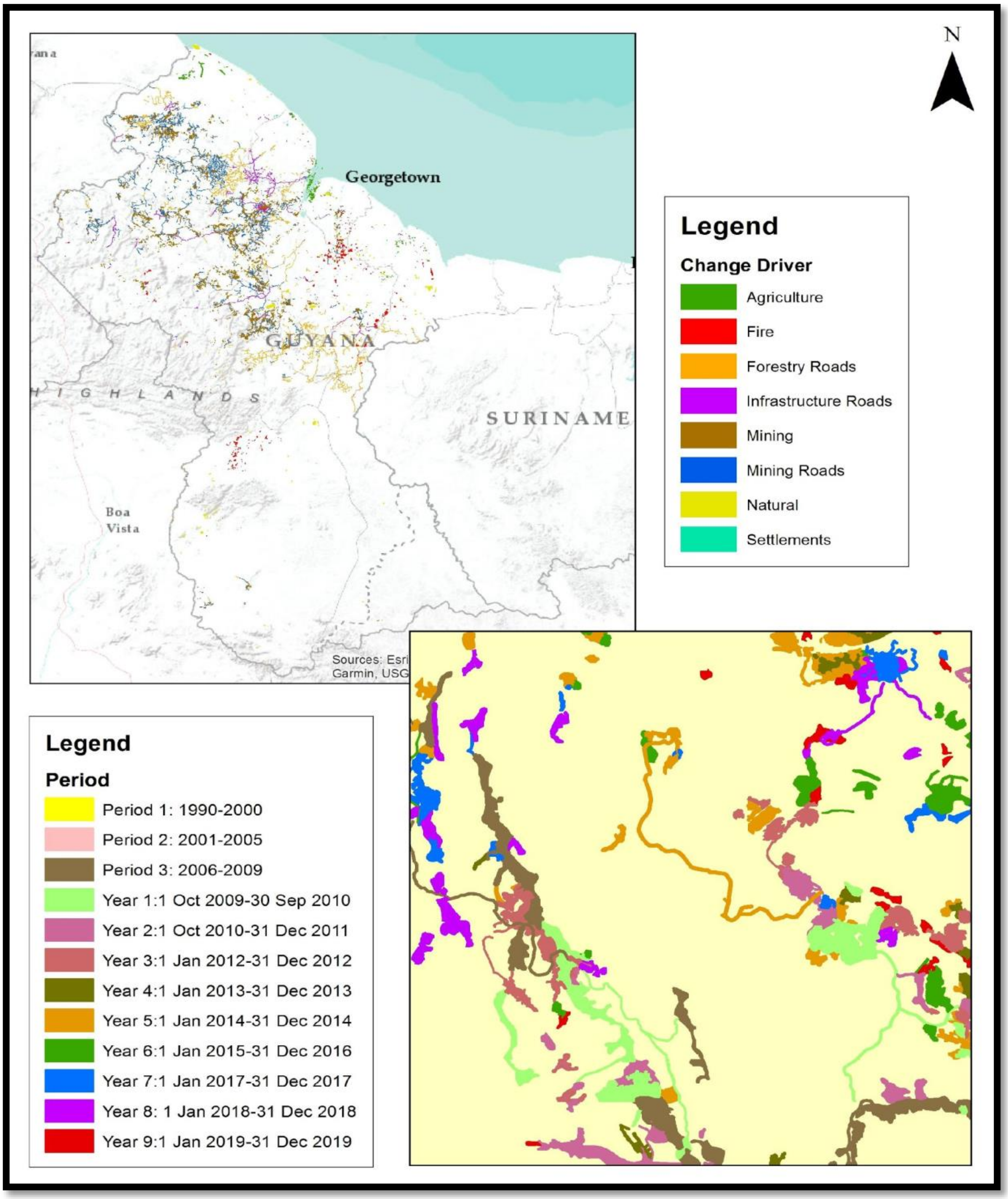
Guyana REDD+ Monitoring Reporting & Verification System (MRVS)
MRVS Report – Assessment Year 2019



December 22, 2020

DISCLAIMER

The GFC advises that it has made every possible effort to provide the most accurate and complete information in the execution of this assignment.

PREFACE

Guyana has commenced implementation of Years 6-9 (2015- 2019) of the MRVS with continued support from the Government of Norway. This is a successor to MRVS Phase 1 implementation under the climate and forest partnership between the Government of Guyana and the Government of the Kingdom of Norway that was initiated in 2009.

Activities for implementation in Years 6-9 will support the establishment and long-term sustainability of a world-class MRVS as a key component of Guyana's national REDD+ programme. This system will provide the basis for verifiably measuring changes in Guyana's forest cover and resultant carbon emissions from Guyana's forests as an underpinning for results-based REDD+ compensation in the long-term.

It is important that the MRVS is a continuous learning process that is progressively improved. This is particularly relevant as the MRV matures and the trends and drivers of forest change are better understood.

Critically, the results generated from the MRV System have potential applications to a range of functions relating to policy setting and decision-making within the natural resources sector and in particular to forest management. Guyana's MRV System has, over the past five years, generated a wealth of data that can be utilized in improving management of the multiple uses of forests. Within the MRVS Year 6 to 9, the application of this data for decision-making will be tested at several levels and scales.

Reporting will continue to be based on the REDD+ Interim Indicators set out in the Joint Concept Note[1] (JCN) or other reporting framework agreed between Guyana and Norway. As appropriate the intention is to further streamline the REDD+ performance indicators. It also represents advancement of the implementation of the actions outlined in the MRVS Roadmap Phase 2, which also look to mainstream the system. Advancements are expected to be made to move to full reporting on emissions and removals by end of this phase.

In 2009 Guyana developed a framework for a national MRVS. This framework was developed as a "Roadmap[2]" that outlines progressive steps over a 3-year period that would build towards a full MRVS being implemented. The aim of the MRVS is to establish a comprehensive, national system to monitor, report and verify forest carbon emissions resulting from deforestation and forest degradation in Guyana. The first year of the roadmap commencement was 2010 which required several initial reporting activities to commence. These were designed to assist in shaping the next steps planned for the following years. In 2014, a Phase 2 Roadmap[3] was developed for the MRVS. The overall objective of the Roadmap Phase 2 seeks to consolidate and expand capacities for national REDD+ monitoring and MRV. This will support Guyana in meeting the evolving international reporting requirements from the UNFCCC as well as continuing to fulfil additional reporting requirements. It will also support Guyana in further developing forest monitoring as a tool for REDD+ implementation.

The initial steps allowed for a historical assessment of forest cover to be completed, key database integration to be fulfilled and for interim/intermediate indicators of emissions from deforestation and forest degradation to be reported for subsequent periods. To date, ten national assessments have been conducted, including the one outlined in this Report from years 2010 to 2019. This Report covers the period January to December 2019.

In tandem with the work summarised in this report, an accompanying and closely connected programme of work will continue to be implemented by Guyana Forestry Commission (GFC), with the assistance of Winrock International (WI) to develop a national forest carbon measurement system and related emission factors. This programme will establish national carbon conversion values, expansion factors, wood density and root/shoot ratios as necessary. Additionally, a detailed assessment of key processes affecting forest carbon, including a summary of key results and capacities as well as a long-term monitoring plan for forest carbon, will be further developed. This aspect of the MRVS work, in tandem with continued work as summarized in this report, will enable a range of areas, including forest degradation to be comprehensively monitored, reported and verified at the national scale.

[1] http://www.lcds.gov.gy/images/stories/Documents/Joint%20Concept%20Note%20%28JCN%29%202012.pdf
[2] http://www.forestry.gov.gy/Downloads/Guyana_MRV_workshop_report_Nov09.pdf
[3] http://www.forestry.gov.gy/wp-content/uploads/2015/09/Guyanas-MRVS-Roadmap-Phase-2-September-2014.pdf

The GFC has attempted to embrace the broader thrust of the MRVS Phase 2 by looking for new and emerging technical solutions across related MRVS areas, as well as to embrace the requirements of implementing a non-REDD+ payment option for the MRVS. This process started Year 6 of the MRVS.

As the MRVS continues to be developed, the reporting in this period, as was the case in previous years will be based on several agreed REDD+ Interim Indicators. The Report therefore aims to fulfil the requirements of several “Interim Indicators for REDD+ Performance in Guyana” for the period 01 January, 2019 to 31 December, 2019, as identified by the JCN Table 2 These intermediate indicators allow for reporting to take place in the interim, while the full MRVS is under development. Concurrently, Guyana’s reporting under the MRVS is moving closer to reporting on emissions by drivers of deforestation and forest degradation. This feature was first introduced in the Year 8 Report and continues in this Report. Additionally, this Report describes the satellite imagery and GIS datasets, and processing of these data. It also provides a summary of the 'Interim Measures' that report on Guyana's progress towards implementation of REDD+.

The methods and results of the assessment for the period 01 January 2019 to 31 December 2019 are subject to independent third-party verification.

Version 1 of the Report will be released for a 6-week period. Following the period of public review, Version 2 of the report will be released and include all comments made under the public review process and feedback to each comment, including corresponding revisions to the report to address these comments where these apply. This Version is subject to independent third-party verification. The final version of the Report (Version 3) includes all elements of Version 2, and additionally, integrates the findings of the verification process, and is made public via the GFC website.

These Reports are issued by the Guyana Forestry Commission (GFC). Indufor Asia Pacific has provided support and advice as directed by the GFC.

James S ingh
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Mr James Singh
Guyana Forestry Commission

SUMMARY

In 2017 the Monitoring Reporting and Verification System (MRVS) moved into its second phase in line with tasks set out in the MRVS Road Map. This document outlines the stepwise progression and development of the MRVS for the next four years 2017 to 2020.

In Year 8 (2018) the GFC reported on total forest carbon emissions and removals, with a focus on reporting emissions. This move was part of the continuous improvement to the System, allowing the GFC to progressively move away from the Interim Indicators. The intention of the reference measure as well as the interim performance indicators were to be applied while aspects of the MRVS were under development and were to eventually be phased out and replaced by a full forest carbon accounting system as methodologies are further developed. Year 8 has placed Guyana at this stage.

For reference the ongoing comparison of performance for the area-based interim indicators is against the values reported in the 2009 "Benchmark Map[4]". From that point onwards, the reporting periods are numbed sequentially with Year 1 covering 2009 to 2010. This report presents the findings of the ninth national assessment which spans a twelve-month period, 1 January 2019 to 31 December 2019.

The purpose of the MRVS is to track at a national-level forest change of deforestation and degradation, by change driver. Deforestation is monitored using a national coverage of satellite imagery. The GFC has sought to incorporate continuous improvements into the MRVS to allow for further efficiencies and sustainability elements to be incorporated. For instance, estimates of degradation as a result of mining and infrastructure is now computed using new methods developed over the years 2018 and 2019. This new method does not necessitate costly high-resolution imagery or aerial surveys to derive these estimates. Further, the method for accounting for shifting cultivation was updated, while reporting on timber harvesting and illegal logging has been mainstreamed under full emissions accounting using existing methods. These improvements provide robust measures of both deforestation and degradation that aligns with Guyana's desire to pursue a low or no-cost REDD+ implementation option – this is an integral part of the Phase 2 objective whilst moving toward full emissions accounting.

Deforestation for the period between 1 January 2019 and 31 December 2019 is estimated at 12 738 ha. This equates to an annualised deforestation rate of 0.070% which is higher than the change reported in the previous year (0.051%). The 2017 rate was the lowest of all annual periods from 2010 to present. As with previous assessments, the GFC's deforestation area has been verified by the Durham University (DU) team using a statistically representative independent sample. The area of deforestation reported by DU closely aligns with the values reported by the GFC (see Appendix 4).

The main deforestation driver for the current forest year reported is Fire, which accounts for 50% of the deforestation in this period. The majority of the deforestation is observed in the State Lands Area. The temporal analysis of forest changes post-1990 indicates that most of the change is clustered around existing road infrastructure and navigable rivers. The findings of this assessment assist to design REDD+ activities that aim to maintain forest cover while enabling continued sustainable development and improved livelihoods for Guyanese.

A summary of the key reporting measures and main results are outlined in Table S1.

[4] Originally the benchmark map was set at February 2009, but due to the lack of cloud-free data the period was extended to September 2009

Table S1 (a): MRVS Results 2019 (Year 9)

Measure Ref.	Reporting Measure on Spatial Indicators	Indicator	Reporting Unit	Adopted Reference Measure	Year 9 (2019)	Difference between Year 9 and Reference Measure
1	Deforestation Indicator	Rate of conversion of forest area as compared to the agreed reference level	Rate of change (%)/yr	0.275%	0.07%	0.205%
2	Degradation Indicator	National area of Intact Forest Landscape (IFL) Change in IFL post Year 1, following consideration of exclusion areas	ha	7 604 820	7 603 487	81 ha loss in year 2019

Table S1 (b): MRVS Results 2019 (Year 9)

Driver	Area (ha)	EF (t CO^2/ha)	Emissions (t CO^2/ha)
Deforestation			
Mining	5,248	1,045	5,484,630
Mining Infrastructure	573	1,045	598,836
Forestry	226	1,045	236,190
Infrastructure	52	1,045	54,345
Agriculture	246	1,104	271,623
Settlements	22	1,045	22,992
Fire	6,371	804	5,123,752
Deforestation Total	**12,738**		**11,792,369**
Degradation			
Timber Harvest			1,766,523
Illegal Logging			10,463
Mining Degradation		22	58,131
Degradation Total			**1,835,117**
TOTAL CO_2 EMISSIONS FOR GUYANA FOR 2019 FROM FOREST SECTOR			**13,627,486**

Reporting on forest carbon removal from REDD+ activities will commence when these activities are initiated.

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SUPPORTING APPENDICES

ACKNOWLEDGEMENTS

In addition to GFC, several agencies and individuals have assisted in providing inputs into the MRVS programme. GFC and Indufor Asia Pacific would like to acknowledge the support of the Ministry of Natural Resources for its strategic guidance.

The continued support and oversight of the members of the MRVS Steering Committee is also acknowledged.

The GFC team would also like to acknowledge the following entities for their support:

- Guyana Geology and Mines Commission for providing location datasets for mining areas.
- Guyana Lands & Surveys Commission for providing spatial data relating to settlements and agricultural leases.
- Conservation International- Guyana for their role in supporting the implementation of this, as well as other aspects of the Guyana MRVS, and for the exemplary efficiency and expertise in its collaborative role with the GFC.
- WWF-Guyana for supporting work on CMRV.
- Winrock International for work on the forest carbon monitoring system.
- Other Partners

GLOSSARY

The following terms and abbreviations are used throughout the report.

AA	Accuracy Assessment
AD	Activity Data
BAU	Business as Usual
CMRV	Community Monitoring Reporting and Verification
CRMS	Continuous Resource Monitoring System
DMC	Disaster Monitoring Constellation
EF	Emission Factors
EPA	Environmental Protection Agency
ESA	European Space Agency
FCMS	Forest Carbon Monitoring System
FCPF	Forest Carbon Partnership Facility
FIRMS	Fire Information for Resource Management System
FRA	Forest Resource Assessment
GFC	Guyana Forestry Commission
GGMC	Guyana Geology and Mines Commission
GIS	Geographic Information System
GLSC	Guyana Lands and Surveys Commission
GOFC GOLD	Global Observation of Forest Cover and Land Dynamics
IFL	Intact Forest Landscape
IPCC	Intergovernmental Panel on Climate Change
JCN	Joint Concept Note
LCDS	Low Carbon Development Strategy
LULUCF	Land Use Land Use Change and Forestry
MNR	Ministry of Natural Resources
MODIS	Moderate Resolution Imaging Spectroradiometer
MRVS	Monitoring Reporting and Verification System
MSI	Multi Spectral Imager
NFMS	National Forest Monitoring System
PAC	Protected Areas Commission
QA/QC	Quality Assurance/Quality Control
REDD+	Reducing Emissions from Deforestation and Forest Degradation Plus
SFA	State Forest Area
SOP	Standard Operating Procedures
UK	United Kingdom
UN REDD	United National Reducing Emissions from Deforestation and Forest Degradation
UNFCCC	United Nations Framework Convention on Climate Change
UoD	University of Durham
UoG	University of Guyana
VCS	Verified Carbon Standard

1. INTRODUCTION

1.1 Country Description

The total land area for Guyana is 21.1 million hectares (ha) and spans from 2 to 8° N and 57 to 61° W. Guyana shares common borders with three countries: to the north-west - Venezuela, the south-west - Brazil, and on the east - Suriname.

Guyana's 460 km coastline faces the Atlantic on the northern part of the South American continent.

The coastal plain is only about 16 km wide but is 459 km long.

It is dissected by 16 major rivers and numerous creeks and canals for irrigation and drainage. The main rivers that drain into the Atlantic Ocean include the Essequibo, Demerara, Berbice, and Corentyne. These rivers have classic wide mouths, mangroves, and longitudinal sand banks so much associated with Amazonia, and mud flows are visible in the ocean from the air.

The geology in the centre of the country is a white sand (*zanderij*) plateau lying over a crystalline plateau penetrated by intrusions of igneous rocks which cause the river rapids and falls.

1.2 Initiation of REDD+ activities in Guyana

On 8 June 2009, Guyana launched its Low Carbon Development Strategy (LCDS). The Strategy outlined Guyana's vision for promoting economic development, while at the same time contributing to combating climate change. The LCDS has two goals:

1. Transform Guyana's economy to deliver greater economic and social development for the people of Guyana by following a low carbon development path; and

2. Provide a model for the world of how climate change can be addressed through low carbon development in developing countries if the international community takes the necessary collective actions, especially relating to REDD+.

As at September 2009 Guyana had approximately 18.5 million ha. Historically, relatively low deforestation rates have been reported for Guyana.

Approximately 85% of Guyana land area is covered by forests, with a low deforestation rate, 0.02% and 0.079% per annum. Deforestation rates typically expand along with economic development, thus prompting the formation of the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD programme), the Forest Carbon Partnership Facility (FCPF) and the REDD+ Partnership, among others.

The activities undertaken, as summarised in this Report, are part of the three-phase Road Map developed for Guyana's MRVS. The objective of the initial MRVS Road Map was to undertake a comprehensive, consistent, transparent and verifiable assessment of forest area change for the historical period of (about) 1990 to 2009 using several period steps of archived Landsat-type satellite data that meet the criteria of the IPCC Good Practice Guidelines for LULUCF.

A Second Phase MRVS Roadmap was developed following a stakeholder consultation process, the year 5 report was the commencement of the first cycle of the Phase 2 Roadmap covering knowledge and capacity sharing aspects.

1.3 Establishing and Monitoring Changes to Guyana's Forested Area

Land classified as forest follows the definition as outlined in the Marrakech Accord (UNFCCC, 2001). Guyana has elected to classify land as forest if it meets the following criteria:

- Tree cover of minimum 30%
- At a minimum height of 5 m
- Over a minimum area of 1 ha.

In accordance with the JCN, the national forest cover as at 1990 based on this definition is used as a start point. The interim measures are benchmarked against 2009 reported values.

In summary, the MRV monitoring process has involved:

- Determination of the 1990 forest area using medium resolution satellite images (Landsat) by excluding non-forest areas (including existing infrastructure) as at 1990. It should be noted that continual updates have been introduced to improve the non-forest boundary based on improved satellite resolution and repeat observation of the forest fringe.

- From this point forward, accounting for forest to non-forest land use changes that have occurred between 1990 and 2009 using a temporal series of satellite data.

- Establishing the benchmark period (1990-2009) and using 30 September 2009 Benchmark Map as a reference point.

- Comparing annual change post 2009 against the 2009 benchmark values

1.4 MRVS Development & Progress

Several areas have been progressively improved since the inception of the MRV. For the current MRV phase 2017-2020 workplan the following are relevant.

The Continuous Resources Monitoring System
With the ongoing support of GFC's technical partner Indufor Asia Pacific a suite of tools termed Continuous Resource Monitoring System (CRMS) have been developed. This development is a parallel and complementary system to the existing MRVS process and over time has begun to replace less efficient elements of the original MRV. This system will be piloted in 2021.

The main advantage of the CRMS concept is that it leverages increased data and cloud processing capacity by using a powerful cloud processing engine for computation. The overall goal is to improve the monitoring and long-term management of natural resources. The design of the prototype Continuous Resource Monitoring System (CRMS) started in 2019 and has involved a review of the existing MRV system in identifying requirements, bottlenecks and potential future monitoring needs as well as the potential of a range of cloud computing platforms and sources of remotely sensed data[5].

Broadly, the CRMS will seek to extend on Guyana's MRVS design to provide analysis-ready data that allows alerts, proactive management of natural resources that leads to improved decisions and policies while also reducing the bottlenecks which hinder the existing MRVS process.

Further, the CRMS aims to reduce the reliance on commercial satellite imagery and software. The solution uses a cloud-based processing environment hosted by Google Earth Engine (under a free license). It seeks to reduce the requirement for local storage and processing capability that a fully desktop-based national scale monitoring system entails. Nevertheless, an important aspect is that the design will be flexible and recognise the existing functionality of the current GIS-focused MRV.

Key features of the CRMS design include:

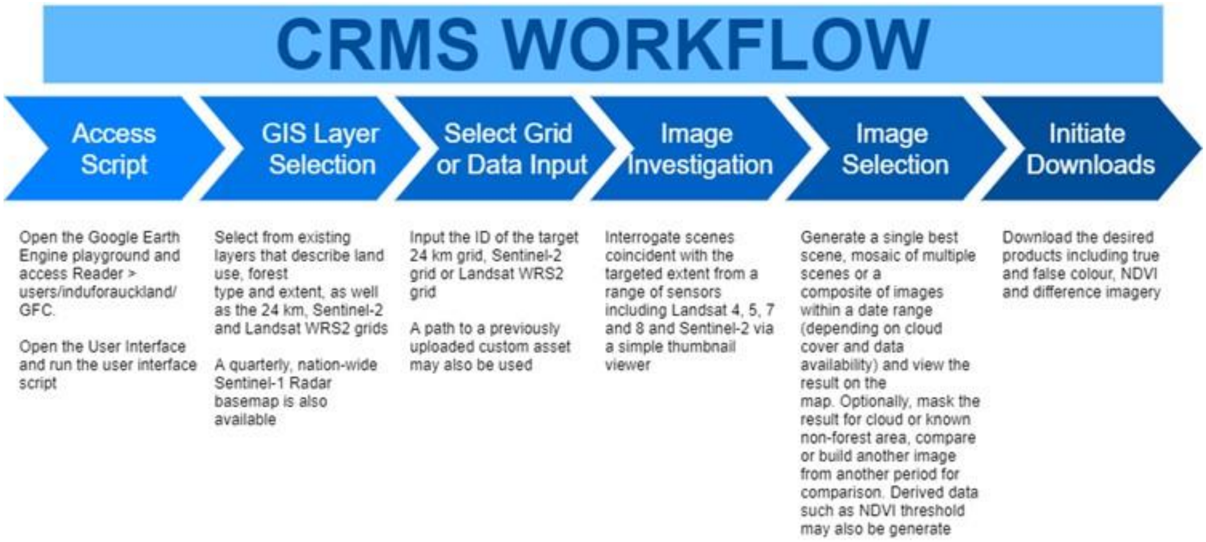
1. Flexibility to ingest a range of satellite imagery – non-commercial and commercial, so to minimise cloud contamination and enable frequent monitoring of change. Target update frequency is each quarter.
2. Use of a cloud-based environment that accesses and processes satellite images in a way that users' do not need to download imagery. Currently, the downloading of large images is time-consuming and slow due to the limited internet connectivity.
3. Image processing completed in the cloud so to increase processing efficiency and reduces the need for the GFC to invest in expensive remote sensing software, image storage and back up.
4. All processing accessible via a simple web-based GUI that allows multiple users to access the same set of algorithms and tools.
5. The process and methods used are documented and repeatable, which allows consistency and an audit trail.

[5] Review of MRVS applications for forest management and land use allocations in Guyana.

6. The detection algorithms are adaptable, i.e. able to work with a range of image types or sensors—incremental improvements based on operational feedback and experience.
7. Monitoring products can be downloaded in a batch mode and divided into tiles so to increase download efficiency and reduces redundancy.

The methods described are implemented within the MRV framework and remove the requirement to download full images and reduce data redundancy and need to store data on external storage.

