant plots	Recommended to monitor potential effects of climate change on Guyana forests; also coordinate with the RAINFOR plot program

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