Figure 1.4-1 Overview of the Current CRMS Workflow



A tool specifically built to produce cloud-free composite imagery was developed to augment the existing CRMS, allowing users to create and download imagery which combines data captured over a range of dates. Within this date range, a cutting edge cloud masking technique that uses a machine-learning algorithm has been employed to provide the cleanest possible output while minimising any false positive errors. This tool has been successfully implemented to generate cloud-free quarterly Sentinel-2 composites.

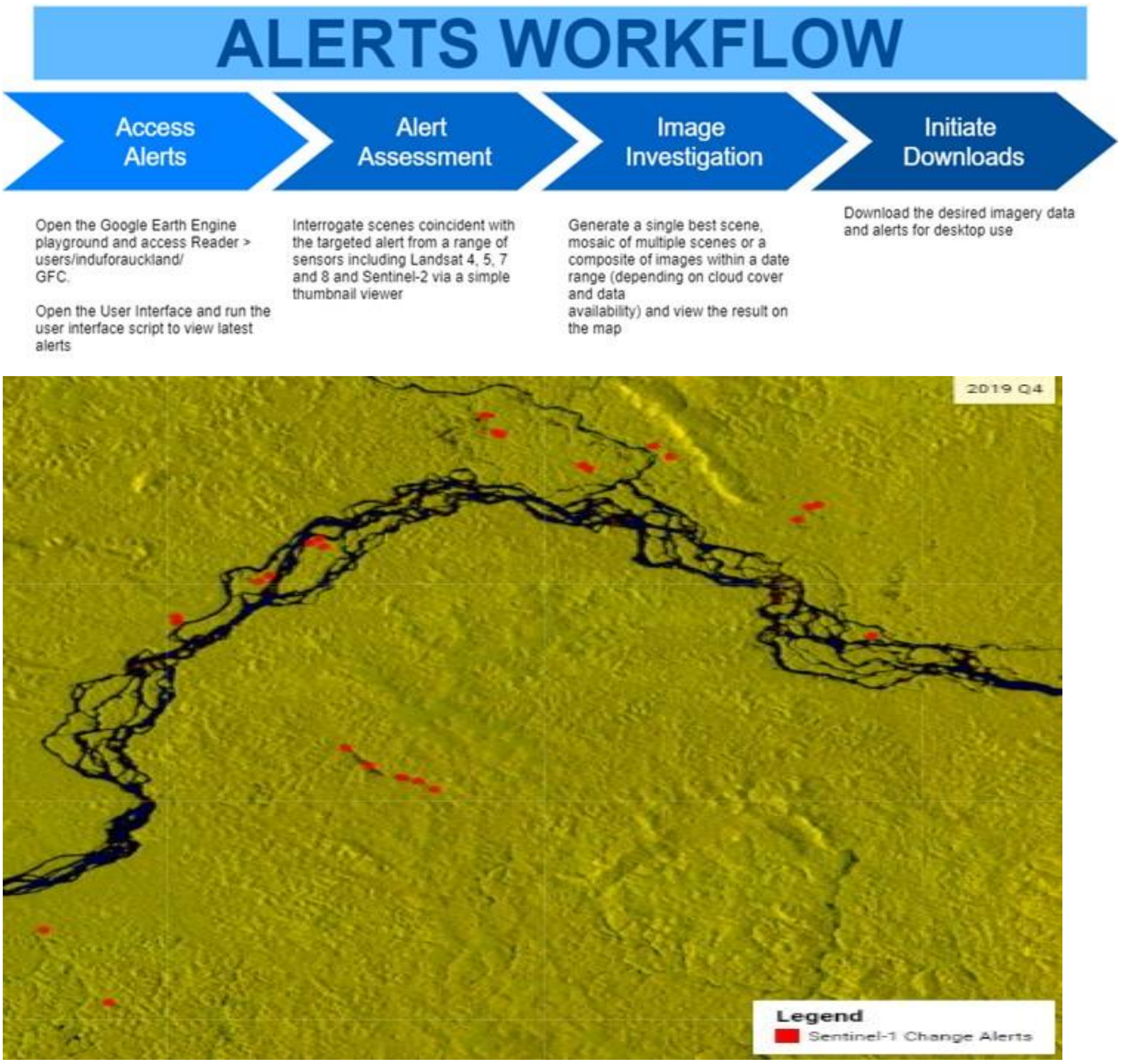
Figure 1.4-2 Example of Cloud-free Composite Tool

Development of Early Warning Alerts
The GFC continues to move the MRVS towards more near real-time monitoring. This has been identified as one of the significant improvements to the system that would enable broader applications of the MRVS data. Moving beyond annual updates presents several challenges, including the aforementioned cloud cover and the manual, hand digitised nature of change mapping within the current MRVS workflow.

To enable the CRMS to facilitate quarterly updates, recent development has focused on leveraging Sentinel-1 synthetic aperture radar (SAR) data to complement the existing optical satellite data used for change detection. Within the context of Guyana, Sentinel-1 provides several key benefits, notably that the microwave energy produced by the sensor penetrates cloud, allowing surface returns to be captured despite the cloud cover. By combining data quarterly, a nationwide composite can be generated. Comparing these quarters allows areas of likely change to be automatically flagged, compared against existing change mapped by GFC and exported as an alert should it be considered new and of sufficient magnitude.

This improvement allows GFC operators to quickly focus and respond to likely change events in a more dynamic and responsive manner, avoiding the need to review every grid nationwide. The following diagram gives an overview of the workflow for this process (Figure 1.4-3). The working prototype of the EWA system is hosted on Indufor's website at https://indufor.co.nz/solutions/national-scale-monitoring

Figure 1.4-3: Overview of Sentinel-1 Alerts Workflow



These Sentinel-1 quarterly composites can also be provided as a basemap for use outside the CRMS. An extension of the system beyond 2020 is planned, and this will focus on the development of products that offer a basis to enhance cross-sector cooperation to improve existing management of resources and compliance processes and aid in the enforcement of forest laws

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The layers produced can be integrated into common GIS packages, or via web-enabled dashboards. GFC has further negotiated access to ESRI's full mapping suite which includes Web-enabled dashboards.

Comprehensive Accounting for REDD+ Programs: A Pragmatic Approach as Exemplified in Guyana

Completeness is an important element for Reducing Emissions from Deforestation and forest Degradation (REDD+) accounting to ensure transparency and accountability. However, including a full accounting for all emission sources in a REDD+ program is often resource-intensive and cost-prohibitive, especially considering that some emission sources comprise far less than 10% of total emissions and are thus considered insignificant according to Intergovernmental Panel on Climate Change (IPCC) guidance.

In the publication titled Comprehensive Accounting for REDD+ Programs: A Pragmatic Approach as Exemplified in Guyana, November 27, 2020[6], Goslee et al. use country forest reference emission level (FREL)/forest reference level (FRL) submissions to the United Nations Framework Convention on Climate Change (UNFCCC) to examine the completeness of REDD+ programs. Guyana was used as an example to demonstrate a pragmatic approach where completeness can be achieved in a manner that balances the significance of emission sources with the cost and precision of emission estimates. Since submitting its FREL in 2014, Guyana has made stepwise improvements to its emission estimates so that the country is now able to report on all deforestation and degradation activities resulting in emissions, whether significant or not.

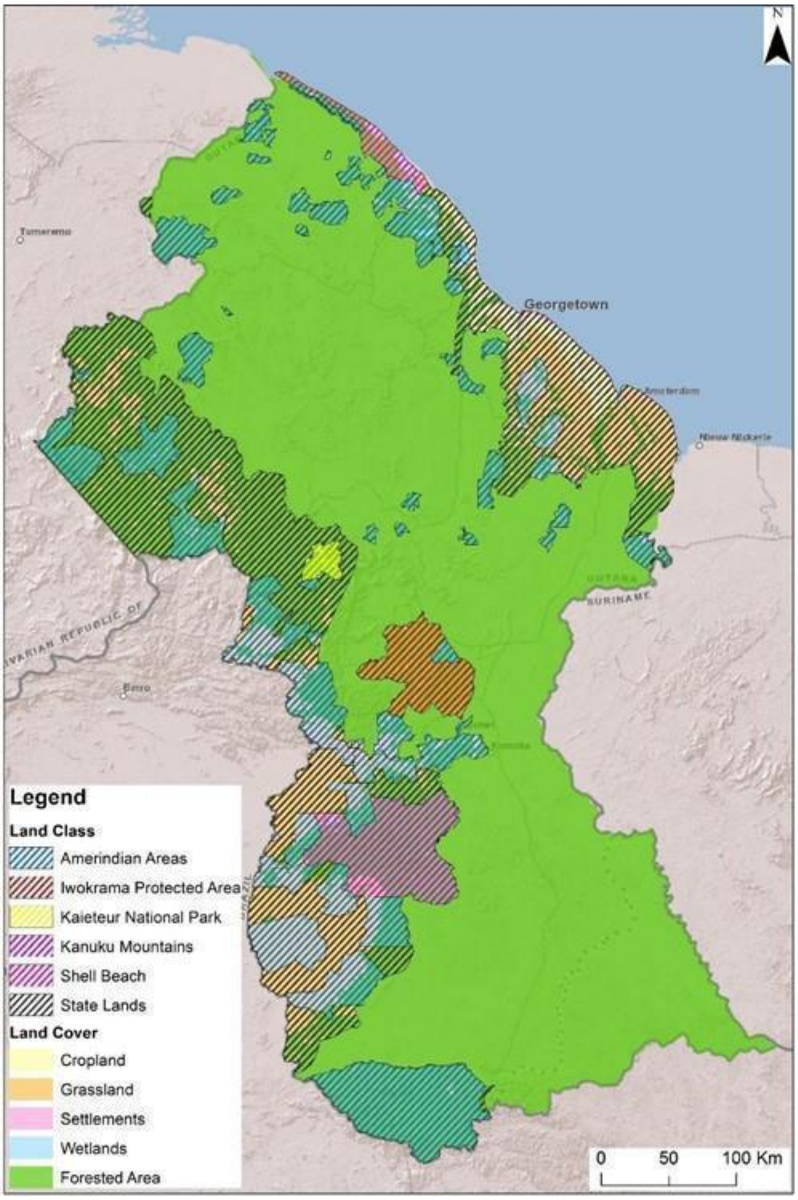
Based on the example of Guyana's efforts, the authors recommend a simplified approach to move towards complete accounting in a cost-effective manner. This approach can be scaled to other countries with other activities that result in greenhouse gas emissions from deforestation and forest degradation. Such complete accounting allows for higher accountability in REDD+ systems and can lead to greater effectiveness in reducing emissions.

[6] https://www.mdpi.com/1999-4907/11/12/1265

2. OVERVIEW OF GUYANA'S LAND CLASSES

There are four main tenure classifications in Guyana, the largest is state forest which is 59% of the total land area, followed by State Lands (20%) Amerindian lands (16%), and Protected Areas (5%). At the commencement of the MRV existing maps of Guyana's land cover developed in 2001 were evaluated and coalesced to align to the six broad land use categories in accordance with IPCC reporting guideline. A description of the land use categories is provided in Appendix 3. The location of these areas is shown below.

Figure 2-1: Guyana's Land Classes



State Forest Area

According to the Forest Act Section 3, Chapter 61:01, the State Forest Area is that area of State Land that is designated as State Forest. This area of State Forest has been gazetted.

State Lands

For purposes of this assessment, State Lands are identified as areas that are not included as part of the State Forest Area that are under the mandate of the State. This category predominantly includes State Lands, with isolated pockets of privately held land, but does not include titled Amerindian villages.

Protected Areas

To date, the four Protected Areas that come under the scope of the Protected Areas Act are: Iwokrama, Shell Beach, Kanuku Mountains and Kaieteur National Park. Altogether these account for a total of 1 141 000 ha designated as Protected Areas.

Titled Amerindian Land

The Amerindian Act 2006 provides for areas that are titled to Amerindian villages. It includes both initial titles as well as extensions that have been granted to these titled areas.

The areas are: State Forest Area (SFA) and State Lands which are calculated from the mapping analysis, is estimated at 14.8 million ha. This excludes Iwokrama, Kaieteur National Park and titled Amerindian Land. Combined, these forested areas make up 3.69 million ha.

Distribution of Tenure & by IPCC Land Classes

Table 2-1 shows the area by the adopted IPCC classes, as at the start of Year 9 (2019). The revised forest area in Table 2-1 includes the forest area mapped as deforestation, as part of the Year 9 mapping period. Non-forest classes can shift from one (non-forest) class to another non-forest class.

Table 2-1: Tenure by Adopted IPCC Land Cover Classes

2018 Land Classes	Forest	Non-Forest					
		Grassland	Cropland	Settlements	Wetlands	Other Land	Total
	(Area '000 ha)						
State Forest Area	12 156	195	106	9	123	6	12 595
Titled Amerindian lands (*including newly titled lands*)	2 485	981	409	46	121	32	4 074
State Lands	2 338	654	282	7	16	8	3 305
Protected Areas	1 091	24	3	0	20	1	1 139
Total Area	18 070	1 854	800	63	280	47	21 114

3. MONITORING & SPATIAL DATASETS

The process developed aims to enable areas of change (>1 ha) to be tracked spatially through time, by driver (i.e. mining, infrastructure and forestry). The approach adopted seeks to provide a spatial record of temporal land use change across forested land (commensurate to an IPCC Approach 3). Mapping is undertaken by a dedicated team located at GFC, and all spatial data is stored on the local server at GFC and builds on the archived and manipulated data output from the previous analyses. The server is managed by the IT department at GFC and is routinely backed up and stored off-site.

3.1 Agency Datasets

Several Government agencies that are involved in the management and allocation of land resources in Guyana hold spatial datasets. Since 2010 GFC has coordinated the storage of these datasets for the MRVS. These agencies fall under the responsibility of the Ministry of Natural Resources (MNR). The Ministry has responsibilities for forestry, mining, and land use planning and coordination.

Table 3-1: Agency Datasets Provided

	Agency	Role	Data Held
Ministry of Natural Resources	Guyana Forestry Commission (GFC)	Management of forest resources	Resource management related datasets
	Guyana Geology and Mines Commission (GGMC)	Management of mining and mineral resources	Mining concessions, active mining areas
Office of the President	Protected Areas Commission	Management of Protected Areas System in Guyana	Spatial representations of all protected areas
	Guyana Lands and Surveys Commission (GL&SC)	Management of land titling and surveying of land	Land tenure, settlement extents and country boundary

Interim datasets have been provided by GFC, GGMC, GL&SC and the PAC. Information is progressively updated as necessary.

3.2 Monitoring Datasets - Satellite Imagery

In keeping with international best practice, the method applied in this assessment utilises a wall-to-wall approach that enables complete, consistent, and transparent monitoring of land use and land use changes over time.

The approach employed allows for land cover change greater than one hectare in size to be tracked through time and attributed by its driver (i.e. mining, shifting agriculture etc.).

The datasets used for the change analysis have evolved over time. Initially, the historical change analysis from 1990 to 2009 was conducted using Landsat imagery. From 2010 a combination of DMC and Landsat was used and from 2011 onwards these datasets were primarily superseded with high-resolution images from RapidEye. For 2015 and 2016 (Year 6), a combination of Landsat and Sentinel data have been used.

Table 3-2: Sentinel Coverage 2019

Image Acquisition Month	Number of Satellite Tiles
August	35
September	47
October	26
November	24
December	4
Total	**136**

Moving forward, data from the Sentinel (2A/2B) multi-spectral imager (MSI) will be the primary dataset for monitoring deforestation, supplemented by Landsat and fire monitoring datasets. Over the 2019 census period, 136 tiles were acquired spanning from August to December.

Degradation is not mapped directly but estimated from a sample of high-resolution aerial imagery (GeoVantage, 4 band multispectral data) and PlanetScope multispectral satellite images.

Overall, the transition to the Sentinel MSI sensor with 10 m pixel size in the visible and near infrared has not had a detrimental impact on the accuracy of the forest monitoring.

3.3 Accuracy Assessment

Historically, the intention of the Accuracy Assessment (AA) has been to provide an assessment of the quality of the GFC's mapping of land cover land use change across Guyana.

From 2013 to 2015 and 2017 to 2019, high-resolution imagery has been captured using a Cessna mounted aerial multispectral imaging system. The camera system (Aeroptic, aka GeoVantage) is a flexible unit that can be installed quickly and easily on to various models of light aircraft. The resolution of the images captured over pre-defined samples ranges from about 25 to 60 cm (varied by the altitude of the aircraft at the time of capture), a resolution capable of identifying forest degradation with some certainty. For further details, see the Accuracy Assessment report in Appendix 5.

The strategy employed uses the imaging system to capture high-quality image data at sites pre-determined by a two-stage stratified-random sample design that provides good coverage of the strata with high and medium risk of change. Full sample coverage is achieved by including satellite images over areas the stratum with low risk of forest change and over any area where it is not possible to safely operate a small aircraft.

In keeping with previous years, the same sample locations were analysed. The locations of these samples were provided to the aerial survey contractor by the independent accuracy assessment team from Durham University, UK.

The estimate of the total area of change in the 12-month Year 9 period from forest to non-forest and degraded forest to non-forest is 8,202 ha, with a standard error of 1,413 ha and a 97.5% confidence interval (5,433 ha; 10,972 ha). The estimate of the annual rate of deforestation that occurred over the Year 9 (12 month) period is 0.0645 % with a standard error of 0.00789% and a 97.5% confidence interval (0.0491%; 0.0800%). The estimate the total area of change in the 12-month Year 9 period from forest to degraded forest between Y8 and Y9 is 9,883 ha, with a standard error of 1,614 ha and a 97.5% confidence interval (6,720 ha; 13,046 ha).

The reason for the difference in area between the accuracy assessment and GFC mapped area for year 9 is likely due to the increase in fire. In general terms, this may not have been identified in the accuracy assessment samples as most samples fall within actively mined areas.

4. NATIONAL MAPPING OF DEFORESTATION & DEGRADATION

Guyana's GIS-based monitoring system is designed to map change events in the year of their occurrence and then monitor any changes that occur over that area each year. Where an area (polygon) remains constant, the land use class and change driver are updated to remain consistent with the previous analysis. Where there is a change in the land cover of an area, this is recorded using the appropriate driver. Deforestation is mapped manually using a combination of repeat coverage Landsat and Sentinel 2 images.

The following drivers of land use change are relevant. Drivers can lead to either deforestation or forest degradation.

4.1 Deforestation

Formally, the definition of deforestation is summarised as the long-term or permanent conversion of land from forest use to other non-forest uses (GOFC-GOLD, 2010). An important consideration is that a forested area is only deemed deforested once the cover falls and remains below the elected crown cover threshold (30% for Guyana). In Guyana's context, forest areas under sustainable forest management (SFM) that adhere to the forest code of practice are not considered deforested if they regain the elected crown cover threshold.

The anthropogenic change drivers that lead to deforestation include:

I. Forestry (clearance activities such as roads and log landings)
II. Mining (ground excavation associated with small, medium and large-scale mining)
III. Infrastructure such as roads (included are forestry and mining roads)
IV. Agricultural conversion
V. Fire (all considered anthropogenic and depending on intensity and frequency can lead to deforestation).
VI. Settlements change such as new housing developments.

4.2 Degradation

There is still some debate internationally over the definition of forest degradation. A commonly adopted definition outlined in IPCC (2003) report is:

"*A direct human-induced long-term loss (persisting for X years or more) of at least Y% of forest carbon stocks [and forest values] since time T and not qualifying as deforestation or an elected activity under Article 3.4 of the Kyoto Protocol* ".

The main sources of degradation are identified as:

I. Harvesting of timber (reported since 2011 using the Gain Loss Method)
II. Associated with mining sites and road infrastructure.

Image evidence and fieldwork have shown that each of these drivers produce a significantly different type of forest degradation. Forest harvest operations are temporally persistent. Forest degradation surrounding new infrastructure is different in nature. Image evidence suggests that this type of degradation is dependent on the associated deforestation site. Forest management and illegal logging are monitored through the Gain Loss Method and mining and infrastructure degradation are monitored through estimating an immediate degradation emission for all new mines, and for mines where expansion has occurred the buffer area is calculated with and without the most recent expansion and the forest degradation emissions calculated only on the expanded area. This approach should be seen as highly conservative as it assumes there is zero regrowth which is very unlikely.

4.3 Land Cover Change Analysis

To facilitate the analysis, Guyana has been divided into a series of regularly spaced grids. The mapping process involves a systematic review of each 24 x 24 km tile, divided into 1 km x 1 km tiles at a resolution of 1:8000.

If cloud is present, then multiple images over that location are reviewed. The process involves a systematic tile-based manual change detection analysis in the GIS.

Each change is attributed with the acquisition date of the pre-and post-change image, driver of change event, and resultant land use class. A set of mapping rules has been established that dictate how each event is classified and recorded in the GIS.

The input process is standardised using a customised GIS tool which provides a series of pre-set selections that are saved as feature classes. The mapping process is divided into mapping and QC. The QC team operates independently to the mapping team and is responsible for reviewing each tile as it is completed.

The following Table 4-1 provides an overview of drivers and associated deforestation or degradation activities that are reported spatially in the GIS as part of the MRVS. Appropriate methods have been established for all activities. Reforestation/Afforestation is the only activity not yet reported in the MRVS. The identification of the driver of specific land-use change depends on the characteristics of the change. Certainty is improved by considering the shape, location and context of the change in combination with its spectral properties.

Table 4-1: Summary of Activities & Drivers Captured in the GIS

Activity	Driver	Criteria	Ancillary Info Available	Spatially Mapped		End Land Use Class
Forestry	SFM	Fall inside the State Forest area and is a registered concession	Annual harvest plans, GIS extent of concession, previously	No.	Volumetric measure used	Degraded forest by type
	Infrastructure	Roads > 10m	Mapped layers, Satellite imagery	Yes		Settlements
Settlements	Settlements	Areas of new human settlement	Population data, image evidence.	Yes		Settlements
Mining	Infrastructure	Roads >10 m	Existing road network, Satellite imagery	Yes		Settlements
	Deforestation	Deforestation sites > 1 ha	Dredge sites, GIS extent of mining concessions, previously mapped layers, Satellite imagery	Yes		Bareland
	Degradation	Estimating an immediate degradation emission for all new mines, and for mines where expansion has occurred the buffer area is calculated with and without the most recent expansion and the forest degradation emissions calculated only on the expanded area.	Existing infrastructure incl. deforestation sites post-2011, Satellite imagery	Yes		Degraded forest by type

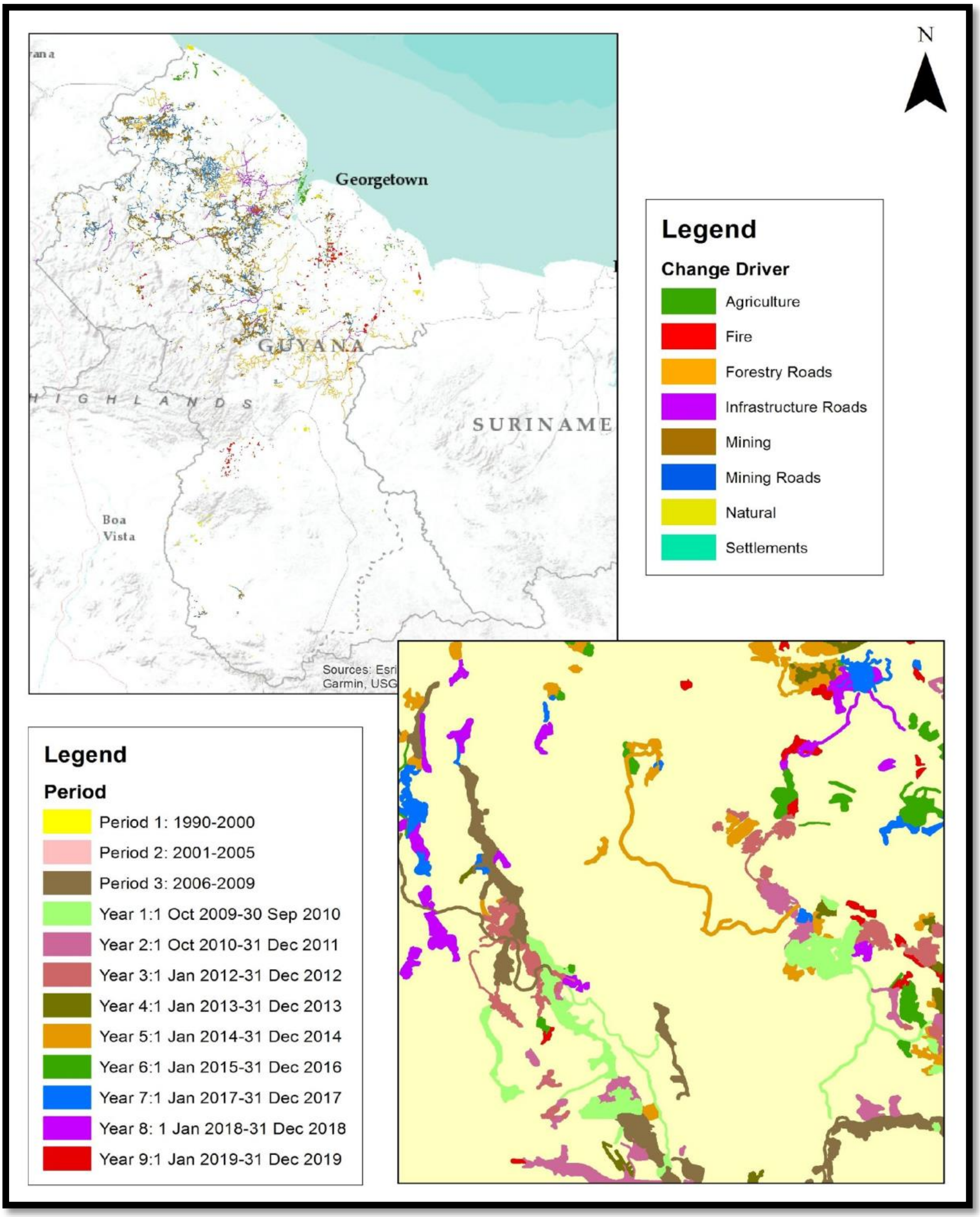
Agriculture	Deforestation	Deforestation sites > 1 ha	Registered agricultural leases, Satellite imagery	Yes	Bareland or crop land
	Deforestation	Deforestation sites > 1 ha	FIRMs fire points, spatial trends satellite imagery	Yes	Bareland or crop land
Fire	Deforestation	Roads >10 m	Existing road network Satellite imagery	Yes	Settlements
Infrastructure	Degradation	Estimating an immediate degradation emission for all new mines, and for mines where expansion has occurred the buffer area is calculated with and without the most recent expansion and the forest degradation emissions calculated only on the expanded area.	Satellite imagery	Yes	Degraded forest by type

Previous assessments and specific projects show that the spatial distribution of change in Guyana follows a pattern and is clustered around existing access routes (GFC Year 1 & 2; 2010, 11; Watt & von Veh, 2009 & von Veh & Watt 2010).

Potentially there is some overlap between drivers as the exact cause of the forest change can be difficult to determine. This is particularly relevant when deciding on the driver of road construction when mining and forestry areas use the same access routes.

Supplementary GIS layers are also included in the decision-making process to reduce this uncertainty. The decision-based rules are outlined in the mapping guidance documentation, or Standard Operating Procedures (SOPs). This documentation, held at GFC, provides a comprehensive overview of the mapping process and rules. The following example provides an overview of the detail captured in the GIS. Evident are temporal changes in forest cover due to a range of forest change drivers.

Figure 4-1: Example of Forest Change Mapping



4.4 Land Use Changes Not (Spatially) Recorded in the MRVS

There are several land cover changes that are not reported spatially in the MRVS at this stage. For completeness the general extent of these areas is mapped to ensure that they are not accounted for as measured land use change – these are listed as follow:

Forest Harvest

Forest harvest activities are accounted for by using extraction records. Large concessionaires are required to submit annual plans to GFC that show intended harvesting activities. All blocks require approval before harvesting may commence. This information is recorded in the GIS by GFC and as practical are tracked using satellite imagery.

On the satellite imagery forestry activities within the State Forest Area are often first identified by the appearance of roading and the degradation caused by surrounding selective harvest areas.

These areas are delineated as a single polygon around the spatial extent of the impacted area (degradation because of forest harvest). Following this, a land use class of degraded forest by the forest type is assigned.

Natural Events

Natural events are considered a non-anthropogenic change, so do not contribute to deforestation or degradation figures. These changes are typically non-uniform in shape and have no evidence of anthropogenic activity nearby. While these are not recorded in the MRVS, they are mapped in the GIS. These areas are attributed with a land class of degraded forest by forest type or bareland as appropriate.

5. FOREST CHANGE

The results presented, summarised the Year 9 period (1 January 2019 to 31 December 2019) forest change from deforestation and forest degradation impacts.

In terms of background the change for each period has been calculated by progressively subtracting the deforestation for each period from the forest cover as at 1990.

The forest cover estimated as at 1990 (18.47 million ha) was determined using a manual interpretation of historical aerial photography and satellite images. This area was determined during the first national assessment (GFC 2010) and verified independently by Durham University (DU 2010 and 2011).

Over time, the forest area has been updated after review of higher resolution satellite images. The outcome has been that the forest/non-forest boundaries are improved, but also the forest area changed - in particular at two points in time 2012 and 2014. In 2018, the forest area was revised to remove areas of historic shifting cultivation, as further study leads to the conclusion that these areas should be considered as non-forest in keeping with Guyana's definition of forests.

Table 5-1 summarises for the entire country the total change and change expressed as a percentage of forest remaining. The forest area at the start of Year 9 is 18.07 million ha.

Table 5-1: National Area Deforested 1990 to 2019

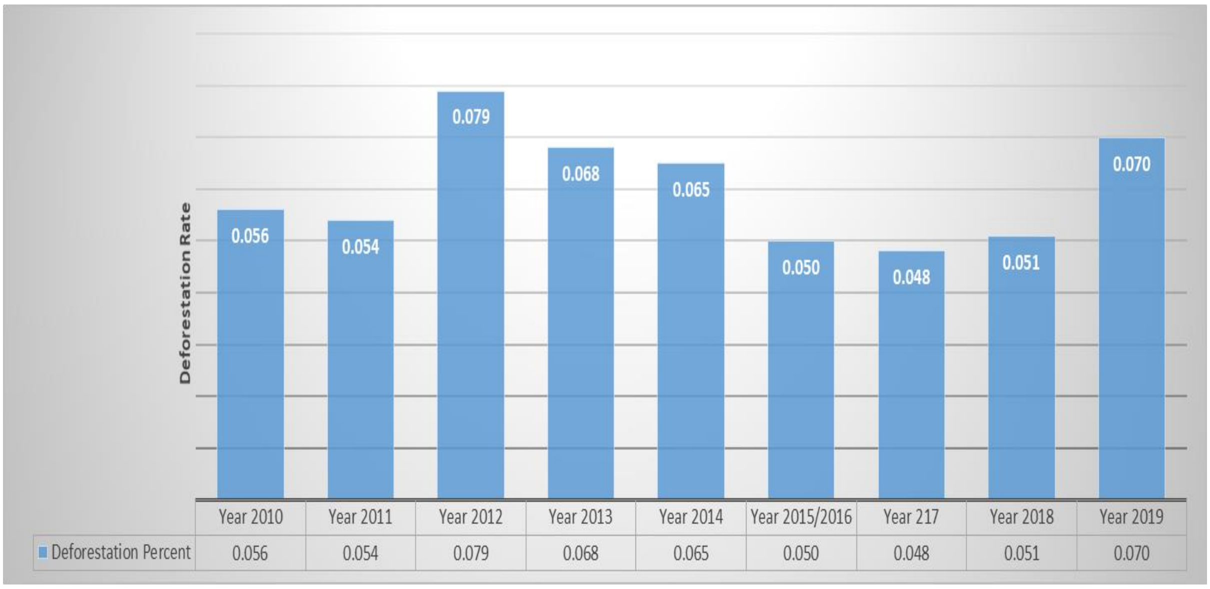
Reporting Period	Year	Years	Satellite Image Resolution	Forest Area	Annualised Change	
				('000 ha)		(%)
Initial forest area 1990	1990		30 m	18 473.39		
Benchmark (Sept 2009)	2009	19.75	30 m	18 398.48	74.92	0.021
Year 1 (Sept 2010)	2010	1	30 m	18 388.19	10.28	0.056
Year 2	2011	1.25	30 m & 5 m	18 378.30	9.88	0.054
Year 3	2012	1	5 m	*18 487.88	14.65	0.079
Year 4	2013	1	5 m	18 475.14	12.73	0.068
Year 5	2014	1	5 m	*18 470.57	11.98	0.065
Year 6	2015-16	2	10 m & 30 m	18 452.16	9.20	0.050
Year 7	2017	1	10 m & 30 m	18 442.96	8.85	0.048
Year 8	2018	1	10 m & 30 m	*18 070.08	9.22	0.051
Year 9	2019	1	10 m & 30 m	*18 057.34	12.73	0.070

*Continual forest area updates based on remapping, using higher-resolution 5 m resolution imagery and removal of shifting cultivation areas.

Overall, Guyana's deforestation rate is low when compared to the rest of South America.

The following figure shows the annualised deforestation trends for all change periods. The trend shows that deforestation rates increased from the 1990 level, and in parallel with gold price increases peaked in 2012 (0.079%). Post 2012 the rate of change fell and in recent years fluctuated between 0.048 to 0.068% and then increased in 2019 to 0.071% on account of forest fires.

Figure 5-1: Annual Rate of Deforestation by Period from 1990 to 2019



5.1 Forest Change by Driver - Deforestation

Forest change caused by deforested is divided and assessed by driver.

Table 5-2 provides a breakdown by forest change drivers

The temporal analysis provides a useful insight into deforestation trends relative to 1990. A more meaningful comparison is provided if the rates of change are divided by driver and annualised. In general, the following trends by driver are observed:

- In this reporting period, Fire is the largest contributor to deforestation, at 6371 ha. This is the first year that fire deforestation has surpassed mining deforestation.
- Forestry related change has remained relatively stable is around 226 ha. Forest roads, as in the case of earlier assessments, are attributed to a forestry driver rather than attributing this change to Infrastructure.
- Agricultural developments causing deforestation peaked at Year 5, with an increase to 817 ha. Over past two reporting periods it has been less than 500 ha rates akin to Years 3 and 4. This figure has remained relatively stable at 246 ha in the Year 9 reporting period.

Table 5-2: Annualised Rate of Forest Change by Period & Driver from 1990 to 2019

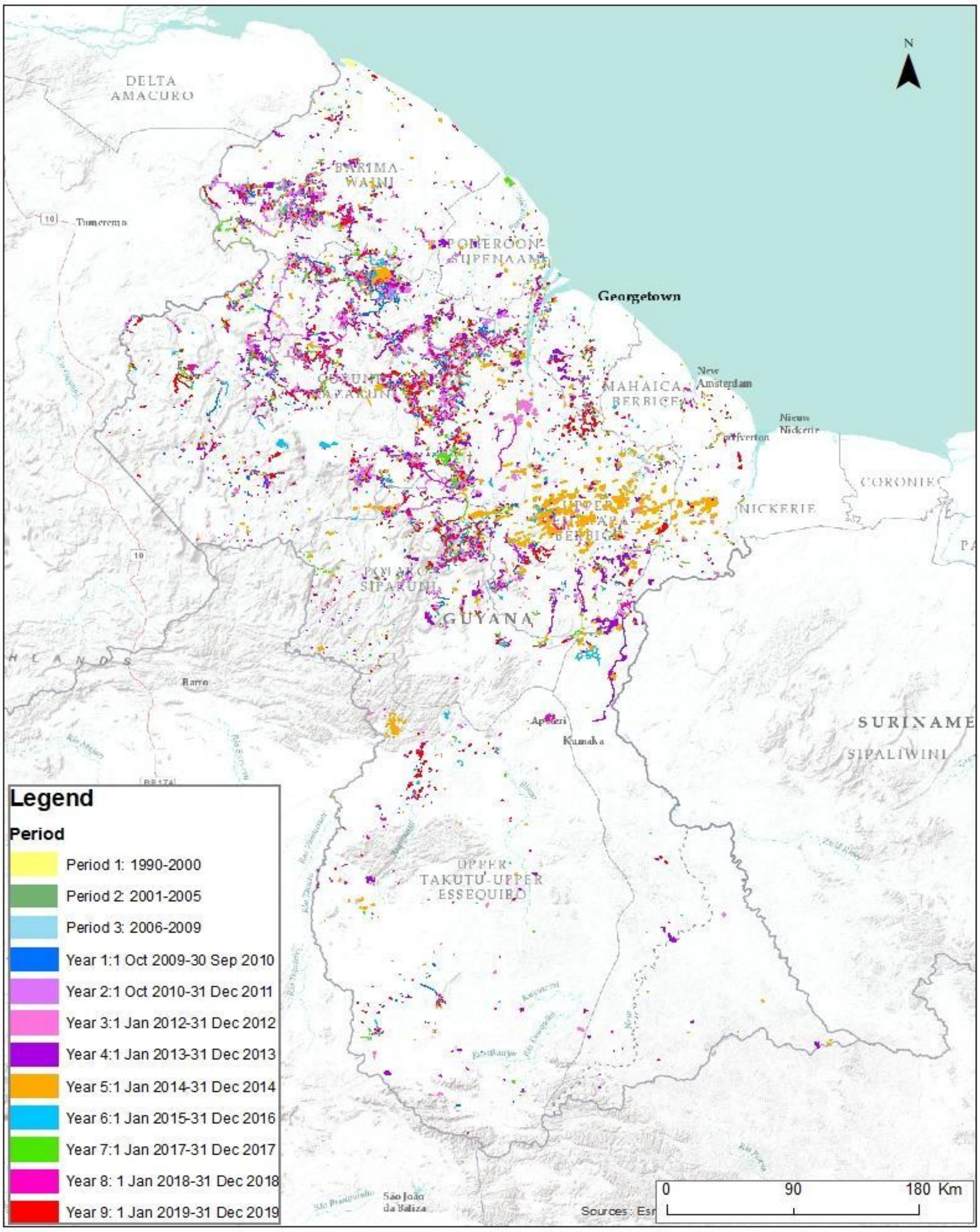
Reference Period	Change Period	Change Period	Annualised Rate of Change by Driver						Annual Rate of Change (ha)
			Forestry	Agriculture	Mining	Infrastruct.	Fire	Settlements	
		Year	Annual Area (ha)						
Historic	1990-00	10	609	203	1 084	59	171	-	2 127
	2001-05	5	1 684	570	4 288	261	47	-	6 850
	2006-09	4.8	1 007	378	2 658	41	-	-	4 084
	2009-11	1	294	513	9 384	64	32	-	10 287
MRV Phase 1	2010-2011	1.25	186	41	7 340	298	46	-	7 912
	2012	1	240	440	13 664	127	184	-	14 655
	2013	1	330	424	11 518	342	96	23	12 733
	2014	1	204	817	10 919	141	259	71	11 975
MRV Phase 2	2015-2016	2	313	379	6 782	217	1 509	8	9 208
	2017	1	227	477	7 442	195	502	7	8 851
	2018	1	356	512	7 624	67	661	7	9 227
	2019	1	226	246	5 821	52	6 371	22	12 738

5.2 Deforestation Patterns

The temporal analysis of deforestation by reporting periods is presented in Figure 6-2. The map, which presents change from all drivers, shows that most of the change is clustered[7] and that new areas tend to be developed near existing activities. Most MRV phase II deforestation activities occur close to or inside the footprint of historical change areas in the north and west of the country.

[7] For the purposes of display the areas of deforestation have been buffered to make them more visible.

Figure 5-2: Forest Change by Reference Period



5.3 Forest Change Across Land Classes

The following table provides a summary by change driver and land class for the 2019 assessment.

Table 5-3: 2019 Area Change by Driver & Land Class

Land Class	Area Change by Driver & Land Class						Total Chng	Proportion of Total %
	Forestry	Agriculture	Mining	Infrastructure	Fire	Settl.		
	Area (ha)							
State Forest Area	178	70	5 104	21	2 002	6	7 381	57.9%
Titled Amerindian Lands (including newly titled lands)	11	32	263	2	908	0	1 216	9.5%
State Lands	12.5	144.6	454	29	3 341	16	3 997	31.4%
Protected Areas	24.5	0	0	0	120	0	144.5	1.2%
Total	**226**	**246**	**5 821**	**52**	**6 371**	**22**	**12 738**	**100%**

Trends by driver for the reporting year follow and are supported by the driver map presented in Figure 6-3.

Mining

As with the previous year's most of the deforestation activity occurs in the State Forest Area (SFA). Mining activities are consolidated in the centre of Guyana. The area mined has decreased and sits well below the 2012 value which marked a point where the gold price was the highest since 1980. Post-2012 the price has declined to around USD1200/ounce. This combined with limited accessibility has gradually reduced the area mined.

Forestry

Most forestry activities are located inside the SFA. During this period, all deforestation events are associated with forestry harvest operations. The main causes of forest clearance include road and log market construction. The reported value 226 ha is an increase when compared to the previous year.

Under the existing interim measures, forest harvesting is reported in terms of carbon removal (tCO^2) rather than spatially. However, overall activity at the harvest block level (each 100 ha in size) across concessions is monitored.

Infrastructure

Infrastructure developments (52 ha) contributes a small area with the level change relatively stable between reporting periods. The area of clearance is in a similar location. The main change is related to road construction activities and tends to be near townships. Figure 6-3 shows the distribution of infrastructure developments. There have been a few new hinterland roads constructed to enhance access to villages.

Agricultural Development

Agricultural developments lead to 246 ha deforestation. The main areas of development are located close to Georgetown and the north-eastern regions of Guyana. Development tends to be near river networks.

Biomass Burning - Fire

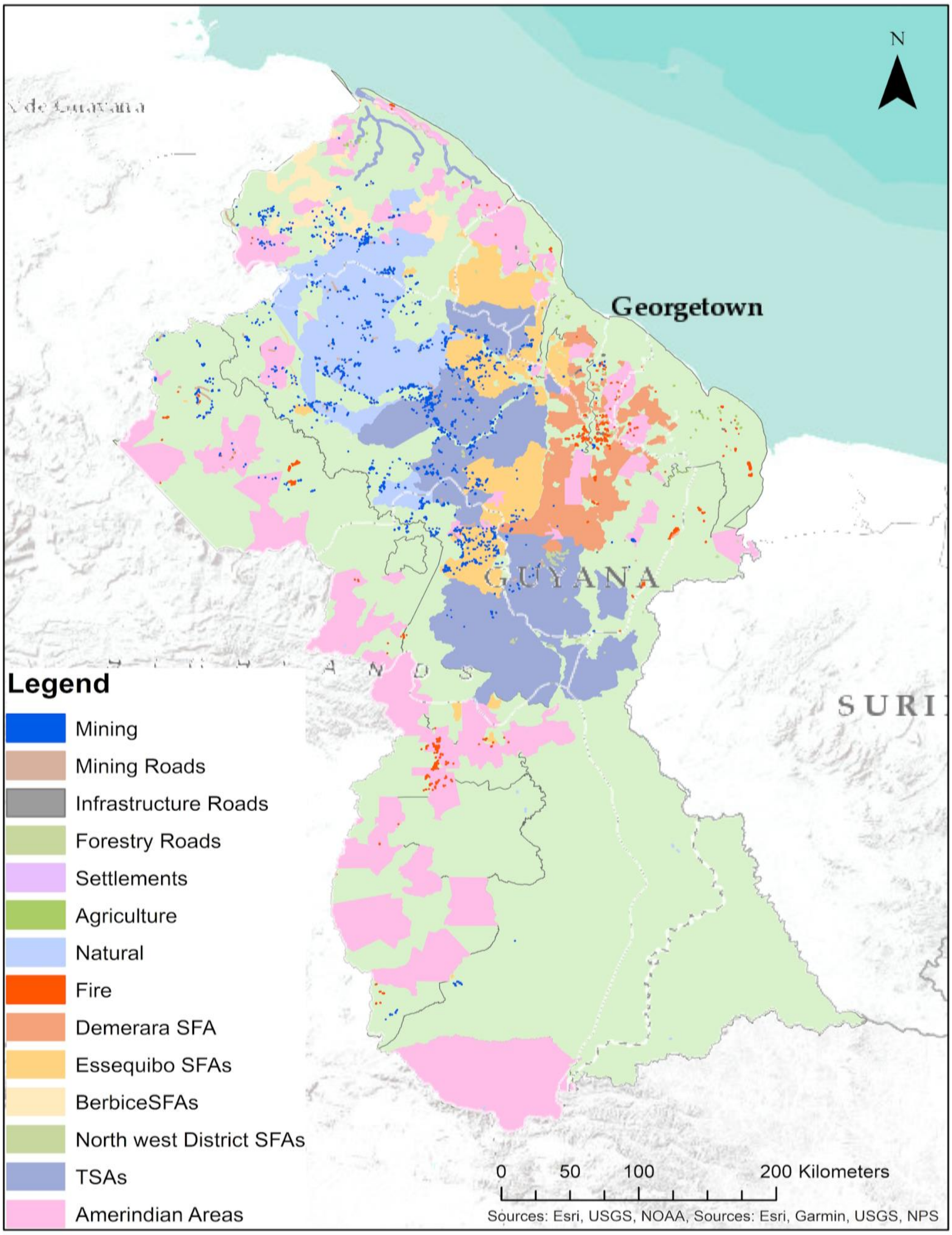
Fire events have a high increase compared to the previous year (660ha) with an area of 6 371 ha mapped. Spatially, they follow historic trends, where events occur in the white sand forest area surrounding Linden and extends towards the eastern border of Guyana.

The large fire events are tied to a prolonged dry spell and are most commonly observed on the drier sand and grassland areas. Although Guyana has seen an increase in forest fires in 2019, it is not as large increase as seen in neighbouring countries.[8]

The following map shows the temporal and spatial distribution of deforestation by driver (mining, forestry and agricultural and biomass burning) for 2019 reporting period. Fire dominates the map as it is the largest single driver of change.

[8] As of August 29, 2019, INPE reported more than 80,000 fires across all of Brazil, a 77% year-to-year increase for the same tracking period, with more than 40,000 in the Brazil's Legal Amazon (*Amazônia Legal* or BLA), which contains 60% of the Amazon. Similar year-to-year increases in fires were subsequently reported in Bolivia, Paraguay and Peru, with the 2019 fire counts within each nation of over 19,000, 11,000 and 6,700, respectively, as of August 29, 2019.[1]

Figure 5-3: Spatial Distribution of Forest Change Drivers (2019)



5.4 Forest Degradation

Reporting on forest harvest continues to be done using the gain-loss method and this is presented in section 6. This method has been applied in this manner from Phase 1.

The methodology for reporting mining and infrastructure degradation has evolved since the inception of the MRVS. Improvement in the process have been introduced in a stepwise manner and through recognition of advances in imaging technologies (spatial and temporal) and estimation processes.

Four refinements have been made:

1. The default approach outlined in the Norway/Guyana JCN stipulated that in the absence of an alternative approach that a 500 m buffer be drawn around deforested areas. This simplistic method returned a degradation estimate of 92 413 ha in year 1.

2. This was refined and replaced using an approach based on interpretation of high-resolution 5 m spatial resolution imagery, with the estimate reducing to 5 467 ha in year 2. The same approach was retained for years 3-5 where the monitoring focused on the area surrounding deforested sites.

3. In tandem, from Year 3 onwards a process for independent verification was included. This involved checking the accuracy of the forest degradation mapping by the GFC teams by randomly sampling areas of change. This process provided a statistical estimate of both gross deforestation and forest degradation.

4. In year 6 (covering the 24 months of 2015 and 2016) the existing “wall to wall” degradation method outlined in step 2 was replaced with the sample-based statistical estimation approach.

5. In year 8, (2018), in a move to embrace the objective of the MRVS Phase 2 to create a more cost sustainable system, a refined approach was developed to report on mining and infrastructure degradation. This approach was developed using the findings of two studies;

    - A Technical Paper produced by Winrock International (2019), titled “Mining Degradation in Guyana”, which built on conclusions of earlier work presented in Brown et al. (2015)

    - Brown, S., A. R. J. Mahmood, and K. Goslee., (2015). “Degradation around mined areas: Methods and data analyses for estimating emission factors”. Submitted by Winrock International to the Guyana Forestry Commission.

These studies lead to the conclusion that mining in Guyana, predominantly for gold and bauxite, is the dominant driver of deforestation. Overall it is responsible for 71% of deforestation greenhouse gas emissions and 57% of total forest greenhouse gas emissions (in 2016).

Application of these studies indicates that emissions associated with mining forest degradation are small (much smaller than estimated in the MOU with Norway) and thus do not warrant high ongoing measurement costs. However, in keeping with Guyana’s desire for completeness in its reporting, the emissions from forest degradation associated with mining are reported. The improved methodology instituted in 2018, uses the approach recommended in Brown et al. (2015) and calculate a 100 m buffer around all areas of mining deforestation and apply the emission factor of 8 t CO^2/ha (2.2 t C/ha). For areas under 1 hectare that are likely moving to full deforestation will be recorded once they reach this size threshold.

Facultatively, this required estimating an immediate degradation emission for all new mines, and for mines where expansion has occurred the buffer area should be calculated with and without the most recent expansion and the forest degradation emissions calculated only on the expanded area. This approach is highly conservative as it assumes there is zero regrowth which is very unlikely.

6. EMISSIONS REPORTING AND ACTIVITY DATA

On 9 November 2009 Guyana and Norway agreed on a framework that establishes the pathway of REDD+ implementation. Under this framework, several forest-based interim measures have been established.

In 2015, a revised Joint Concept Note (JCN) under the Guyana/Norway Agreement was issued and replaced the JCN of 2012. The revised JCN updated the progress in key areas of work including on the MRVS. REDD+ Interim Indicators and reporting requirements, as had been outlined in the 2009 JCN, were maintained.

The intention is that these interim measures will be phased out as the MRVS is established[9].

The basis for comparison of most of the interim measures is the 30 September 2009 benchmark map[10]. The first reporting period (Year 1) is set from 1 Oct 2009 to 30 Sept 2010.

A summary of the key reporting measures and a brief description for these interim measures are outlined in Table 6-5. The calculations to determine the rate of deforestation (ref. measure 1) are reported in Section 7.

Outputs and results are provided for the Intact Forest Landscape (ref. measure 2) and forest management indicators (ref. measure 3 and 4) are outlined in this section.

Whilst reporting continues on Interim Indicators as originally agreed to under the Guyana Norway Agreement Framework, in keeping with the commitment to move to full emissions reporting, this Report presents a complete emissions reporting table for all drivers of deforestation and forest degradation impacts has been presented.

Table 6-1 (a): MRVS Results 2019 (Year 9)

Measure Ref.	Reporting Measure on Spatial Indicators	Indicator	Reporting Unit	Adopted Reference Measure	Year 9 (2019)	Difference between Year 9 and Reference Measure
						Difference
1	Deforestation Indicator	Rate of conversion of forest area as compared to the agreed reference level	Rate of change (%)/yr	0.275%	0.07%	0.205%
2	Degradation Indicator	National area of Intact Forest Landscape (IFL) Change in IFL post Year 1, following consideration of exclusion areas	ha	7 604 820	7 603 487	81 ha loss in the year 2019

[9] The participants agree that these indicators will evolve as more scientific and methodological certainty is gathered concerning the means of verification for each indicator, in particular the capability of the MRV system at different stages of development.
[10] Originally the benchmark map was set at February 2009, but due to the lack of cloud-free data the period was extended to Sept 2010.

Table 6-2 (b): MRVS Results 2019 (Year 9)

Driver	Area (ha)	EF (t CO^2/ha)	Emissions (t CO^2/ha)
Deforestation			
Mining	5,248	1,045	5,484,630
Mining Infrastructure	573	1,045	598,836
Forestry	226	1,045	236,190
Infrastructure	52	1,045	54,345
Agriculture	246	1,104	271,623
Settlements	22	1,045	22,992
Fire	6,371	804	5,123,752
Deforestation Total	**12,738**		**11,792,369**
			Degradation
Timber Harvest			1,766,523
Illegal Logging			10,463
Mining Degradation		22	58,131
Degradation Total			**1,835,117**
TOTAL CO_2 EMISSIONS FOR GUYANA FOR 2019 FROM FOREST SECTOR			**13,627,486**

6.1 Gross Deforestation

Emissions from the loss of forests are identified as among the largest per unit emissions from terrestrial carbon loss in tropical forests. Above ground biomass and below ground biomass combined represent approximately 82% in Above Ground Biomass and Below Ground Biomass including dead wood, litter, and soil to 30 cm which account for the remaining percent[11]. Several key performance indicators and definitions have been developed as follows.

- Comparison of the conversion rate of forest area as compared to agreed reference level as set out in the JCN.
- Forest area as defined by Guyana in accordance with Marrakesh Accords.
- Conversion of natural forest to tree plantations shall count as deforestation with full loss of carbon.
- Forest area converted to new infrastructure, including logging roads, shall count as deforestation with full carbon loss.

6.2 Intact Forest Landscape

The interim measure provided to monitor degradation is based on the definition of Intact Forest Landscapes (IFL).

"*IFL is defined as a territory within today's global extent of forest cover which contains forest and non-forest ecosystems minimally influenced by human economic activity, with an area of at least 500 km^2 (50 000 ha) and a minimal width of 10 km (measured as the diameter of a circle that is entirely inscribed within the boundaries of the territory)*".

The reason for this indicator stems from the concept that degradation of intact forest through human activities will produce a net loss of carbon and is often the precursor to further processes causing long-term decreases in carbon stocks.

Furthermore, preserving intact forests will contribute to the protection of biodiversity. The extent of Intact Forest was determined at the end of September 2010. It is a requirement that the total area of intact forest must remain constant from this date. In determining the IFL, only those areas that meet the forest definition are included.

Within the areas that qualify as IFL, the following rules (first 4 bullets are elimination criteria) are defined:

- Settlements (including a buffer zone of 1 km).
- Infrastructure used for transportation between settlements or for industrial development of natural resources, including roads (except unpaved trails), railways, navigable waterways (including seashore), pipelines, and power transmission lines (including in all cases a buffer zone of 1 km on either side).
- Agriculture and timber production used for local use.
- Industrial activities during the last 30-70 years, such as logging, mining, oil and gas exploration and extraction, peat extraction, etc.

Areas with evidence of low-intensity and old disturbances are treated as subject to "background" influence and are eligible for inclusion in an IFL. Sources of background influence include local shifting cultivation activities, diffuse grazing by domestic animals, low-intensity village-based selective logging, and hunting.

6.3 IFL Data Sources & Methods

The following provides a description of the process and datasets used to generate the IFL. The datasets used were available as at 2010. Since the generation of the reference IFL layer GFC has continued to improve the quality of the base datasets and moved to high-resolution countrywide coverage. This has enabled continuous

[11] Results derived from field study conducted in Guyana as part of the Forest Carbon Monitoring System.

monitoring of forest change (deforestation and degradation) at a national level. It is proposed that the IFL be replaced in the near term to reflect these improvements.

The areas excluded from IFL are:

Settlements

The population of Guyana is approximately 782 000, of which 90% reside on the narrow coastal strip (approximately 10% of the total land area of Guyana). Guyana's coastal strip ranges from 10 to 40 miles (16 to 64 km) in width.

Settlement extents were provided by GL&SC for six municipalities. In addition, the Bureau of Statistics provided 2002 census data for settlements with population >1000 people. The approximate extent of these settlements was determined from satellite imagery. The national Gazetteer which provides a spatial location of settlements was used to identify the remaining settlements. Included are Amerindian titled areas that were digitised as at 2009.

Infrastructure, Mining & Navigable Rivers

Infrastructure used for transport was identified using satellite images and assisted by GPS tracks. Infrastructure associated with SFM is not subtracted from the IFL unless it connects settlements. Only those roads that can be mapped from medium resolution satellite imagery or those leading to settlements have been included.

Historical and current mining areas and the associated infrastructure from 1990 to 30 September 2009 are subtracted from the IFL. These areas have been mapped from medium resolution satellite imagery

Navigable waterways and seashore are as defined from medium resolution images and 1995-96 radar imagery. Only those rivers identified from satellite imagery (~30 m width) have been included in the analysis. All of the rivers mapped in Year 1 are considered navigable.

Permanent Agriculture & Forest Production

Areas of permanent agriculture as identified from satellite imagery and supported by available agricultural leases are digitised from paper maps by GL&SC. Forest production areas under SFM are held by GFC and are available in a GIS format. These areas are excluded from the IFL.

Industrial-scale Exploitation of Resources

Industrial-scale exploitation of timber (clear-felling with no natural regeneration), peat extraction and oil exploration are not practiced in Guyana in the period under review.

Background Sources

Background sources such as shifting cultivation. Shifting cultivation areas have been defined from medium resolution satellite imagery.

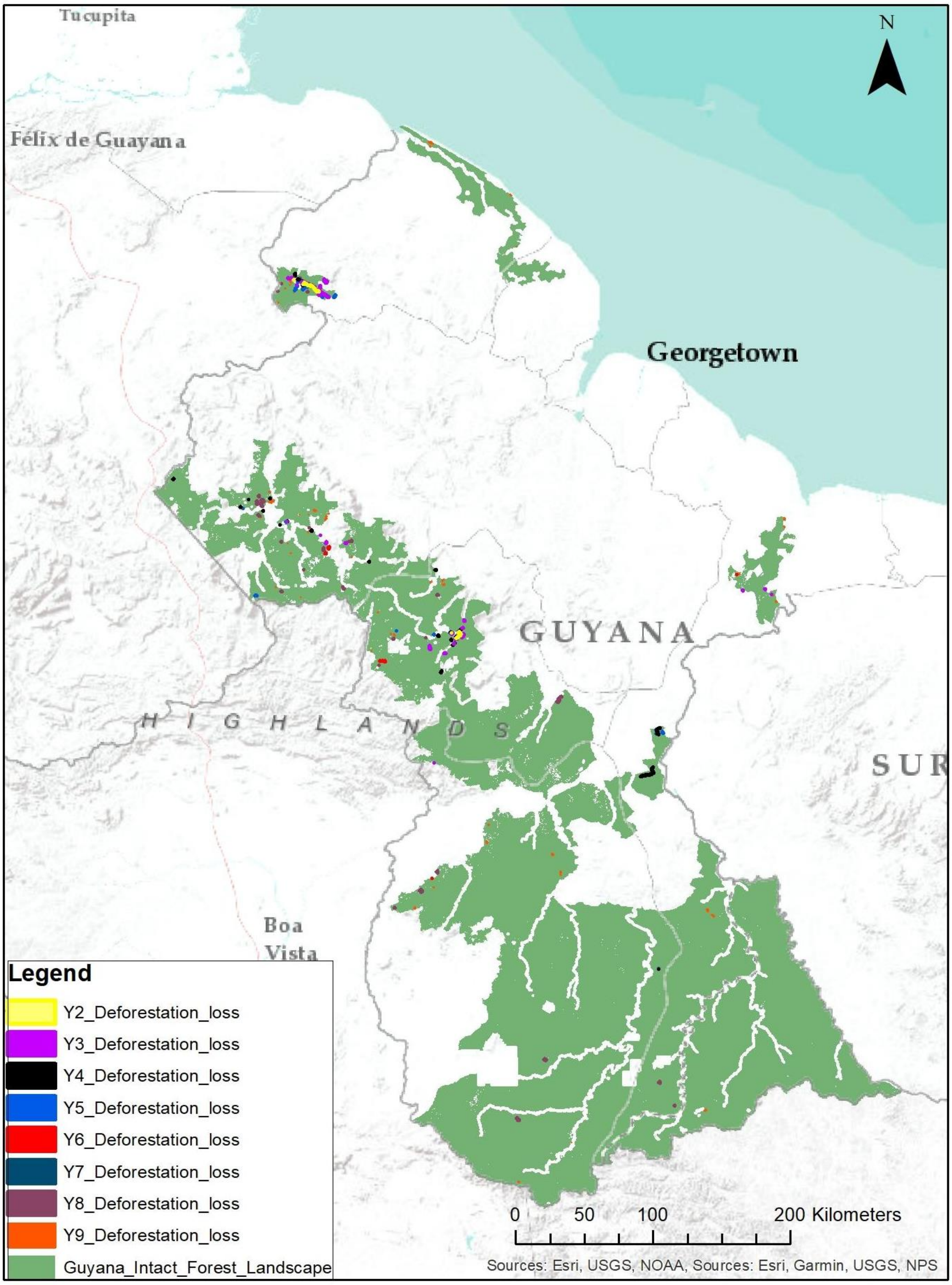
6.4 Calculation of the Year 9 Intact Forest Landscape

In accordance with the interim indicators the total area of intact forest must remain constant from the benchmark date (30 September 2009) onwards. Any change in area shall be accounted for as deforestation with full loss of carbon. The intention of the IFL is to allow a user to determine whether a specific activity falls within or outside an IFL with a margin of error of less than 1 km.

For this report the same benchmark IFL area was used. The analysis identified 81ha of deforestation in IFL areas.

When the Intact Forest Landscape was established in Guyana the total area was estimated at 7.60 million ha. The map below identifies the deforestation that has occurred inside the IFL since Year 2. The change to the 2009 IFL has been increased in size to improve the visualisation

Figure 6-1: Intact Forest Landscape Map



6.5 Improved Methodology for Mining and Infrastructure Degradation

Mining in Guyana, predominantly for gold and bauxite, is the dominant driver of deforestation and is responsible for 71% of deforestation greenhouse gas emissions and 57% of total forest greenhouse gas emissions (in 2016). It is a reasonable expectation therefore that forests surrounding mining sites are damaged and the resulting forest degradation emissions have the potential to be significant. Analysis of remote sensing data has shown that there is some forest degradation associated with mining activity in Guyana (GFC and Indufor 2012[12]).

The original Memorandum of Understanding (MOU) between the Governments of Norway and Guyana specified that the area of 500 m buffers around annual deforestation from mining be reported. In addition, they specified that 50% reduction of the carbon stock in these buffers would occur due to degradation.

Field work has shown that degradation from mining in Guyana is concentrated in a limited area around active deforestation from mining (GFC and Indufor 2012 and Brown et al. 2015[13]). Winrock and the GFC[14]) concluded that given the low relative annual emissions from forest degradation associated with mining that a simplified approach using buffer areas around mining deforestation should be used. The field work and analyses of Brown et al. (2015) determined that applying an emission factor to a 100 m buffer around each individual polygon of deforestation due to mining is an appropriate and conservative approach. This analysis is conducted in ArcMap 10.7 using Guyana's yearly forest change dataset.

The original dataset is multipart, such that one attribute of loss defined by date of observation and driver contained multiple polygons of various sizes. To conduct the analysis, the multipart dataset must be split to a single part such that each attribute was associated with a single polygon. Polygons with an area of 1 ha or greater, the driver of mining, and the relevant year are selected for further analysis. Using the buffer coverage tool, a 100m buffer is defined using the 'no dissolve feature'. This preserves the associated attribute information and creates overlapping polygons. The 'erase tool' is then used to remove any areas of loss from the specified year that overlaps the 100 m buffers. The assumption here as supported by field measurements (transects) is that the forested area within 100 m of mining is within the degradation zone unless it is lost to another driver, such as road creation.

The dataset is then spatially dissolved so that the degradation zones of adjacent loss polygons are merged. The area of the dissolved polygon represents the total area of a 100 m degradation buffer around deforestation parcels due to mining, excluding all polygons of loss due to other drivers.

This area is the activity data for degradation from mining activity. The emission factor of 8 t CO^2/ha (2.2 t C/ha), derived from the field work described in Brown et al. (2015), is then applied to the activity data to produce the estimate of emissions from mining degradation across Guyana. This also means that for areas under 1 hectare that are likely moving to full deforestation by mining, these areas will be recorded when it reaches this state.

The approach requires estimating an immediate degradation emission for all new mines, and for mines where expansion has occurred the buffer area is calculated with and without the most recent expansion and the forest degradation emissions calculated only on the expanded area. This approach should be seen as highly conservative as it assumes there is zero regrowth which is very unlikely.

[12] GFC and Indufor 2012. Guyana REDD+ Monitoring, Reporting and Verification System (MRVS): Year 2 Interim Measures Report, Version 3. Available from: http://www.forestry.gov.gy/Downloads/

[13] Brown, S., A. R. J. Mahmood, and K. Goslee. 2015. Degradation around mined areas: Methods and data analyses for estimating emission factors. Submitted by Winrock International to Guyana Forestry Commission.

[14] Winrock International. 2019. Recommendations Paper: Mining Degradation in Guyana. Submitted by Winrock International to the Guyana Forestry Commission.

6.6 Forest Management

Forest management includes selective logging activities in natural or semi-natural forests.

The intention of this measure is to ensure sustainable management of forest with net-zero emissions or positive carbon balance in the long term. The requirement is that areas under SFM be rigorously monitored and activities documented such as harvest estimates. The following information is documented by the GFC and available for review for the period 1 January 2019 to 31 December 2019, with the annualised total presented:

- Production by forest concession
- Total production.

The reporting requirements include data on extracted timber volumes post 2008 and are available for verification. These are compared against the mean volume from 2003-2008. Any increase in extracted volume above the 2003-2008 mean is accounted for as an increase in carbon emissions. This is unless otherwise documented using the Gain Loss or stock difference methods as described by the IPCC for forests remaining forests. In addition to harvested volume, a default expansion factor shall be used to account for losses due to harvesting, i.e. collateral damage. This is unless it can be shown this is already accounted for in the recorded extracted volume.

Production volumes are recorded on declaration/removal permits, issued by the GFC to forest concession and private property holders. Upon declaration, the harvested produce is verified, permits collected and checked and sent to the GFC's Head Office, followed by data input into the central database. The permits include details on the product, species, volume, log tracking tags number used, removal and transportation information, and in the case of large timber concessions, more specific information on the location of the harvesting. Production reports are generated by various categories including total volume, submitted to various groups of stakeholders and used in national reporting. Details on the main processes are provided below:

Monitoring of Extracted Volume: Monitoring in the forest sector is coordinated and executed by the GFC and occurs at four main levels: forest concession monitoring, monitoring through the transportation network, monitoring of sawmills and lumberyards, and monitoring ports of export.

For forest harvesting and transport, monitoring is done at station level, at concession level and supplemented by random monitoring by the GFC's Internal Audit Unit and supervisory staff. At all active large concessions, resident forest officers perform the function of ensuring that all monitoring and legality procedures are strictly complied with. In instances of breach, an investigation is conducted and, based on the outcome, action is instituted according to GFC's standard procedures for illegal actions and procedural breaches.

Prior to harvesting, all forest concessions must be in possession of valid removal permit forms. Permit numbers are unique to operators and are issued along with unique log tracking tags. Production volumes are declared at designated GFC offices with checks made to verify legality of origin and completion of relevant documents, including removal permit, production register and log tracking. Removal permits require that operators declare: date of removal, type of product, species, volume, destination, vehicle type, vehicle number, name of driver/captain, tags, diameter of forest product (in case of logs) and other relevant information. This is one of the initial control mechanisms that is in place whereby monitoring is done for proper documentation and also on the declared produce, etc. Control and quality checks are also undertaken at another level once entered in the centralised database for production. Removal permits, and log tracking tags are only valid for a certain period and audit for use beyond that time is also an important part of the QA/QC checks conducted by the GFC. The unique identity of each tag and permit by operator also allows QA/QC to be conducted for individual operators' use. Thus, checks are allowed across time, by operator and by produce being declared.

In the case of large forest concessions, only approved blocks (100 ha) in Annual Plans are allowed to be harvested in a given year. Harvesting outside of those blocks, even if these areas are within the legally issued concessions, is not permitted. As such, this forms part of the QA/QC process for large concessions (Timber Sales Agreements and Wood Cutting Leases). As one prerequisite for approval of Annual Plans, forest inventory information at the pre-harvest level must be submitted, accompanied by details regarding the proposed operations for that 12-month period, such as maps, plans for road establishment, skid trail alignment etc. The QA/QC process that is executed at this initial stage requires the application of the guidelines for Annual Plans which must be complied with prior to any such approval being granted. A new addition to the monitoring mechanism has been the use of bar code scanners that allow for more real-time tracking of legality of origin of forest produce.

In the case of Amerindian lands and private property, the documentary procedures outlined above regarding the removal permitting and log tracking, are only required if the produce is being moved outside the boundaries of the area. From this point onwards, the procedures that apply to State Forest concessions, apply to this produce as well.

Data Collection: Following receipt of removal permits and production registers, monthly submissions are made to GFC's Head Office for data entry. There is a dedicated unit in the GFC's Management Information System section that is responsible for performing the function of data collection, recording, and quality control. Data is entered in SQL databases custom designed for production totals. This database has built in programmatic QA/QC controls that allow automatic validation and red flagging of tags being used by unauthorised operators, or permits being incorrectly, incompletely or otherwise misused, and cross-checking of basic entry issues including levels of production conversion rates, etc.

As a second stage of QA/QC all entries are validated, and the validated data is then secured in a storage area in the database. There are security features at several levels of the database operations including a read/write only function for authorised users, and change tracking of production information by staff, as well as others. At the end of every month, data is posted to the archives and a separate unit of the GFC is responsible for cross-checking volume totals by species, concession and by period, and preparing the necessary report for external consumption.

Forest Products included in MRVS Report: in tabulating the declared volumes for forest management, the following primary products that are extracted from the forest were:

- Logs
- Lumber (chainsawn lumber)
- Roundwood (piles, poles, posts, spars)
- Splitwood (shingles, staves)
- Fuelwood (charcoal, firewood)

Logging Damage – Default Factor

In 2011 progress was made in developing a methodology and finalising factors to assess Collateral Damage in a Technical Report developed by Winrock International for the GFC: *Collateral Damage and Wood Products from Logging Practices in Guyana,* December 2011.

The objective of the report is to examine how emission factors were developed that relate total biomass damaged (collateral damage) and thus carbon emissions, to the volume of timber extracted. This relationship will allow the estimation of the total emissions generated by selective logging for different concession sizes across the entirety of Guyana. The following field data have been collected with which the emission factors have been developed:

1. Measurements in a sample of logging gaps to collect data on the extracted timber biomass and carbon in the timber tree and the incidental carbon damage to surrounding trees.

2. Estimating the carbon impact caused by the logging operations such as skid trails. Although selective logging clears forest for roads and decks, their emissions will be estimated through the stock-change method based on estimates of area deforested by logging infrastructure determined in the land cover change monitoring.

Accounting for the impact of selective logging on carbon stocks involves the estimation of a number of different components:

- Biomass removed in the commercial tree felled – emission.
- Incidental dead wood created as a result of tree felling – emission.
- Damage from logging skid trails – emission.
- Carbon stored in wood products from extracted timber by product class – removal.

- Regrowth resulting from gaps created by tree felling - removal.

The **emissions** from selective logging are expressed in equation form as follows:

Emissions, t CO^2/yr = {[Vol x WD x CF x (1-LTP)] + [Vol x LDF] + [Lng x LIF]}*3.67 (Eq. 1)

Where:

Vol = volume of timber over bark extracted (m^3)

WD = wood density (t/m^3)

CF = carbon fraction

LTP = proportion of extracted wood in long term products still in use after 100 yr (dimensionless)

LDF = logging damage factor—dead biomass left behind in gap from felled tree and incidental damage (t C/m^3 extracted)

Lng = total length of skid trails constructed to extract Vol (km)

LIF = logging infrastructure factor—dead biomass caused by construction of infrastructure (t C/km of skid trail to extract the Vol)

3.67 = conversion factor for t carbon to t carbon dioxide Wood in

long term products

Not all the carbon in harvested timber gets emitted to the atmosphere because a proportion of the wood removed may be stored in long term wood products. Total carbon stored permanently into wood products can be estimated as follows.

$$C_{WP} = C * (1 - WW) * (1 - SLF) * (1 - OF) \qquad \text{(Eq. 2)}$$

15

Where:

$C^{WP:}$ = Carbon stock in long-term wood products pool (stock remaining in wood products after 100 years and assumed to be permanent); t C ha^{-1}

C = Mean stock of extracted biomass carbon by class of wood product; t C ha^{-1}

WW = Wood waste. The fraction immediately emitted through mill inefficiency by class of wood product

SLF = Fraction of wood products with a short life that will be emitted to the atmosphere within 5 years of timber harvest by class of wood product

OF = Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest by class of wood product

The methodology presented here is a module in an approved (double verified) set of modules for REDD projects posted on the Verified Carbon Standard (VCS) set of methodologies. The reported difference between the annual mean for the period 2003-2008 and the assessment year of 1 January 2019 to 31 December 2019, presented an an annualised total, is shown in the table below. For this period t CO^2 has reduced by 1,766,523t $CO^{2.}$

Table 6-6: Interim Indicator on Forest Management

Period	Description	Volume ($t\ CO^2$)
1 January 2019 – 31 December 2019	$t\ CO^2$ emissions arising from timber harvesting	1,766,523
2003-2008 (annual average)	$t\ CO^2$ emissions arising from timber harvesting	3 386 778
Difference ($t\ CO^2$)		1,620,255

6.7 Illegal Logging

Areas and processes of illegal logging must be monitored and documented as far as practicable. Monitoring and estimation of such areas is recommended to be done by assessing the volumes of illegally harvested wood. In the absence of hard data, a default factor of 15% (as compared to the legally harvested volume) is required to be used. It is stated in the Joint Concept Note that this factor can be adjusted upwards and downwards pending documentation on illegally harvested volumes, inter alia from Independent Forest Monitoring. Additionally, medium resolution satellite imagery can be used for detecting human infrastructure and targeted sampling of high-resolution satellite images for selected sites.

In the historic reporting, the default level of 15% of harvested production of 705 347 m^3 corresponding to 411,856 $t\ CO^2$, is used in the absence of a complete database of illegal activities being in place at that time. This level includes provision for collateral damage arising from logging activities. Production volumes are recorded in custom designed databases which are updated monthly by the GFC, subject to internal verification, and are backed up and stored monthly offsite.

The rate of illegal logging for the assessment Year 9, 1 January 2019 to 31 December 2019, is informed by a custom designed database that is updated monthly, and subject to routine internal audits. This database records infractions of illegal logging in Guyana in all areas.

Table 6-7 Interim Indicator on Illegal Logging

Period	Description	Volume ($t\ CO^2$)
1 January 2019 – 31 December 2019	$t\ CO^2$ emissions arising from illegal logging	10,463
2003-2008 (annual average)	$t\ CO^2$ emissions arising from illegal logging	411 856
Difference ($t\ CO^2$)		401,393

Reporting on illegal logging activities is done via the GFC's 36 forest stations located strategically countrywide, as well as by field, monitoring and audit teams, through the execution of both routine and random monitoring exercises. The determination of illegal logging activities is made by the application of standard GFC procedures. The infractions are recorded, verified and audited at several levels. All infractions are summarised in the illegal logging database and result in a total volume being reported as illegal logging for any defined time period.

Explanatory Note 1

The following steps are taken in the computation of gross emissions from forest management activities:

Step 1: Compile background data to inform computations

Compile annual production of forest products

Compile annual area under harvest of various categories of Operators taking into consideration blocks under harvest by large concessions, small forest concessions areas, and titled Amerindian Areas involved in forestry activities.

Compute Yield in cubic meters per hectares by dividing the harvest level by the area size.

Step 2: Computing impact of incidental impact and collateral damage emanating from logging activities. Factors derived from data collected from 121 Logging Plots.

Compute total skid trails constructed during the assessment period.

Applying a logging damage factor of 0.95 t C/m3, and a logging infrastructure factor of 32.84 t C/km, derive total gross carbon emission impact from collateral damage and logging infrastructure by:

(Area under harvest in hectares **X** Average Yield per ha in cubic meters) **X** Logging Damage Factor of 0.95 t C/m3)

X (length of skid trails of that year in km **X** logging infrastructure factor of 32.84 t C/km)

Step 2 results in t C of collateral damage and infrastructure impacts from forest harvest, which then multiplied by 3.67 as the multiplier of t C to CO2, is the total CO2 emanating from forest management activities resulting from collateral damage and forest infrastructure.

Step 3: Computing the actual impact of extracted wood including provision for storage in long term wood products. Long term wood products storage computation based on Winjum et al 1998.

Compute total gross emissions emanating from wood extracted by:

(Area under harvest in hectares **X** Average Yield per ha in cubic meters)

X (Average carbon storage value per cubic meters of 0.4 t C/m3) – (Carbon Stored in Long Term Wood Products computed by method proposed in Winjum et al 1998)

Step 3 results in the computation of total gross emissions taking account of wood stored in Long Term Wood Products and is converted to CO2 by multiplying the above product by 3.67.

Explanatory Note 2

The following steps are taken in the computation of the total emissions from illegal logging activities:

Step 1: Compile background data to inform computations

Compile annual illegal logging timber volume

Compile annual area under harvest of various categories that may have been subject to illegal logging.

Compute Yield in cubic meters per hectares by dividing the illegal logging production by the area size

Step 2: Computing impact of collateral damage emanating from illegal logging activities. Factors derived from data collected from 121 Logging Plots.

Applying a logging damage factor of 0.95 t C/m3, derive total gross carbon emission impact from collateral damage by:

(Area under harvest in hectares **X** Average Yield per ha in cubic meters) **X** Logging Damage Factor of 0.95 t C/m3)

Step 2 results in t C of collateral damage from illegal logging activities, which then multiplied by 3.67 as the multiplier of t C to CO2, is the total CO2 emanating from illegal logging activities resulting from collateral damage.

Step 3: Computing the actual impact of extracted wood including provision for storage in long term wood products. Long term wood products storage computation based on Winjum et al 1998.

Compute total gross emissions emanating from wood extracted by:

(Area under harvest in hectares **X** Average Yield per ha in cubic meters)

X (Average carbon storage value per cubic meters of 0.4 t C/m3) – (Carbon Stored in Long Term Wood Products computed by method proposed in Winjum et al 1998)

Step 3 results in the computation of total gross emissions taking account of wood stored in Long Term Wood Products and is converted to CO2 by multiplying the above product by 3.67.

Step 4: Computing the total CO2 emissions from total illegal logging

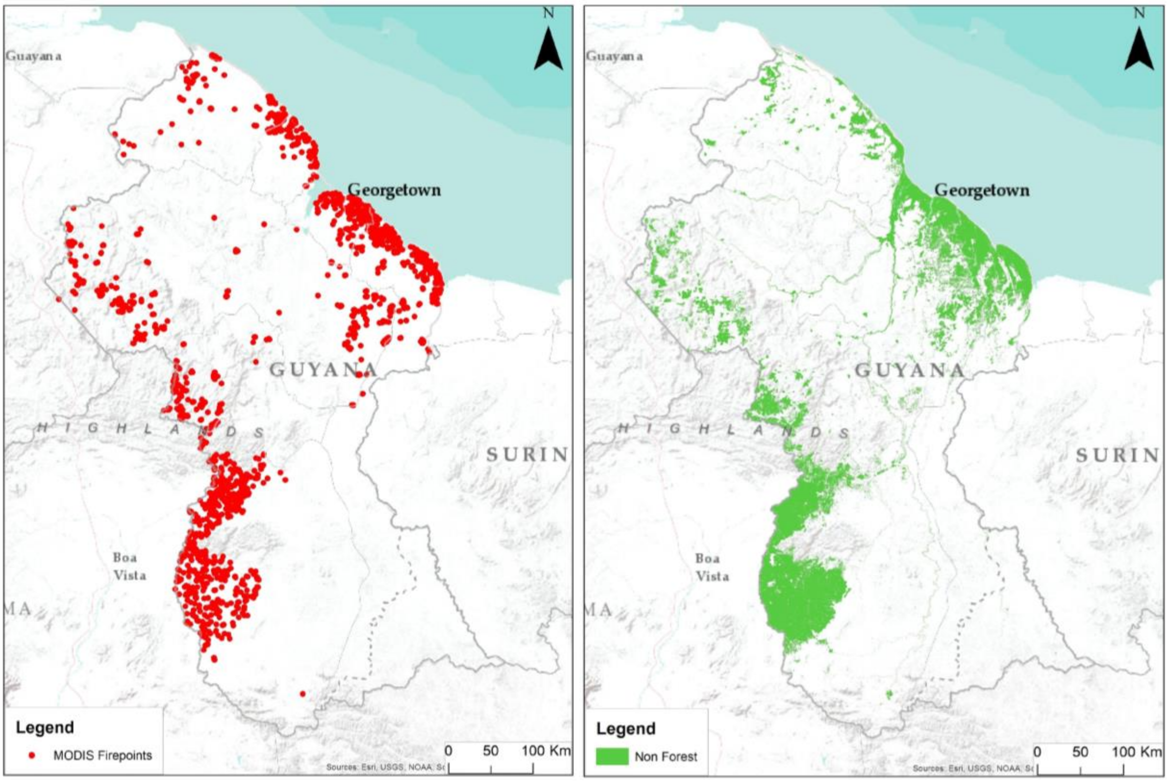
Results of Step 2 + Results of Step 3

6.8 Forest Fires

The FIRMS fire point data from MODIS was used to identify potential fire locations. In addition, a systematic review of all fire points was undertaken to validate the presence of fire and establish the extent using Sentinel imagery. This is an accepted approach that is documented in the GOFC-GOLD sourcebook.

The initial approach used to set a reference level was to calculate the area burnt for the 1990 to September 2009 period. Over this 19-year period a total of 33 700 ha of forest was identified as degraded by burning[15]. This equated to a mean annual area of 1 700 ha. The mean area burnt was accepted as a suitable Interim Measures benchmark against which all subsequent change could be compared. In this reporting period the area deforested by forest fires is 6 371ha.

Figure 6-5: Non Forest Area & FIRMS Fire Data 2019



The main non-forest areas are in the south along the Brazilian border and closer to Georgetown on the coastal fringe.

[15] This does not include areas deforested because of fire events. This has been recorded as deforestation. The .El Niño weather pattern is known to have occurred during this period.

7. REFERENCES

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Appendix 1

Year 9 Satellite Image Catalogue

All new imagery that is available has been added to the existing archive at GFC. The following table describes the naming conventions and column headings for the image catalogue as below. This archive is dynamic and will be continually added to over time.

Image Naming Conventions

Landsat Image Stack Name	Image name in the following format: Satellite (2-3), Path (4), Row (1-3) _ Image Date (YYMMDD)_Image Provider (1)_Processing level (1-2)
Sentinel Image Stack Name	Image name in the following format: datatake sensing start time_data take sensing stop time_tile ID
Acquisition Month	The month when image was taken
Mapping Stream	The mapping analysis that the imagery is for.
Data Provider	The name of the data provider/source of data
Satellite Instrument	The satellite or instrument of origin

Summary of 2019 Satellite Images

Stack Name	Satellite/ Instrument	Data Provider	Resolution (m)	Acquisition Year	Acquisition Month
20190804T142801_20190804T142757_T21NUG.tif	Sentinel	ESA	10	2019	August
20190804T142801_20190804T142757_T21NUH.tif	Sentinel	ESA	10	2019	August
20190819T142759_20190819T142758_T20NQL.tif	Sentinel	ESA	10	2019	August
20190819T142759_20190819T142758_T20NRK.tif	Sentinel	ESA	10	2019	August
20190819T142759_20190819T142758_T20NRL.tif	Sentinel	ESA	10	2019	August
20190819T142759_20190819T142758_T20NRM.tif	Sentinel	ESA	10	2019	August
20190819T142759_20190819T142758_T20NRN.tif	Sentinel	ESA	10	2019	August
20190819T142759_20190819T142758_T21NTB.tif	Sentinel	ESA	10	2019	August
20190819T142759_20190819T142758_T21NTE.tif	Sentinel	ESA	10	2019	August
20190819T142759_20190819T142758_T21NTF.tif	Sentinel	ESA	10	2019	August
20190819T142759_20190819T142758_T21NUF.tif	Sentinel	ESA	10	2019	August
20190819T142759_20190819T142758_T21NUG.tif	Sentinel	ESA	10	2019	August
20190824T142751_20190824T142754_T20NQN.tif	Sentinel	ESA	10	2019	August
20190824T142751_20190824T142754_T20NRG.tif	Sentinel	ESA	10	2019	August
20190824T142751_20190824T142754_T20NRH.tif	Sentinel	ESA	10	2019	August
20190824T142751_20190824T142754_T20NRJ.tif	Sentinel	ESA	10	2019	August
20190824T142751_20190824T142754_T20NRK.tif	Sentinel	ESA	10	2019	August
20190824T142751_20190824T142754_T20NRL.tif	Sentinel	ESA	10	2019	August
20190824T142751_20190824T142754_T21NTC.tif	Sentinel	ESA	10	2019	August
20190824T142751_20190824T142754_T21NTG.tif	Sentinel	ESA	10	2019	August
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20190827T143751_20190827T143748_T20NQN.tif	Sentinel	ESA	10	2019	August
20190829T142759_20190829T142756_T20NQN.tif	Sentinel	ESA	10	2019	August
20190829T142759_20190829T142756_T20NRM.tif	Sentinel	ESA	10	2019	August
20190829T142759_20190829T142756_T20NRN.tif	Sentinel	ESA	10	2019	August
20190829T142759_20190829T142756_T20PRQ.tif	Sentinel	ESA	10	2019	August
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20190829T142759_20190829T142756_T21NTJ.tif	Sentinel	ESA	10	2019	August

20190829T142759_20190829T142756_T21NUJ.tif	Sentinel	ESA	10	2019	August
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20190908T142759_20190908T142754_T20NQM.tif	Sentinel	ESA	10	2019	September
20190908T142759_20190908T142754_T21NTH.tif	Sentinel	ESA	10	2019	September
20190908T142759_20190908T142754_T21NUD.tif	Sentinel	ESA	10	2019	September
20190908T142759_20190908T142754_T21NUE.tif	Sentinel	ESA	10	2019	September
20190908T142759_20190908T142754_T21NUG.tif	Sentinel	ESA	10	2019	September
20190908T142759_20190908T142754_T21NUH.tif	Sentinel	ESA	10	2019	September
20190910T142041_20190910T142035_T21NTC.tif	Sentinel	ESA	10	2019	September
20190913T142751_20190913T142751_T20NRH.tif	Sentinel	ESA	10	2019	September
20190913T142751_20190913T142751_T20NRJ.tif	Sentinel	ESA	10	2019	September
20190913T142751_20190913T142751_T20NRK.tif	Sentinel	ESA	10	2019	September
20190913T142751_20190913T142751_T20NRL.tif	Sentinel	ESA	10	2019	September
20190913T142751_20190913T142751_T21NTC.tif	Sentinel	ESA	10	2019	September
20190913T142751_20190913T142751_T21NTD.tif	Sentinel	ESA	10	2019	September
20190913T142751_20190913T142751_T21NTE.tif	Sentinel	ESA	10	2019	September
20190913T142751_20190913T142751_T21NUG.tif	Sentinel	ESA	10	2019	September
20190913T142751_20190913T142751_T21NUH.tif	Sentinel	ESA	10	2019	September
20190913T142751_20190913T142751_T21NUJ.tif	Sentinel	ESA	10	2019	September
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20190925T142039_20190925T142037_T21NVF.tif	Sentinel	ESA	10	2019	September
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074_20190728_rgb.jgw	Aerial Imaging Cxamera System	Geovantage	0.25-0.55	2019	July
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Appendix 2
Corrective Actions Request (CARS)

Corrective Actions Requests

<table>
<tr><th rowspan="2">CARS AND OBS</th><th colspan="2">GFC's Response</th></tr>
<tr><th>@ time of audit</th><th>GFC Update</th></tr>
<tr><td>2014- CAR 4 MINOR
Non-Compliance: Biomass assessment plots of degraded forest within shifting cultivation areas are not adequately reflected within overall biomass calculation.

Objective evidence:
• Fieldwork evidence shows that most, if not all, SA mapped as pioneer actually is rotational.
• Fieldwork evidence shows that the currently map identification of primary forest in shifting cultivation areas has led to the allocation of areas as primary forest where ground truthing of the same areas identified the area as rotational agriculture/degraded secondary forest.

Audit results Year 6 audit
GFC has started work on the re-stratification of its forest types however due to the delays with the Norway /Guyana Agreement and the priorities for the Year 6 reporting the CAR has not been fully implemented.
CAR remained open and will be verified during the next audit.</td><td>The brief inspection conducted during the audit indicated that rotational shifting cultivation was classified as pioneer. It is worth noting that this the first year shifting cultivation has been reported. It is anticipated that as an approach 3 MRVS and with further repeat image coverages the attribution of both historical and new shifting cultivation areas will be improved.
While the areas in question still fall within Guyana's definition of forest, it is recognised that this is secondary forest. It is expected that the historical extent of shifting cultivation areas will improve in line with annual coverages of high resolution imagery. The current work on Emission Factors by GFC will account for the differing carbon contents.
It is planned for field assessments to be conducted to inform an emission factor for Shifting Agriculture.
This will inform the impact that this activity has on biomass. This will remove the dependence of categorising shifting agriculture type using remove sensing methods only, which evidently has specific challenges.
It is envisaged that an Emission Factor will be developed in 2015-2016 for Shifting Agriculture. It is likely that the emission factor will be a function of the forest-fallow cycle and local practices.
The challenge will be how to count for the net emissions from this activity. It is still being assessed whether Shifting Cultivation mosaics are lengthening or shortening or stable. This determination will help to decide their role. Once an estimate of the average C stock is derived in different Shifting Cultivation mosaics then this can be used with pioneer shifting cultivation—i.e. first time cleared, as the net effect will not be the C stock of the forest to begin with but the C stock of initial forest minus the long term</td><td>Updates to methods in Year 8 have taken account of areas affected under non forest classification.

This issue is therefore closed.</td></tr>
</table>

2015- OBS 2 **Potential Non-Compliance**: Original hypotheses around forest stratification (grouping of forest types) not confirmed in final stratum. **Objective evidence**: Originally GFC demonstrated and argued that carbon content within different forest types were negligible and as such could be group all under forest. However, this was based on data collected predominantly within the traditional forest logged by commercial operations. Now that new data is getting available from the savannah areas (in LPfC stratum) where forest types appear to have lower carbon content, it is not clear if this original conclusion to group all forest types together holds true. **Observation remains open**	It is intended that following the completion of the three phases of data collection, matters such as those outlined in the objective evidence will be examined. One approach is to consider post stratification of the LPfC area where this matter seems to be prevalent. We note that this was not an issue in the other two strata of HPfC and MPfC where there are multiple forest types and a prevalence of logged and unlogged forest, along with other land use and land management activities. GFC will collate the results of the data analysis from the LPfC stratum and examine this further. This will be further examined in Year 6.	Follow completion of all data collection for the Forest Carbon Monitoring System, it was concluded that there is no statistically significant difference across the sampling classes. This is reflected in the revised Forest Carbon Monitoring Report 2019. This has resulted in a single (average) forest carbon stock number applied to all classes. This issue is therefore closed with the developments that have taken place post 2017.
2016 (Year 6) CAR 2 MINOR **Non-Compliance**: Incomplete SOP of mapping degradation & deforestation **Objective evidence**: • Current SOP does not address the changes that have been adopted in relation to the determination of degradation • Current SOP makes reference to Rapid Eye applicability whilst this is no longer used. **CAR now a MINOR**	The Mapping SOP will be updated in 2018 to reflect the change in the degradation method. As part of that process GFC will provide additional documentation that outlines the approach. This will include supporting analysis of field measurements collected across sites representative of degradation. Inclusion of text and materials to ensure the approach is well documented and can be replicated in the future. For Year 7, national data on forest degradation will be estimated from a stratified random change sample. The reference data used for the analysis will be PlanetScope, Sentinel and, where available, GeoVantage aerial imagery. The SOP will be updated to clarify that RapidEye data has been superseded with more recent earth observation satellites. The documentation that relates to the image processing chain will also be adapted to more accurately reflect current use of freely available image sources and subsequent improvements that are being made to image analysis processes.	The SOP for mapping has been updated and all deforestation mapping processes appropriately updated including imagery source being used. From Years 8 and 9, the method for assessing mining and infrastructure degradation has been improved and there is no reliance on separate sampling for this aspect as it utilizes the same approach for Deforestation mapping and applies an emission factor derived from field work in Guyana. This has also been peer reviewed. This is outlined in Section 5.4 of the main report above. This issue is therefore closed.
2016 (Year 6) CAR 3- MINOR **Non-Compliance**: Accuracy Assessment have become part of	The element of independent assessment of the change data will be reintegrated in year 7.	An ArcGIS Toolbar add-in for tracking degradation was created to update and track changes. A SOP has also been created to

value determination instead of quality control **Objective evidence**: · With the adoption of the sampling technique of the degradation through the accuracy assessment team the degradation value is not subject to the same level of independent assessment as the deforestation data receives through the accuracy assessment. **CAR now a MINOR**	It is intended that the revised degradation methods will be routinely applied to future years. To enable this GFC will develop in conjunction with Durham University a training module that allows the estimation or 'accuracy assessment' methods to be replicated at GFC. An innovation for Year 7 will be the development of a new SOP that will allow GFC staff to conduct the change interpretation part of the forest degradation estimation process. GFC staff will be trained in the use of the reference data and the methodology for change assessment using the bespoke GIS toolbar. Durham University will then be provided with the change data and will undertake the statistical analysis of the forest degradation results and provide tabular data/analysis for reporting purposes. In so doing, Durham University will continue to support the approach and will be responsible for auditing the GFC's interpretation of change and associated deforestation and degradation estimates. In this way the process supports GFC to attain the necessary skills required to perform the assessment while also incorporating the independent verification process –which is an integral part of the MRVS. The accuracy assessment report will be replaced with an independent report on GFC's results and estimates by Durham University	reflect the new methodology adopted for tracking degradation. The toolbar was installed at GFC on 6th September 2018 to work with ArcGIS 10.6. Training on how to interpret and assess Forest Degradation was conducted by Durham University team at the GFC from the 28th March – 6th April 2018. The Durham University team ran a refresher training session with the GFC mapping team on 21st August 2018. The GFC mapping team completed the interpretation of the sample areas provided by Durham University. This was then followed by consistency checks which was done by all members of the GFC mapping team on randomly selected samples. Quality assurance on the GFC sample interpretations was undertaken by Durham University team. In 2019 the process was repeated. This action is also closed.
2016 (YEAR 6) CAR 4 MINOR **Non-Compliance**: Lack of clarity in SOP and Report that minimum acceptable mapping requirements for the information needs of GFC remain fulfilled. **Objective evidence**: With the increasing developments around images that are available in the open source market and commercial market and the GFC's adoption of some of these elements in Year 6, the GFC needs to more effectively justify that the existing defined minimum criteria of the MRVS remain fulfilled under the new	The GFC recognises the fast pace that new sensors are becoming available. We intend to add clarity in both the SOP for Mapping as well as in future Reports that document the integrating of these developments. A fuller justification will be provided, including a checklist with test scenarios that the new developments meet the defined minimum criteria of the GFC's MRVS which include: fulfilling the requirements of the SOP for Mapping, remaining consistent to	In the Updated Mapping SOP there is a Section (**Section 4.2**) that explains and justifies the use of Sentinel imagery.

technologies that have been used and that these meet the needs of GFC to continue its reporting requirements under the UNFCCC and/or Donor Countries. Current SOP does not contain QA/QC controls to verify that images may not be correctly aligned over time. **CAR to be closed out during next verification**	the definition of forest, and uniformly applying the MMU. Additionally, structural changes will be made to the Year 7 and future reports to more effectively present these new developments and show how they are synergistic to the existing main tenants (including defined minimum criteria) of the MRVS.	
2016 (Year 6) CAR 5 MINOR **Non-Compliance**: No operational linkage between CMRV and the national MRV **Objective evidence**: · Although initial capacity building, training, and data-gathering exercises have commenced and continued between GFC and its partner organizations implementing the CMRV progress with local Amerindian communities, no operational link between the monitoring or with the data gathered and the greater MRVS system has been made to date, nor has there been any progress made with regards to the opt-in mechanism and a corresponding pilot program, which according to the JCN, should have commenced in 2015. · JCN Table 1 key REDD+ enabling Efforts. Requires the start of a pilot during 2015 for the Opt-In Mechanism. However, the verification team realizes that the GFC and its corresponding Ministry have undergone a restructuring where by some of the Ministries responsibilities may have moved to Office of Climate Change, hence the team seeks further information on how and if the GFC will support the new government body with the implementation of the JCN requirements. **CAR to be closed out during next verification**	The Office of Climate Change is the lead agency coordinating the implementation of the Opt In Mechanism. The GFC is not the lead agency for this REDD+ activity. The GFC will support the implementation of the Opt In as it advances however, with the Commission not being in the leadership role in this project, the GFC cannot dictate the pace or method of implementation. The GFC stands ready to support the Opt In in any way requested. The Commission will look out for those requests. Notwithstanding this, the GFC will continue to work with partners, including the WWF, on CMRV related work as far as practicable whilst the Opt In evolves to a piloting status. This work will seek to support the national MRVS and vice versa. The Commission is careful to not create a parallel/divergent track to what may be required under an Opt In mechanism and for this reason stand ready to support this process when needed and in the way needed.	Over the years, the GFC along with a few of its partners have provided support, engaged in various CMRV outreaches, and training exercises across the country. In 2014 and 2017, communities from the NRDDB and Konashen have received training in CMRV related activities. The GFC, in continuing its support to this process has initiated a program in phase 2 to train representatives from 23 Indigenous communities across the country in CMRV. So far, 23 villages with over 37 individuals trained. The training involved both practical and theoretical aspects of the National MRV. Participants were provided with an overview of the national MRV system, past work done on CMRV and taught on procedures associated with the mapping and identification of the various drivers of deforestation and degradation. Practical exercises included training on the use of GPS (waypoint marking, tracking), compass and map reading. In addition, test areas mapped for various drivers e.g. shifting cultivation, fire, mining were visited. Following each engagement, the participants were asked to utilize some of the skills gained from the training to facilitate some field verification exercises on behalf of the Commission, which is intended to feed into the national MRVS. So far, the response has been positive with just a handful of communities remaining to submit.
2016 (YEAR 6) OBS 1 **Requirement**: Overall Guyana MRV programme **Potential Non-Compliance**: Potential misunderstanding by stakeholders on how the applied MRV methodology is driven by existing experience and knowledge within the programme	Since 2009 GFC has progressively improved the MRVS to recognize changes in data availability, improvements in sensor's spatial and temporal resolution. It is envisaged that GFC will continue to take advantage of new technologies and as appropriate add these to the MRVS. As new elements are added these are rigorously tested	Improvements to the MRV have been ongoing and SOP have been updated to reflect the improvements in sensor technology and availability. Improvements are progressive and in this reporting period the GFC team have focused on updating the SOP around the use of Sentinel data for forest change detection and use of a sample-based approach for providing estimates of degradation.

Objective evidence: Currently the programme is still modifying its methodology to incorporate the changes away from RapidEye and Geovantage. Although this may have impact in actual data there is a need to verify that methodology remain consistent with the build-up experience to date. **Obs to be verified during next audit**	by GFC to ensure that they meet the established MRVS reporting standards and interim measures. Compliance against these standards and measures is verified annually through the accuracy assessment and audit process. In 2018 GFC plan to update the existing SOP to reflect the changes incorporated to ensure that any new methods adopted are well described and able to be replicated. Some amount of structural modifications will also be made to the Year 7 Report to focus more on the current work and approaches whilst showing that the methods applied remain consistent.	The reporting format has been revised with the intention of improving its readability.

Appendix 3

Land Use Class Description

IPCC Land Use Categories

The following land use classes will be used as the MRVS is developed. These are briefly introduced below and currently are based on the default categories as defined by IPCC guidelines.

1. Forest land

- This category includes all land with woody vegetation consistent with thresholds used to define forest land in the national GHG inventory, sub-divided into managed and unmanaged, and also by ecosystem type as specified in the *IPCC Guidelines*3. It also includes systems with vegetation that currently fall below, but are expected to exceed, the threshold of the forest land category.
- During the MRVS development a stratification map will be produced. This builds on existing work undertaken at GFC in 2001 by consolidating the existing forest strata into six classes (see below).

2. Grassland

- This category includes rangelands and pasture land that is not considered as cropland. It also includes systems with vegetation that fall below the threshold used for the forest land category that are not expected to exceed, without human intervention, the threshold used in the forest land category. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvi-pastural systems, subdivided into managed and unmanaged consistent with national definitions.

3. Cropland

- This category includes arable and tillage land, and agro-forestry systems where vegetation falls below the thresholds used for the forest land category, consistent with the selection of national definitions

4. Wetland

- This category includes land that is covered or saturated by water for all or part of the year (e.g., peatland) and that does not fall into the forest land, cropland, grassland or settlements categories. The category can be subdivided into managed and unmanaged according to national definitions. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.

5. 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 the selection of national definitions

6. Other land

- This category includes bare soil, rock, ice, and all unmanaged 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.
- The following table provides an overview of the preliminary land use classification for Guyana.

Guyana Land Use Classes

Land Use	Land Use Type	2001 Classes	Map Classes
Forest Land	Mixed forest	1 to 1.4 & 1.8	Class 1
	Wallaba/Dakama/Muri Shrub Forest Swamp/Marsh forest	2 to 2.6 3.1 to 3.3	Class 2 Class 3
	Mangrove	4.1	Class 4
	Savannah >30% cover	5, 6	Class 5
	Montane & steep forest	1.5 -1.7[20], 7.1, 7.2. 8.1	Class 6
	Plantations	Locations in GFC's GIS	Area insignificant
Grassland	Savannah <30% cover	Grouped as non-forest	Class 15
	Grassland		
Cropland	Cropland		Class 17
	Shifting Agriculture		Class 22
Wetland	Wetland open water		Classes 18 and 19
	Herbaceous wetland		
Settlements	Settlements		Class 20
Other land	Other land		Class 18 and 30

Documentation for Notation keys used:

Afforestation/reforestation activity in Guyana occurs through regeneration of abandoned mining sites primarily. These areas are not monitored at present and have been reported as not estimated (NE).

There is no human induced conversion from forest to grasslands or forest to wetlands in Guyana (NO).

Area in non-forest land uses (area remaining and land use changes) have not been estimated in this reporting period (NE).

Forest Type Mapping by GFC

● In 2001 a series of detailed forest vegetation maps was produced for the entire State Forest Area. These combine various existing vegetation maps with new interpretations of aerial photographs and satellite radar imagery (JERS-1), coupled with analysis of field data collected during the Commission's forest inventories. The resulting maps are to be made available to forest concession holders to assist with their forest management planning activities.

● Secondly, a less detailed map has been produced for the entire country, based mainly on national soil survey data made available by the National Agricultural Research Institute (NARI). This map will be available to all of the Commission's stakeholders.

● To complete this work GFC's Forest Resource Information Unit drew on the skills and experience of former Tropenbos Program Manager, Dr Hans ter Steege. Dr ter Steege has extensive knowledge of Guyana's diverse forest vegetation types and specialist skills in digital cartography.

National Vegetation Map of Guyana

● Produced for the Guyana Forestry Commission and Dr Hans ter Steege, University of Utrecht, Netherlands, in collaboration with the GFC Forest Resources Information Unit 2001.

Methods

- The following provides a summary of the process used to create these maps.
- The National Vegetation Map is based on the GINRIS soil map (1:1 000 000) which was kindly provided for this purpose by the NRMP. Although problems were encountered with the accuracy of the National Map, it was felt that at the 1:1 000 000 scale they were of less importance and that using the GINRIS basemap would ensure compatibility among National Theme Maps.
- In making the National Map, use was made of the usually strong correspondence between major forest and soil types, realizing that the soil map is in fact an interpretation of vegetation cover. Based on the strong correspondence a first forest type was assigned to each of the soil classes. Problems then arose in a few areas.
- For instance, white sands are covered by Wallaba forest, Dakama forest, Muri scrub, or grass, and peat soils may have palm swamp, broadleaved swamp forest, or open swamps.
- To improve the interpretation of the forests on white sand first a digital combination of low forest of Vinks NE-Guyana map (Vink 1957) with the white sands of the soil map was created. Low forest on white sand was classified as Dakama. Then a combination of the new 'Vegetation map' was made with the dry and wet savannah themes of Vink. Dry savannah on white sand was classified as Muri scrub/grassland, dry savannah on other soil as (intermediate) savannah, wet savannah on peat was classified as open coastal swamp, on white sand as wet savannah/muri scrub on white sand, the other as open swamp. Because in the two maps that were intersected edges of similar vegetations are not identical, a great number of small 'stray' polygons were created that had to be manually removed.
- For central and North West Guyana, FIDS maps were used to classify the various white sand areas. In a few cases white sand polygons were split into the different types of forest, especially in central Guyana. Large stretches of wet forest exist in south Guyana. These were digitized into the National Map on the basis of the regional FIDS maps. In other cases, large forest areas classified as wet forest were reclassified into mixed forest in accordance with FIDS coverage.

- In the southwest savannah cover from the FIDS maps was superimposed. However, the level of detail was much greater than the other parts of the map and it was decided to use the savannah interpretation of Huber et al (1995) for this vegetation type, which is nearly identical. In the Pakaraimas, also the interpretation of Huber et al. (1995) was used for the open non-forest vegetation types. The forests in this area were not classified on the basis of soil but rather on altitude. Submontane forest from 500-1500 m and montane forest above 1500 m. These areas were obtained by intersecting the vegetation map with altitudes obtained from a digital elevation model of Guyana.

- Several draft versions were produced and discussed. At close inspection it became clear that even at the 1:1 000 000 scale there were inconsistencies between the vegetation map and the river base map[21]. However, as the vegetation map appeared to be correct in most instances no further changes were made.

- A descriptive legend of the map was produced based on ter Steege and Zondervan (2000), Fanshawe 1952, Huber et al 1995 and FIDS reports (de Milde and de Groot 1970 a-g) (see below).

- The map was finally produced in three sizes, A4 (letter), A3 (tabloid) and A0 (1:1 000 000). TIFF & JPG versions for the GFC web page were also produced (See The Map in Appendix 3).

Provisional Forest Types

- The following forest types have been grouped into 1 of 6 forest classes. This classification will form the basis of the forest carbon stratification map. This map groups forest types according to their carbon storage potential and identifies those forest areas under threat of degradation or deforestation. The intention is to use the map to assist with the design of the carbon monitoring plot network.

Class 1: Mixed rainforest

The following mixed forest classes have been merged to form a single class

1. Mixed rainforests on Pleistocene brown sands in central to NW Guyana

Forests on the brown sands of the Berbice formation are almost invariably characterised by species of *Eschweilera* and *Licania*. Species, which may be locally dominant are *Eschweilera sagotiana, E. decolorans, E. confertiflora, Licania alba, L. majuscula, L. laxiflora, Chlorocardium rodiei, Mora gonggrijpii, Alexa imperatricis, Swartzia schomburgkii, S. leiocalycina, Catostemma commune, Eperua falcata, Pouteria guianensis, P. cladantha, Aspidosperma excelsum* and *Pentaclethra macroloba*. Mono-dominance is common in forests on brown sands in central Guyana and tends to get less in an eastward direction. Towards the east in Guyana and across the border in Suriname the species mix changes slightly and the more common species are *Goupia glabra, Swartzia leiocalycina, Aspidosperma excelsum, Manilkara bidentata, Terminalia amazonica, Parinari campestris, Vochysia surinamensis, Emmotum fagifolium, Humiria balsamifera, Catostemma fragrans, Hymenaea courbaril, Licania densiflora* and *Eperuafalcata.* The latter forest on light brown

21The rivers base layer has subsequently been improved as part of the MRVS implementation

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sands extends south towards the Kanuku mountains, where it grades into semi-evergreen mixed forest of the Rupununi district (1.4).

2. Mixed rainforests of the Northwest District

The dry land forests of the Northwest District of Guyana and eastern Venezuela are characterised by a high abundance of *Eschweilera sagotiana, Alexa imperatricis, Catostemma commune, Licania* spp. and *Protium decandrum*. These species are found abundantly in almost every dry land forest type in this region. Poor mono-dominant stands of *M. gonggrijpii* are found on the (probably) more clayey soils between the Cuyuni and Mazaruni.

3. Mixed rainforest in the Pakaraimas

Dicymbe altsonii (endemic to Guyana) is the main characteristic and one of the most common canopy species in the 'mixed forests' of the lowland eastern Pakaraima Mountains. *Dicymbe* may be absolutely dominant over large areas. Co-dominants are *Eperua falcata, Eschweilera sagotiana, E. potaroensis, Mora gonggrijpii, Alexa imperatricis, Licania laxiflora, Swartzia leiocalycina, Vouacapoua macropetala* and *Chlorocardium rodiei*. *Eschweilera potaroensis,* an endemic of this region, may be co-dominant in forests around the confluence of the Potaro and Essequibo Rivers.

4. Mixed rainforest in south Guyana

Dry (deciduous) forest types fringe the savannahs in south Guyana. Most of the dry forest stands show high presence of *Goupia glabra, Couratari, Sclerolobium, Parinari, Apeiba, Peltogyne, Catostemma, Spondias mombin* and *Anacardium giganteum.* South of the Cuyuwini river to east of the New River the forest is characterised by a high presence of *Geissospermum sericeum*, *Eschweilera* cf. *pedicellata, Lecythis corrugata, Pouteria coriacea* and *Pourouma* spp. Several other taxa, characteristic of late secondary forest, have fairly high presence this region: *Parkia, Ficus, Sclerolobium, Trichilia, Parkia, Parinari* and *Goupia*. *Eperua falcata(rugiginosa?), Pterocarpus* and *Macrolobium acaciifolium* are common in forests along the rivers in this area.

5. Complex of mixed forest and swamp forest in south Guyana

Large stretches of this type occur in SW Guyana between the upper reaches of the Oronoque and New Rivers. The forest is characterised by high occurrence of *Geissospermum, Pterocarpus* and *Eperua*.

Class 2: Wallaba/Dakama/Muri Scrub Forest

These are forests located on excessively drained white sands and include the following classes;

1. Clump wallaba forest

Clump wallaba forest, dominated by *Dicymbe altsonii* and *D. corymbosa* with co-dominance of *Eperua, Catostemma* and *Hyeronima* is found on excessively drained white sand ridges in the Mazaruni basin.

2. Clump wallaba/wallaba forest

In the upper Mazaruni basin *Dicymbe corymbosa* and *Eperua* spp. dominate nearly all forests on white sand. *Chamaecrista* and *Micrandra* are common co-dominants.

3. Wallaba forests (dry evergreen forest)

Dry evergreen forest on bleached white sands (albic Arenosols) occurs from the Pakaraima escarpment, through central Guyana and northern Suriname into a small narrow portion of French Guiana. *Eperuafalcata* and *E. grandiflora* are strongly dominant and may form, alone or together, more than 60% of the canopy individuals. Common other species in the canopy layer are *Catostemma fragrans, C. altsonii, Licania buxifolia, Talisia squarrosa, Formosacousinhood, Eschweilera corrugata, Aspidosperma excelsum, Terminalia Amazonia, Chamaecrista adiantifolia, Chamaecrista apocouita, Swartzia* spp., *Dicymbe altsonii* (west Guyana only), *D. corymbosa* (ibid.), *Manilkara bidentata* (Pomeroon-Waini water divide) and *Pouteria*.

4. Forests on white sands in south Guyana

Very small patches of forests on white sand are found in south Guyana. In SW. Guyana *Eperua* is the most commonly found tree genus.

5. Dakama forest

Forest dominated by *Dimorphandra conjugata* (Dakama forest) is common on the higher parts of waterdivides from central Guyana to western Suriname. This forest type is characterised by very high standing litter crop (up to 800 ton/ha, Cooper 1982) and is very fire prone. Other species, characteristic for Dakama forests, are *Eperua falcata, Talisia squarrosa, Emmotum fagifolium* and *Swartzia bannia*. *Humiria balsamifera* (Muri) co-dominates the degraded Dakama forest and Dakama-Muri scrub with *Dimorphandra*.

6. Muri scrub/white sand savannah

In areas where fires are very regular or in flood-prone areas Dakama forest degrades into Muri-scrub, dominated by *Humiria* balsamifera. Other common species in this scrub are *Swartzia bannia, Clusia fockeana, Licania incana, Bombax flaviflorum, Ocotea schomburgkiana, Trattinickia burserifolia, Ternstroemia punctata* and *Byrsonima crassifolia*.

Class 3: Swamp/Marsh forest

This class combines Swamps, swamp and marsh forests

2. **Open swamps**

Herbaceaous and grass swamps in brackish and sweet water with *Cyperus, Montrichardia, Commelina,* Paspalum and *Panicum.*

3. **Marsh Forest**

Mora excelsa forms extensive stands along the rivers on alluvial silt up to the confluence of Rupununi and Rewa rivers. Canopy associates of the *Mora* forest are *Carapa guianensis, Pterocarpus officinalis, Macrolobium bifolium, Eschweilera wachenheimii, E. sagotiana, Clathrotropis brachypetala, C. macrostachya, Eperua falcata, E. rubiginosa, Catostemma commune, C. fragrans, Pentaclethra macroloba, Vatairea guianensis, Symphonia globulifera, Terminalia dichotoma* and *Tabebuia insigni*.

The rivers in the savannah area are bordered by gallery forest, which is inundated during part of the year. Trees species such as *Caryocar microcarpum*, *Macrolobiumacaciifolium*, *Senna latifolia*, *Zygia cataractae* and *Genipa spruceana* occur along all the rivers in S-Guyana. In the open savannah *Mauritia* is a dominating element in the landscape.

4. Coastal swamp forest

In permanently flooded, flat plains in the present coastal zone a low swamp forest is found. Characteristic species are *Symphonia globulifera, Tabebuia insignis/fluviatilis, Pterocarpus officinalis* and *Euterpe oleracea*. Species that can become locally dominant in this forest type in Guyana are

Pentaclethra macroloba, Vatairea guianensis, Pterocarpus officinalis and *Virola surinamensis*. *Manicaria saccifera* is commonly found as a narrow belt along rivers. More inland the duration of flooding is less pronounced and forest composition is slightly different. Common species here are *Symphonia globulifera, Virola surinamensis, Iryanthera* spp., *Pterocarpus officinalis, Mora excelsa, Pachira aquatica, Manicaria saccifera* and *Euterpe oleracea*.

Class 4: Mangrove forest

1 Mangrove forests

Mangrove forests occur in a narrow belt of a few kilometres wide along the coast and along the banks of the lower reaches of rivers. The mangrove forest along the coast consists mainly of *Avicennia germinans*, with occasional undergrowth of the salt fern, *Acrostichum aureum*. *Rhizophora* occupies the more exposed, soft silts in river mouths and shores. Where the water is distinctively brackish a third mangrove species can be found, *Laguncularia racemosa*. Further inland mangrove species mix with *Euterpe oleracea* palms and such trees as *Pterocarpus officinalis.*

Class 5 Savannah >30% forest cover

This class contains forest with lower volume that still meets the national definition of forest. Those areas that do not have been excluded and are treated as non-forest

1. **Lowland shrub and grass savannah**

Lowland grass savannahs

Lowland savannahs, dominated by the grasses *Trachypogon* and *Axonopus* and the shrubs *Curatella* and *Byrsonima* are found mainly in the southern parts where the Pakaraima Mts. border the Rupununi and Rio Branco savannahs and are also scattered throughout the western part of the region. At slightly higher altitude *Echinolaena* and *Bulbostylis* are also typical. Savannahs on white sands have more sedges and also include more genera typical of the alpine meadows.

Lowland shrub savannah

Fire-climax savannah vegetation, which contains characteristic species such as: *Curatella americana, Byrsonima crassifolia, Byrsonima coccolobifolia, Antonia ovata, Palicourearigida*, *Tibouchina aspera* and *Amasonia campestris*. The main grasses belong to the genera *Trachypogon, Paspalum, Axonopus* and *Andropogon* and the main sedges to the genera *Rhynchospora* and *Bulbostylis*

Highland open vegetation types

2. **Xeromorphic scrub**

Xeromorphic scrub is found throughout the Pakaraimas. *Humiria, Dicymbe, Clusia* and *Dimorphandra* are typical genera of this vegetation type.

3. **Tepui scrub**

At high altitudes tepui scrub is found - in Guyana only on Mts. Roraima and Ayanganna. Most characteristic genera are *Bonnetia, Schefflera, Clusia,* and *Ilex*.

4. **Upland savannah**

Uplands savannahs are very similar in composition to lowland savannahs. The upland savannahs on white sands have more sedges and also include more genera typical of the alpine meadows.

5. **Alpine meadows**

The alpine meadows are also a very rich and distinct formation within the Guyana Highlands. In Guyana it is only found in the upper reaches of the Kamarang R., Mt. Holitipu and Lamotai Mt., both along the lower Kamarang R. Grasses are usually not dominant but are replaced by *Stegolepis*spp.. Other common genera include *Abolboda, Xyris, Orectanthe, Chalepophyllum, Lagenocarpus* and *Brocchinia*.

Class 6: Montane & steep forest

This class groups forests found at higher altitudes and on steep slopes.

1. **Submontane forest of south Guyana**

Submontane forest is found in the Acarai Mts from 600-800 m. The forest is quite similar to the forest in the Kanuku Mts. with *Centrolobium, Cordia, Peltogyne, Vitex, Inga, Protium, Tetragastris, Parkia, Pseudopiptadenia, Spondias* and *Genipa.* Forests on the mountain tops are dominated by Myrtaceae and *Clusia* on Sierra do Acarai.

2. **Rain forest and evergreen forest on steep hills**

Throughout the central and North West Guyana dolerite dykes penetrate through the sediments. These dykes are often covered with lateritic soils that are rocky, gravelly or clayey. There is little quantitative information available on the forest composition on these soils, except for central Guyana. Common trees are *Eschweilera* spp., *Licania* spp., *Swartzia* spp., *Mora gonggrijpii*, *Chlorocardium rodiei*. On lateritic soils in central Guyana a local endemic, *Vouacapoua macropetala*, forms extensive stands with *Eschweilera sagotiana, Licania laxiflora, Sterculia rugosa, Poecilanthe hostmanii* and *Pentaclethra macroloba*. On the rocky phase of laterite, a low shrubby forest is found. Myrtaceae (*Eugenia* spp., *Calycolpes, Marlierea*) and Sapotaceae (*Ecclinusa, Manilkara*) dominate here. Because of the occurrence of steep slopes landslides are not uncommon on laterite ridges. Often liana forest is encountered on such landslides. Pioneers, such as *Cecropia* spp., *Schefflera morototonii, Jacaranda copaia* and *Pentaclethra macroloba* are also abundantly present on such sites in central Guyana.

3. **Forest on steep hills in Pakaraimas**

Not much is known about specific composition of this forest. The composition, though, is quite similar to mixed rain forest (1.3), with *Dicymbe altsonii, Mora gongrijppii* and *M. excelsa*. In the forests along the foothills of the southern Pakaraima Mts., *Cordia/Centrolobium* forest is found (see 1.7).

4. **Forest on steep hills in south Guyana**

Forests along the foothills and middle slopes of the Kanuku Mts. are characterised by *Cordia alliodora, Centrolobium paraense, Apeiba schomburgkii, Acacia polyphylla, Pithecellobium* s.l., *Peltogyne pubescens, Manilkara* spp., *Cassia multijuga* and *Vitex* spp. *Manikara* dominates the higher areas. Low forest/woodland with *Erythroxylum* and *Clusia* are on slopes with bare rock.

The South Rupununi Savannah, in particular, has rock outcrops with a typical ‘rock vegetation’. The species present on the smallest rock plates are: *Cereushexagonus, Melocactus smithii, Cnidoscolus urens, Cyrtopodium glutiniferum* and *Portulacasedifolia*.

5. **Submontane forests of the Pakaraima uplands**

Submontane forests, from 500 – 1,500 m, are fairly similar in composition to the lowland forests surrounding them, with species from *Dicymbe, Licania, Eschweilera, Mora, Alexa* being common to dominant. On white sands *Dicymbe, Dimorpandra, Eperua* and *Micrandra* are the most characteristic genera. Dry submontane forest is characterised by *Dicymbe jenmanii* (endemic to the Kaieteur region), *Moronobea jenmanii, Humiria balsamifera, Chrysophyllum beardii, Tabebuia* spp., *Anthodiscus obovatus, Saccoglottis, Dimorphandra cuprea* and *Clusia* spp.

6. **Upper montane forests of the Pakaraima highlands**

Upper montane forests (1,500-2,000 m) are only found on the high table mountains, such as Mts. Roraima, Ayanganna and Wokomung. Typical highland genera such as *Bonnetia tepuiensis, Schefflera, Podocarpus, Magnolia* and *Weinmannia* are found here. Low scrubs with Melastomataceae, Rubiaceae, *Ilex* and *Podocarpus steyermarkii* are also expected.

Non-forest Classes

In 2014 the non-forest areas were mapped from high-resolution satellite images and further divided into the following IPCC classes.

- Cropland
- Grassland
- Wetland and open water
- Settlements
- Other land

Literature cited and/or used:

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Appendix 4

Accuracy Assessment Report

Accuracy Assessment Report Year 9 (2019) Guyana REDD+ MRVS

Durham University

Assessment Year 2019

ACCURACY ASSESSMENT REPORT GUYANA REDD+ MRVS

11 November 2020

Version 3.3

Guyana REDD+ Monitoring Reporting and Verification System (MRVS)

Accuracy Assessment Report

Year 9

Daniel Donoghue, Department of Geography, Durham University

Nikolaos Galiatsatos and Matthew Wiecek

EXECUTIVE SUMMARY

1. This report was commissioned by Indufor Asia Pacific Ltd for the Guyana Forestry Commission (GFC) in support of a system to Monitor, Report and Verify (MRVS) for forest resources and carbon stock changes as part of Guyana's engagement in the UN Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation Plus (REDD+). The scope of the work was to conduct an independent assessment of deforestation, forest degradation and forest area change estimates for the period January–December 2019. Specifically, the terms of reference asked that confidence limits be attached to forest area estimates.

2. The methods used in this report follow the recommendations set out in the GOFC-GOLD guidelines to help identify and quantify uncertainty in the level and rate of deforestation and the amount of degraded forest area in Guyana over the period January-December 2019 (Interim Measures Period – Year 9). NASA Landsat, ESA Sentinel-2, Planet-PlanetScope, and Aeroptic (aka GeoVantage) imagery was used to assess change.

3. A change analysis using two-stage stratified random sampling design was conducted to provide precise estimates of forest area. Three strata were selected according to "risk of deforestation". The drivers (cause) of change were identified from expert image interpretation of high spatial resolution satellite imagery.

4. The estimate of the total area of change in the 12-month Year 9 period from forest to non-forest and degraded forest to non-forest is **8,202 ha**, with a standard error of 1,413 ha and a 97.5% confidence interval (5,433 ha; 10,972 ha).

5. The estimate of the annual rate of deforestation that occurred over the Year 9 (12 month) period is **0.0645 %** with a standard error of 0.00789% and a 97.5% confidence interval (0.0491%; 0.0800%).

6. The estimate the total area of change in the 12-month Year 9 period from forest to degraded forest between Y8 and Y9 is **9,883 ha**, with a standard error of 1,614 ha and a 97.5% confidence interval (6,720 ha; 13,046 ha).

7. Three changes, totalling 2.00 ha were detected within the boundary of the Intact Forest Landscape. These are interpreted as caused by shifting agriculture.

   PSU – 167; SSU - 115, Forest-Degradation, Shifting cultivation, 0.45 ha

   PSU – 324; SSU - 211, Forest-Degradation, Shifting cultivation, 0.80 ha

   PSU – 324; SSU - 231, Forest-Degradation, Shifting cultivation, 0.75 ha

8. The sample-based estimates for land cover class areas for December 2019 are as follows:

   a. Forest = 18,447,535 ha

   b. Degraded forest = 282,763 ha

   c. Non-forest = 1,985,182 ha

   d. Note that the total area of Guyana in the sample-based estimates is 1.5% different from the GIS-based area because the stratification uses a 5 km by 15 km grid that intersects with the national boundary polygon.

1 AREAS OF ACTIVITY

1. To assess Year 9 deforestation, taking note of IPCC Good Practice Guidelines and GOFC/GOLD recommendations.

2. To outline a methodology for accuracy assessment, including an outline of the (1) sample design, (2) response design, and (3) analysis design[1]. For the design component, reference data to be used should be identified, and literature cited for methods proposed. The design must ensure the representativeness of the scenes selected for analysis. The sampling specifications used must be stated.

3. To support independent verification of the REDD+ interim measures and national estimates (Gross Deforestation, Intact Forest Landscape, Extent of Degradation associated with new infrastructure, and emissions from forest fires – referred to in the context of the Joint Concept Note between the Governments of Guyana and the Kingdom of Norway), including initial interim results, with a priority being on gross deforestation and the associated deforestation rate (i.e. change over time) and assessing their error margins/confidence bands, and providing verification of the deforestation rate figure for Year 9 as an area change total and by driver.

4. To conduct an independent assessment of the deforestation mapping undertaken by the Guyana Forestry Commission and comment on the attribution of types of changes, e.g. agriculture, mining, forestry and fire. Make recommendations that can be used to improve efforts in the future. This assessment should be done with the recognition that "best efforts" will have to be applied in situations where there is a challenge in terms of availability of reference data. The error analysis should highlight areas of improvement for future years to decrease uncertainties and maintain consistency. Additionally, the assessment should also consider the quality of how missing data were treated for national estimation (if this is observed to be the case). It is required that real reference data is used either from the ground, ancillary data (e.g. for concessions), and/or high-resolution imagery.

5. For 2019 (Year 9), forest degradation was not interpreted and mapped from satellite imagery to create a 'forest degradation' GIS layer. Instead, forest degradation was estimated from a two-stage statistical sample with randomisation of the first stage.

6. To use the sample data to estimate the extent of forest degradation for Year 9 for the whole of Guyana and to report error margins/confidence bands, and provide verification of the forest degradation rate for Year 9 as an area change total and by driver. This assessment is done with the recognition that "best efforts" will have to be applied in situations where there is a challenge in terms of availability of reference data. The discussion section highlights areas of improvement for future years to decrease uncertainties and maintain consistency. Additionally, the assessment considers the effect of missing data for national estimation. It is required that real reference data are used either from the ancillary map data (e.g. for concessions), and the data acquired specifically for accuracy assessment, including high spatial resolution imagery.

[1] GOFC GOLD Sourcebook (2016) Section 2.7.

2. AREA REPRESENTATION

The total land area for Guyana is 21,123,486 hectares, calculated from the national boundary GIS Shapefile provided by GFC in 2014. The digital maps contained in the report were obtained from the Guyana Forestry Commission (GFC), and the Guyana Land and Surveys Commission (GL&SC). All maps use the WGS 84 datum and are projected to UTM Zone 21N.

2.1 Forest Area

Land classified as **forest** by GFC follows the definition from the Marrakech Accords (UNFCCC, 2001). Under this agreement, forest is defined as: a minimum area of land of 1.0 hectare (ha) with tree crown cover (or equivalent stocking level) of more than 10-30% with trees with the potential to reach a minimum height of 2-5 m at maturity in situ.

In accordance with the Marrakech Accords, Guyana has elected to classify land as forest if it meets the following criteria:

- Tree cover of minimum 30%
- At a minimum height of 5 m
- Over a minimum area of 1 ha.

The forest area was mapped by GFC by excluding non-forest land cover types, including water bodies, infrastructure, mining and non-forest vegetation. The first epoch for mapping is 1990, and from that point forward land cover change from forest to non-forest has been mapped and labelled with the new land cover class and the change driver. GFC have conducted field inspections and measurements over a number of non-forest sites to verify the land cover type, the degree of canopy closure, the height of the vegetation and its potential to regenerate back to forest.

The assessment in this report does not look at the GFC mapping; it is an independent analysis. For reference, we note that the Y9 mapping process involves a systematic review of Landsat and Sentinel data. Details of the GFC Y9 mapping are explained in the Standard Operating Procedure (SOP) for Forest Changes Assessment. Areas mapped as deforested during the period 1990 - 2009 are used to establish the *deforestation rate* for the benchmark reporting period.

The purpose of this report is to build upon the estimates of deforestation established for the Norway-Guyana agreement and to quantify the precision of the estimate of deforestation and forest degradation observed in the Year 9 period. A second task is to identify the processes (drivers) that are responsible for deforestation and degradation, and where possible to estimate the precision of area estimates.

3 SAMPLING DESIGN FOR VERIFYING YEAR 9 FOREST CHANGE

3.1 Change sample design

The Year 9 assessment for gross deforestation and forest degradation in Guyana used a two-stage stratified random sampling design. Stratification was based on past patterns of deforestation from Period 1 (1990) through to Year 8 (Dec 2018), where the primary drivers of land cover change are alluvial gold mining, logging, anthropogenic fire, agriculture and associated infrastructure including roads.

The assessment is guided by established principles of statistical sampling for area estimation and by good practice guidelines (GOFC-GOLD, 2016, UNFCCC Good Practice Guidance (GPG) and Guidelines (GL)). The purpose of stratification is to calculate the within-stratum means and variances and then calculate a weighted average of within-stratum estimates where the weights are proportional to the stratum size. Stratification will reduce the variance of the population parameter estimate and provide a more precise estimate of forest area and forest area change than a simple random sample.

The sampling design and the associated response design are influenced by the quality and availability of suitable reference data to verify interpretations of the GFC Forest Area Assessment Unit (FAAU). In Year 3, 4 and 5 the GFC Forest Area Assessment Unit (FAAU) used RapidEye as the primary mapping tool and so the whole country was mapped from multiple looks of orthorectified RapidEye resampled data to 5m pixel size. For Year 6, 7, 8 and 9 the GFC Forest Area Assessment Unit (FAAU) used Landsat and Sentinel-2 imagery as the primary mapping tool. The Y9 response design used PlanetScope, GeoVantage, and Sentinel-2 imagery as an appropriate fine-resolution source of data to validate land cover changes in all but the low risk of change areas where the assessment was based on interpretation of Sentinel-2 and Landsat data.

For Guyana, the established MRV protocol is for the entire country to be remapped on an annual basis, and so a forest change map will be generated from wall-to-wall coverage of satellite data. To assess the accuracy of land cover change statistics, an independent reference sample is needed. The focus of the independent assessment places emphasis on inference that is optimising the precision of the change estimates. Therefore, we generate an *attribute change sample* as the reference data to estimate gross deforestation and forest degradation area.

A change sample for reference data will:

a. have a smaller variance than an estimate of change derived from two equivalently sized sets of independent observations, provided the correlation coefficient is positive;

b. increase the precision of the change estimate by virtue of the reduction of the variance of estimated change;

c. despite its obvious advantage, encounter practical and inferential problems if resampling the same areas proves difficult, or if, as time passes, the sample or the stratification of the sampling scheme, is no longer representative of the target population (Cochran 1963; Schmid-Haas, 1983);

d. for the same sample size, require no additional resource but allow both map accuracy and area estimation to be performed;

e. be an alternative to wall-to-wall mapping and may be preferred because of lower costs, typically smaller classification error, and rapid reporting of results;

f. have value when assessing any additional forest change map product such as the University of Maryland Global Change map 2000-2018 (Galiatsatos *et al.*, 2020) or any annual updates published by Maryland.

The desired goal of this validation is to derive a statistically robust and quantitative assessment of the uncertainties associated with the forest area and area change estimates.

Several factors potentially impact on the quality of forest mapping (GOFC GOLD, 2016), namely

i. The spatial, spectral and temporal resolution of the imagery

ii. The radiometric and geometric pre-processing of the imagery

iii. The procedures used to interpret deforestation, degradation and respective drivers

iv. Cartographic and thematic standards (i.e. minimum mapping unit and land use definitions)

v. The availability of reference data of suitable quality for evaluation of the mapping

The Standard Operating Procedure for Forest Change Assessment (GFC and Indufor Ap Ltd, 2015) outlines approaches used to minimise sources of error following IPCC and GOFC-GOLD good practice guidelines as appropriate.

The verification process used follows recognised design considerations in which three distinctive and integral phases are identified: response design, sampling design, and analysis and estimation (Stehman and Czaplewski, 1998).

3.2 Response Design

Table 3.1 summarises the data available to validate the deforestation and forest degradation change estimates for 2019, that is from the end of 2018 to the end of 2019 (year 9). It also specifies the areal coverage of the imagery used for change assessment.

Table 3.1: Data sources used for Validation (Application: Forest Change Assessment)

Dataset used	Provider	Sensor	Spectral Range	Date of Acquisition	Pixel size (m)	Area (ha)	% of Guyana
RGB and CIR aerial photography	GeoVantage	Four channel multi- spectral sensor	Visible and NIR	Oct 18 Sept 19	0.25-0.60	90,327 90,906	0.42 0.43
PlanetScope	Planet	Four channel multispectral sensor	Visible and NIR	Aug-Dec 18	3	1,279,067	6.05
Sentinel-2	ESA	Four channel multispectral sensor (at 10m)	Visible and NIR	Aug-Dec 18 Oct-Dec 19	10	19,347,200	91.5
Landsat	USGS	ALI	Visible and NIR	Aug-Dec 18 Aug-Dec 19	30	21,127,762	100

Table 3-2 – Year 8 Deforestation and Forest Degradation Assessment Exclusions

Reference	Criteria
1	Land use change that occurred prior to 1 January 2019 or after 31 December 2019
2	Roads less than a 10 m width.
3	Naturally occurring areas – i.e. water bodies
4	Cloud and cloud shadow

The following sections provide a summary of the datasets available and the way they were used for the accuracy assessment.

3.3 GeoVantage

GeoVantage is an aerial imaging camera system mounted externally to a light aircraft, in our case a Cessna 172. The camera system comprises a multispectral sensor, capturing red, green, blue, and near infrared spectral bands. The spatial resolution of the imagery depends on the altitude that the data is captured. For this project the operating altitude ranged from 2000 to 5000 ft, and the resultant imagery ranged from a pixel size of 25 cm to 60 cm. Deriving a change sample-based of aerial imagery over tropical forests is a challenging task given the constraints of weather, cloud cover and navigating the exact same flight path as the previous year. GeoVantage imagery was acquired in September-October 2018 over approximately 106 sample areas in mostly High and Medium Risk strata. The acquisition was repeated in August-September 2019, again acquiring imagery in mostly High and Medium Risk strata for 109 sample areas. These very high resolution images are helpful for confirming the status of sample areas at the end of the assessment period, particularly for identifying areas of forest degradation because the area of forest loss can be measured easily from the imagery using GIS tools.
The GeoVantage data were acquired by Agrisat S.A, who also performed image mosaicking, rectification and colour balancing. The majority of GeoVantage imagery for 2018 and 2019 were of good geometric quality; some frames exhibited saturation which made land cover interpretation difficult.

3.4 PlanetScope

PlanetScope data were downloaded from the Planet Explorer Beta GUI tool that can be used to search Planet's catalogue of imagery, view metadata, and download full-resolution images[2].

PlanetScope is a swarm of more than 120 micro (10cm x 10cm x 30cm) satellites orbiting the Earth at 475 km altitude, and offering the capability of daily revisit. The first three generations of Planet's optical systems are referred to as PlanetScope 0, PlanetScope 1, and PlanetScope 2. PlanetScope 2 has a 4-band multispectral imager (blue, green, red, near-infrared) with a Ground Sample Distance of 3.7m. The radiometrically-corrected orthorectified product (that was used in this project) is resampled to 3m.

The radiometric resolution is 12-bit, and sensor-related effects are corrected using sensor telemetry and a sensor model. The bands are co-registered, and spacecraft-related effects are corrected using attitude telemetry and best available ephemeris data. Data are orthorectified using GCPs and fine DEMs (30 m to 90 m posting). PlanetScope imagery was found to be of mostly good radiometric and geometric quality but was only available for 2018.

[2] http://www.planet.com/explorer (last accessed: December 2018)

3.5 Sentinel-2

The Sentinel satellites are launched by ESA in support of the EU Copernicus programme. Sentinel-2A and -2B carry an innovative wide swath high-resolution multispectral imager with 13 spectral bands primarily intended for the study of land and vegetation. The bands vary in spatial resolution, with four bands (Blue, Green, Red, and NIR) at 10m, six bands (four in NIR and two in SWIR) at 20m, and three bands (Blue, NIR and SWIR) at 60m. Although data are processed to different levels, only Level-1C (orthorectified product) is provided to users. The Sentinel Toolbox[3] can then be used to generate a Level-2A (Bottom of Atmosphere reflectance product). Although the pixel size of 10m is not as fine as PlanetScope, the Sentinel-2 radiometric resolution was found to be superior, thus providing a clearer (but not finer) land cover image.

GFC acquired multiple Sentinel-2 scenes to cover the whole land area of Guyana for Aug-Dec 2018. For the period Oct-Dec 2019 Google Earth Engine was used to select the best cloud-free images that matched the target sampling period. These were clipped to the PSUs and downloaded.

3.6 Sampling Design for Change Analysis

The sampling design refers to the methods used to select the locations at which the reference data are obtained. To assess the area and rate of deforestation a two-stage sampling strategy with stratification of the primary units was adopted. First, a rectangular grid of 5 km by 15 km in size was created within the spatial extent of the country's national boundary[4]. The shape was selected to assist with the collection of North-South orientated strips of aerial GeoVantage imagery as this shape minimises the cost of acquisition of the imagery. Gridding resulted in 2837 rectangles; note that only rectangles with a centroid within the Guyana national boundary were selected.

As the area of the country is large, and the pattern of deforestation is clustered around relatively small areas of human activity, it is efficient to adopt a stratified sampling framework rather than use simple random or systematic sampling (Gallego, 2000; Foody, 2004; Stehman, 2001). For each stratum, sample means and variances can be calculated; a weighted average of the within stratum estimates is then derived, where weights are proportional to stratum size. In this case, the goal is to improve the precision of the forest (or deforestation) area using a stratum-based estimate of variance that will be more precise than using simple random sampling (Stehman and Czaplewski, 1998; Stehman, 2009; Potapov *et al.*, 2014).

Strata are based on actual observations of deforestation (particularly Years 1 to 7). The method first selected the grid rectangles that intersected deforestation events. For every year of deforestation, the value 1 (one) was given. If no event was recorded, then the value 0 (zero) was given. For example, the rectangle with value 0000011 intersects deforestation events that were recorded for Years 6 and 7. When there have been deforestation events for the last two years, then the rectangle was assigned to High Risk (HR) stratum. All other rectangles were assigned to LR (Low Risk) stratum.

After this, and based on geographical data provided by GFC, MR (Medium Risk) grid rectangles were selected from the LR stratum and stratified according to factors closely associated with risk of deforestation and forest degradation. In particular, data about the location of logging camps, mining dredges, settlements, and the existing road network were used (see Table 3.3 and Figure 3.1). This way, all grid rectangles that satisfied the following criteria were selected to be included in the MR stratum.

Contain at least one of: logging camps, mining dredges, or settlements,

<OR>

[3] https://earth.esa.int/web/sentinel/toolboxes/sentinel-2 (last accessed: December 2018)

[4] According to the Interim Measures Report October 2013, the national boundary (that was used for the stratification) was defined by following information received from the GL&SC and with the aid of RapidEye imagery.

Intersect with at least one road.

This resulted in the classification of grid rectangles into three strata: 611 HR, 773 MR, and 1453 LR. (see Figure 3.1 – left).

Table 3.3 – Spatial data used to assist with defining risk strata

Data Group	Layer Name	Created/Update Frequency	Description
Admin	guyana_boundary	Received August 2013	Updated country boundary for Guyana.
Managed Forest Areas	logging_camps	N/A	Point location of logging camp sites, based on the Annual Operating plan.
Roads	Roads_Gy_2016	3-6 months	All GPS roads and trails as at August 2016.
Mining Areas	mining_dredges	Upon granting of mining permit/licence/claim	Mining Dredge sites normally found in/around rivers
Population	Settlements	N/A	An extraction of several larger settlements from the place names point feature class.

The map in Figure 3.1 suggests that there is lower probability of sampling deforestation in the Low Risk stratum than the High and Medium Risk strata and so, in order not to under sample and miss deforestation events in this stratum, a weighting was applied when randomly selecting rectangles to analyse in detail. This resulted in 69 HR rectangles, 65 MR rectangles and 190 LR rectangles (see figure 3.1 - right).

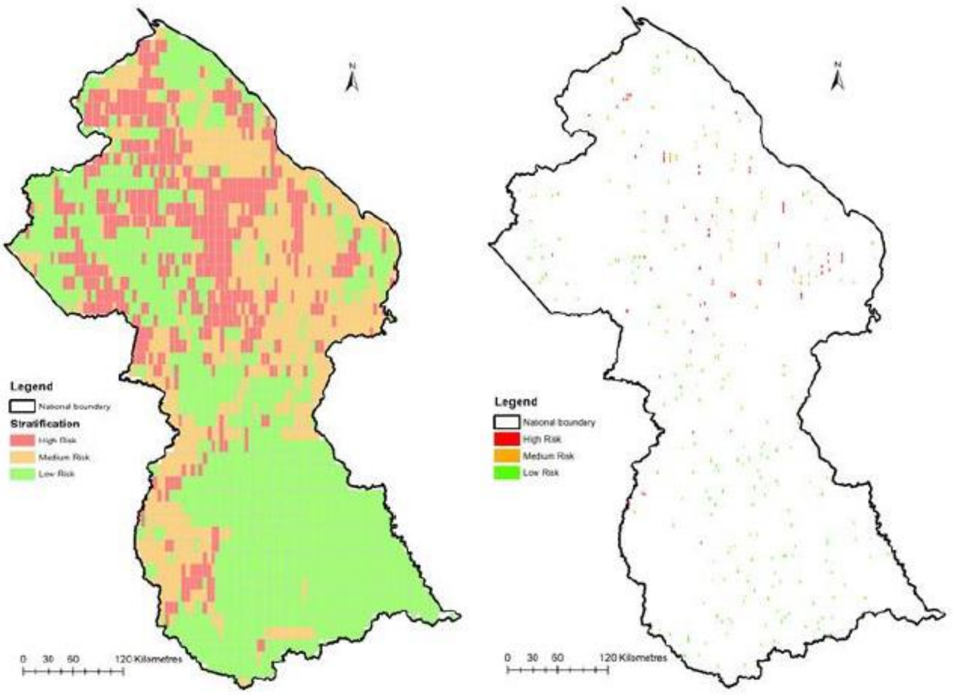

Figure 3.1 – High, Medium, Low, and Zero Risk strata (left) and final random sampling of the strata (right image).

A systematic grid of 300 hectares was then generated at the centre point of each of the first-stage samples. In total, 97,200 one-hectare samples became available for accuracy assessment.

For each primary sampling unit, the land cover class (e.g. Forest or Non-Forest, Degradation or Non-Degradation) is determined for the Year 9 deforestation and degradation map. The assessment follows a systematic procedure where the GIS table for the samples is populated using a GIS toolbar.

Specifically, the tools used to interpret and validate Year 9 land cover change included high-resolution satellite imagery (see Table 3.1). Also available were GIS data indicating mining, forestry and agricultural concessions.

Year 9 Change Assessment involved the collection of 324 equally-sized primary sample units (each with 300 ha) with a direct correspondence with Year 8. The reference data selected for the change assessment in Year 9 was a combination of GeoVantage, Planetscope and Sentinel-2 imagery for the High and Medium Risk strata, and Sentinel-2 and Landsat imagery for the Low Risk stratum.

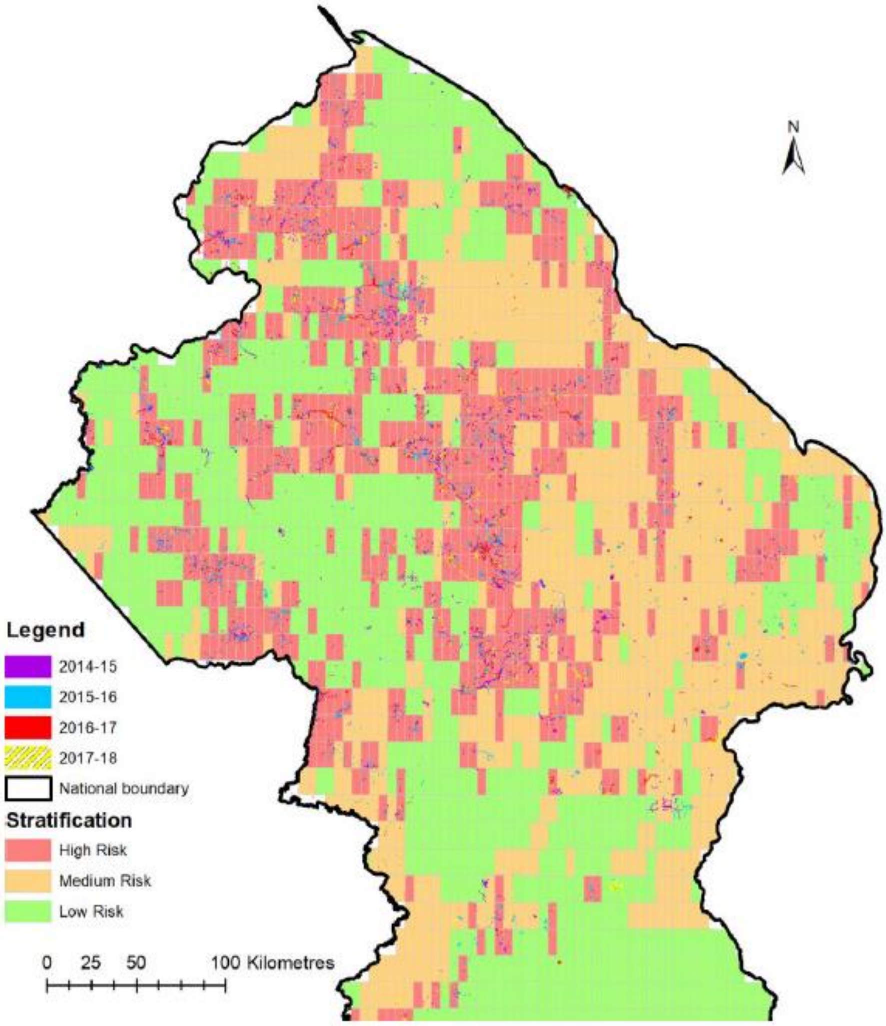

Figure 3.2 – As the deforestation moves, some of it' leaks' into MR and LR. As a result, the strata may need to change for future sampling.

3.7 Precision of Area Estimates for Deforestation and Forest Degradation

The two-stage sampling with stratification of the primary units design optimises the probability of sampling deforestation and forest degradation in Year 9 when the area concerned represents only a small fraction of the national land area. Furthermore, there are several factors such as cloud cover, accessibility, safety and cost that limit the availability and quality of reference data.

A key consideration is minimising the risk of introducing any possible bias into the estimates. Bias may arise from sampling, from cloud cover patterns and perhaps from the distribution and coverage of the reference data. Sampling bias can be assessed from the joint probability matrices. The distribution of cloud cover has been assessed qualitatively from cloud cover masks, but this can be quantified more formally from the sample area data and from the cloud mask data derived from analysis of the satellite imagery.

The Covid-19 Pandemic outbreak and the resulting lockdown and furlough of Guyana Forest Commission staff meant that the GFC mapping team, having completed the deforestation mapping exercise, were not able to perform the forest degradation and accuracy assessment as they had done for the past two years. GFC, therefore, requested that the Durham University team who had trained the mapping team take over the interpretation exercise. The University validation team consists of three well qualified and experienced image interpreters, all of whom are familiar with land cover and forest types in Guyana. The analysis involved identifying change, paying strict attention of the definitions of 'forest cover', 'degraded forest cover' and 'non- forest' as well as the interpretation rules for deforestation and forest degradation.

One of the interpreters was experienced in image interpretation but new to Guyana forests and so training was provided on several occasions in March/April 2020 to introduce the reference data sets, the GIS Change-Assessment Toolbar, and the mapping rules as detailed in the Standard Operating Procedures for Forest Change Assessment: A Guide for Remote Sensing Processing & GIS Mapping, along with Operating Procedures for REDD+ Accuracy Assessment.

3.8 Decision Tree for 2019 (Year 9) Change Analysis

The analysis will report a gross deforestation change estimate based on a stratified random change estimator. This will provide confidence interval information on the deforestation estimate (i.e. the amount of change). Put another way; there is no sub-sampling other than to break down the measurement into a hectare-sized grid to make the assessment manageable. Appendix 8 provides information about how decisions are made when a deforestation, forest degradation, or afforestation event is met by the interpreter, to complete the contingency matrix (see Table 3- 4).

Table 3-4 Contingency matrix to represent change as detected by the assessment team.

	End Reference Class			
Start Reference Class	Forest	Degradation	NonForest	**Total**
Forest	Stable Forest	Loss	Loss	
Degradation	Gain	Stable Degradation	Loss	
NonForest	Gain	Gain	Stable NonForest	
Total				

When assessing degradation, it is important to follow the Mapping Rules that define degraded-forest and non-forest that are detailed in the Standard Operating Procedure for Forest Change Assessment (see Appendix 8).

The most important points to note are:

1. Only areas of forest degradation that relate to Years 8 and 9 are assessed.
2. Areas of shifting cultivation are classified as "Rotational" even if they are smaller in size than the minimum mapping unit (1 ha) and classified as forest degradation.
3. Areas of water bodies are classified as non-forest.
4. Areas cloud and shadow or missing data are labelled as *Omitted*.
5. Areas representing Year 10 change (post-Dec 2019) were also omitted from the analysis as this change postdates the Year 9 reference imagery.

The rules for validating each sample unit point account for small discrepancies with the geometric alignment among the various remote sensing data sets. The change samples are ideally interpreted at 1:5,000 scale using 2018 imagery (GeoVantage, PlanetScope, or Sentinel-2 / Landsat) and 2019 imagery (GeoVantage or Sentinel-2 / Landsat) imagery. Factors, other than human error that might explain misinterpretation include land obscured by cloud or cloud shadow and change that is too small to be detected on the available cloud-free imagery.

Furthermore, where a discrepancy between the mapping and the validation data is detected, an interpretation will be made of the correct assignment for the sample point. The toolbar included a confidence label on a 0-4 scale. The uncertainty refers to confidence in interpreting either change or the driver for change, and is recorded on a four interval percentage scale. This allows for uncertainties in interpretation to be removed from the estimation and validation process if required.

3.9 Precision of Area Estimates for Deforestation and Forest Degradation

Just before the Accuracy Assessment exercise, a training session was run by Durham University in GFC premises for the team of interpreters to get accustomed to the rules and the tools. It was followed by a consistency check on 300 samples, analysis of the disagreements and discussion among the team. A small 'refresher' also took place a week before the Accuracy Assessment exercise. Following the exercise, a consistency check was run on the areas of change. The outcome is presented in Table 3-5.

Table 3-5 – Consistency check results over 13,200 samples, on the identification of change or no-change in the sample (grey cells).

	User A	User B	User C
User A			
User B	99.9		
User C	99.7	99.6	

4 STATISTICAL METHODOLOGY

4.1 Change Sample Estimates

We treat the design as a stratified cluster design. The clusters are rectangles. The strata are HR, MR and LR. A simple random sample of rectangles from each stratum is taken. Then, within each rectangle, all hectares are systematically evaluated, and all change measured quantitatively using the best available reference data.

The reference data consisted of 324 primary sample units stratified into HR (20,700 ha), MR (19,500 ha) and LR (57,000 ha) areas as described in the sampling design (Section 3.6) and randomly sampled within each stratum. This design allows a probability-based inference approach to be applied. This approach assumes (1) that samples are selected from each stratum randomly; (2) that the probability of sample selection from each stratum can be estimated; and (3) the sampling fraction in each stratum is approximately proportional to the total population and that the relative sample size reflects.

The total number of 1-ha samples analysed in the whole survey was 97,200. Of this total, only 2,033 were omitted due to cloud cover or cloud shadow in the reference imagery. The proportion of the total omitted in Year 9 is 0.021, which represents 2.09 % of the sample. This is less than Year 6 (2015-16) where the equivalent proportion of omitted samples was 0.05708 (5.7 %) and more than Year 7 (2016-17) where the equivalent proportion of omitted samples was 0.00215 (0.22 %). In Year 8 proportion of the total omitted is 0.01904, which represented 1.9 % of the sample.

Key inputs to the analysis are the total number of samples in each stratum. These are 4,810,002 ha (20,700 sampled hectares) for HR, 5,658,869 ha (19,500 sampled hectares) for MR and 10,654,582 (57,000 sampled hectares) for LR.

Apart from no change samples (Forest-Forest; NonForest-NonForest; Degradation-Degradation), the key changes are Forest-NonForest, Forest-Forest Degradation, and Forest Degradation-NonForest.

4.2 Software and estimators

To carry out the analysis, we have used the survey package available with the statistical package R Core Team (2014). This package is free and used by and supported by most of the world's academic statisticians, and increasingly is the commercial tool of choice. The survey package provided in Lumley (2004, 2014) provides functionality similar to that provided by the SAS package[5], and uses the same standard formulae for estimation of means and variances. These formulae are set out below and described conveniently in Lumley (2014).

Definitions and Notation

For a stratified clustered sample design, together with the sampling weights, the sample can be represented by an $n \times (P+1)$ matrix

$$(W, Y) = (w_{hij}, y_{hij})$$
$$= (w_{hij}, y_{hij}^{(1)} y_{hij}^{(2)}, \dots \dots \dots, y_{hij}^{(p)})$$

Where

[5] SAS SURVEYMEANS procedure. http://www.math.wpi.edu/saspdf/stat/pdfidx.htm

$h = 1,2, \dots \dots \dots, H$ is the stratum number, with a total of H strata

$i = 1,2, \dots \dots \dots, n_h$ is the cluster number within stratum h, with a total of n_h clusters

$j = 1,2, \dots \dots \dots, m_{hi}$ is the unit number within cluster i of stratum h, with a total of m_{hi} units

$p = 1,2, \dots \dots \dots, P$ is the analysis variable number, with a total of P variables

$n = \sum_{h=1}^{H} \sum_{i=1}^{n_h} m_{hi}$ is the total number of observations in the sample

w_{hij} denotes the sampling weight for observation j in cluster i of stratum h

$y_{hij} = (y_{hij}^{(1)} y_{hij}^{(2)}, \dots \dots \dots, y_{hij}^{(p)})$ are the observed values of the analysis variables for observation j in cluster i of stratum h, including both the values of numerical variables and the values of indicator variables for levels of categorical variables.

Mean

$$\hat{\bar{Y}} = \frac{\left(\sum_{h=1}^{H} \sum_{i=1}^{n_h} \sum_{j=1}^{m_{hi}} w_{hij} y_{hij}\right)}{w}$$

Where

$$w_{\dots} = \sum_{h=1}^{H} \sum_{i=1}^{n_h} \sum_{j=1}^{m_{hi}} w_{hij}$$

Is the sum of the weights over all observations in the sample.

Confidence limit for the mean

The confidence limit is computed as

$$\hat{\bar{Y}} \pm StdErr\left(\hat{\bar{Y}}\right).t_{df,\infty/2}$$

Where $\hat{\bar{Y}}$ is the estimate of the mean, $StdErr\left(\hat{\bar{Y}}\right)$ is the standard error of the mean, and $t_{df,\infty/2}$ is the $100(1 - {}^{\infty}/_{2})$ percentile of the t distribution with the df calculated as described in the section "t Test for the Mean".

Proportions

The procedure estimates the proportion in level c_k for variable C as

$$\hat{p} = \frac{\sum_{h=1}^{H} \sum_{i=1}^{n_h} \sum_{j=1}^{m_{hi}} w_{hij} y_{hij}^{(q)}}{\sum_{h=1}^{H} \sum_{i=1}^{n_h} \sum_{j=1}^{m_{hi}} w_{hij}}$$

Where $y_{hij}^{(q)}$ is value of the indicator function for level $C = c_k$

$y_{hij}^{(q)}$ equals $\mathbf{1}$ if the observed value of variables C equals c_k, and

$y_{hij}^{(q)}$ equals $\mathbf{0}$ otherwise.

Total

The estimate of the total weighted sum over the sample,

$$\hat{Y} = \sum_{h=1}^{H} \sum_{i=1}^{n_h} \sum_{j=1}^{m_{hi}} w_{hij} y_{hij}$$

For a categorical variable level, $\hat{Y}$ estimates its total frequency in the population.

Variance and standard deviation of the total

$$\hat{V}(\hat{Y}) = \sum_{h=1}^{H} \frac{n_h(1 - f_h)}{n_h - 1} \sum_{i=1}^{n_h} (y_{hi\cdot} - \bar{y}_{h\cdot\cdot})^2$$

Where

$$y_{hi\cdot} = \sum_{j=1}^{m_{hi}} w_{hij} y_{hij}$$

$$\bar{y}_{h\cdot\cdot} = (\sum_{i=1}^{n_h} y_{hi\cdot}) / n_h$$

The standard deviation of the total equals

$$Std(\hat{Y}) = \sqrt{\hat{V}(\hat{Y})}$$

Confidence limits of a total

$$\hat{Y} \pm StdErr\,(\hat{Y}).t_{df,\infty/2}$$

5 RESULTS

5.1 Estimates of forest cover in Year 8

We can ignore that we have Year 9 information and obtain estimates of Year 8 forest cover. These can be compared to estimates obtained by other means. Table 5.1 shows the total areas classified as Degraded, Forest, and NonForest, together with a standard error and a 97.5% confidence interval. For example, the estimate of non- degraded Forest cover in 2018 (year 8) is 18,465,620 ha, standard error 21,244 ha, and 97.5% confidence interval (18,423,983; 18,507,258) ha.

Table 5.2 gives the same information as in Table 5.1 but shows proportions rather than totals. So, the proportion of Forest cover in 2018 is 0.891, standard error 0.001, 97.5% confidence interval (0.889, 0.893). Note that proportions add to one.

Table 5.1 Analysis of Y8 hectares of all classes

	Hectares	SE	2.5%	97.5%
2018 Degraded forest	273344	8014	257637	289052
2018 Non degraded forest	18465620	21244	18423983	18507258
2018 Non forest	1976515	20181	1936962	2016069

Table 5.2 Analysis of Y8 proportions of all classes

	Mean	SE	2.5%	97.5%
2018 Degraded forest	0.013	4.00E-04	0.012	0.014
2018 Non-degraded forest	0.891	1.00E-03	0.889	0.893
2018 Non-forest	0.095	1.00E-03	0.094	0.097

5.2 Estimates of forest cover in 2019 (Year 9)

We now repeat these analyses for Year 9. Table 5.3 shows the total areas classified as degraded forest, non- degraded forest, and non-forest, together with a standard error and a 97.5% confidence interval. For example, the estimate of non-degraded forest cover in Year 9 is 18,447,535 hectares, standard error 21,314 hectares, and 97.5% confidence interval (18,405,761; 18,489,309) hectares. Table 5.4 shows proportions instead of totals. Otherwise, the interpretation is as for Year 8.

Table 5.3 Analysis of Y9 hectares of all classes

	Hectares	SE	2.5%	97.5%
2019 Degraded forest	282763	8162	266765	298760
2019 Non-degraded forest	18447535	21314	18405761	18489309
2019 Non forest	1985182	20215	1945562	2024802

Table 5.4 Analysis of Y9 proportions of all classes				
	Mean	SE	2.5%	97.5%
2019 Degraded forest	0.014	4.00E-04	0.013	0.014
2019 Non-degraded forest	0.891	1.00E-03	0.889	0.893
2019 Non forest	0.096	1.00E-03	0.094	0.098

5.3 Estimates of change from Year 8 to Year 9.

We analyse the change from Year 8 to Year 9 as follows. We have matched pairs of sample data, where the hectares seen in Year 8 are seen again in Year 9. Therefore it is natural to concentrate upon the change for each pair. This is analogous to the matched paired t-test, where we calculate differences between pairs, and then analyse the differences.

There are three possible outcomes for each pair, depending on how the hectare was classified in Year 8. If the classification had been Forest (non-degraded), the possibilities are Forest in Year 8 and Year 9, Forest in Year 8 and Degraded in Year 9, and Forest in Year 8 and Non-Forest in Year 9. Therefore, these will result in a total of nine possible combinations of change.

Table 5.5 Totals of Class Changes from Forest for 2018-2019				
Stratum / Class	Hectares	SE	2.50%	97.50%
2018-2019 Forest -> Degradation	9883	1614	6720	13046
2018-2019 Forest/Degraded -> NonForest	8202	1413	5433	10972
2018-2019 Forest -> Forest	18447535	2144	18443334	18451736

In Table 5.5 we estimate the area of Guyana which was classified as Forest in Year 8 and NonForest in Year 9. The estimate is 8,202 hectares, standard error 1,413 hectares, 97.5% confidence interval (5,433 ha; 10,972 ha). Appendix 1 gives the same information as Table 5.5 but disaggregated by stratum and by proportions rather than totals.

In Year 9 the GFC mapping team found no change from Non-Forest to Forest or Degraded Forest (reforestation). Note that it would be challenging to identify reforestation with any certainty in the LR stratum because only Sentinel- 2 and Landsat data is available. Nevertheless, no reforestation was found in either the HR or MR strata using the high-resolution PlanetScope or GeoVantage imagery.

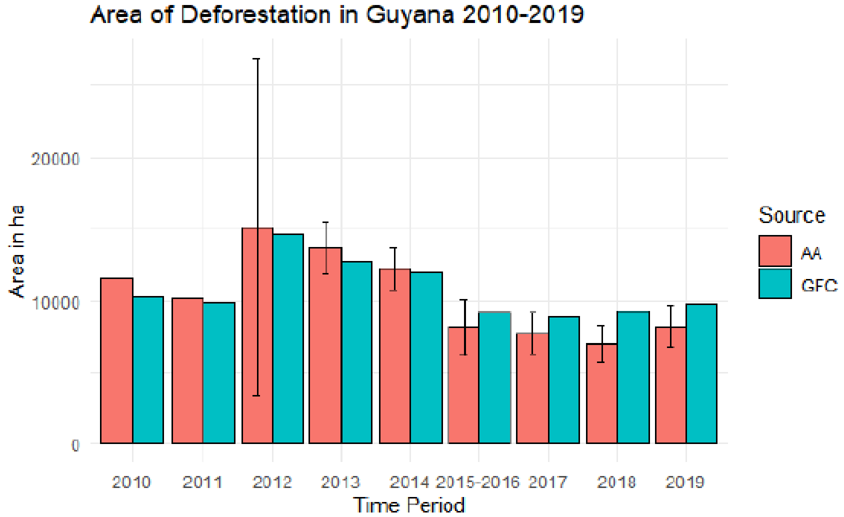

Figure 5.1 Trends in Deforestation observed from GFC MRVS and sample-based estimates

The change from forest to degraded forest was measured precisely for each sample where change (forest loss) was identified. This was done manually using the 'measure tool' in ArcGIS, and the value entered in the database using the Accuracy Toolbar to the nearest 5% for each sample hectare. The amount of loss is classed as degraded forest when forest area of 0.5 ha or more is lost, up to the point that 30% or less of the area is forest canopy covered; after that, the sample hectare would be classed as deforested.

In this way partial deforestation and forest degradation is assessed quantitatively within each sample area. The total area for change from Forest to Degraded forest is 9,883 hectares, standard error 1,614 hectares, 97.5% confidence interval (6,720 ha; 13,046 ha), see table 5.5.

5.4 Estimating rate of change.

The key issue is to estimate the rate of change of gross deforestation. To do this, we restrict attention to hectares which in Year 8 were classified as forest or degraded, and then estimate the rates at which they continued to be Forest, or were classified as non-forest.

The estimated number of hectares of forest in Year 8 changed to Degraded Forest in Year 9 is 9,883 hectares with a standard error of 1614 hectares, 97.5% confidence interval (6,720 ha; 13,046 ha). The estimated number of hectares of forest in Year 8 lost to non-forest in Year 9 is 8,202 hectares. These changes translate into a mean rate of deforestation on 0.0645 % with a SE of 0.00789 % with a 97.5% confidence interval for the rate of change of 0.0491 % to 0.0800 %, see Table 5.6.

Table 5.6 Mean Deforestation annual rate per hectare (%)

	Mean	SE	2.5%	97.5%
Year 9 (2019) Forest loss	0.0645	0.00789	0.0491	0.0800

5.5 Deforestation rate comparison

Table 5.7 shows the Year 8 to Year 9 deforestation area and rate data compared. Note that the map-based estimate does not have a standard error associated with it but that the mapping and the change sample estimates are of similar magnitude. Note that the sample-based estimate considers only the areas available to sample, that is, the LR, MR and HR strata. Figure 5.2 shows the trend in deforestation rate from 2010 to 2019. Year 9 shows a small increase in the rate of change according to the sample-based change estimates. The rate of loss shown in Table 5.6 assumes that all of the forest in every change sample is lost. However, it is possible for a sample to retain some forest cover even though the sample does not meet the definition of forest cover set out in Section 2.1; that is a minimum of 30% canopy cover. Table 5.7 and Figure 5.2 show a lower change rate of 0.0524 % if the actual area of change is incorporated into the analysis.

Table 5.7 Comparison of Forest Change Estimates Source

	Forest area change (ha) Year 9	Change Rate (%)	SE of Y9 Rate (%)
GFC Map Estimate	9,767		
Change Sample Estimate	8,202	0.0645	0.0079
Change Rate Estimate using the actual area of deforestation per sample (see Table A23)		0.0524	0.0183

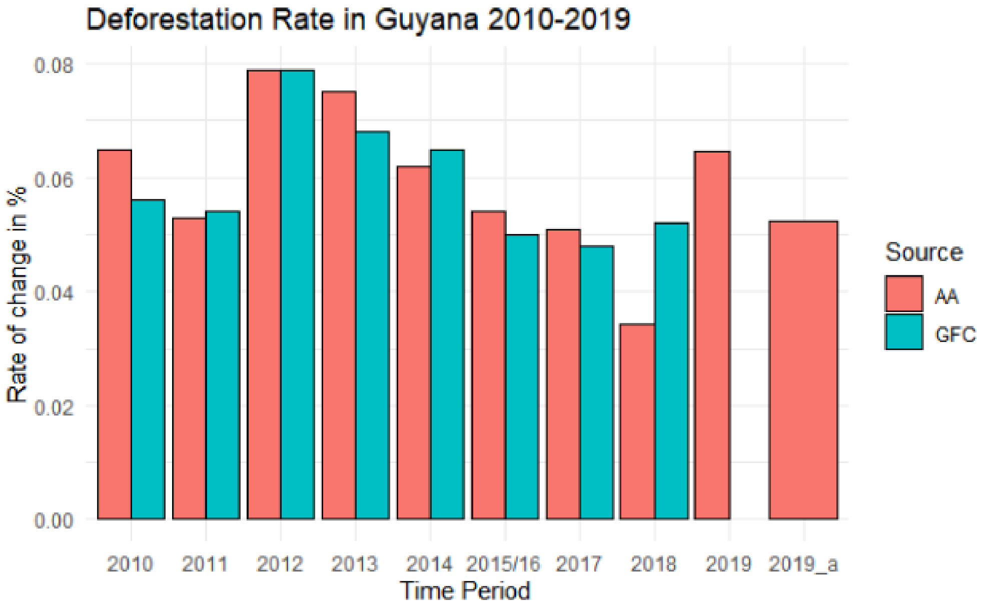

Figure 5.2 Deforestation Rates observed from GFC MRVS and Accuracy Assessment sample-based estimates. Note that 2019_a uses the actual area of deforestation per sample to estimate the change rate

6 DISCUSSION

The results divide into two areas that warrant further discussion:

i) reliability of the sampling strategy used to identify deforestation and estimate change area from imagery

ii) estimation of the drivers of forest loss;

6.1 Deforestation levels

The approach taken by GFC to produce a comprehensive (wall-to-wall) map for forest / non-forest for Guyana is ambitious and provides very precise, location-specific data. The mapped area of gross deforestation is higher than the sample-based estimate, although the mapped area falls within the confidence interval of the sample-based estimate.

There are a number of possible reasons that might explain the small difference between the two measures of gross deforestation.

1. the MRV mapping is based on Sentinel-2 MSI and Landsat 8 imagery, and so areas identified as deforestation might in fact be forest degradation;
2. the overall amount of deforestation is low, and so it is possible that a few small areas account for the differences and these areas, by chance, fall outside the sampled areas;
3. the proportion (approx. 2.09%) of samples Omitted (because of cloud cover) is higher than in Y8 and may obscure change areas;
4. The accuracy assessment for deforestation did not check the GIS map product; instead, it estimated forest loss from an independent probability-based sample.

In the figures 6.1-6.6, different examples are presented that illustrate situations where the GIS mapping and the sample-based estimation methods differ in their interpretation of both deforestation and forest degradation. However, both follow the established mapping rules as described in the standard operating procedures.

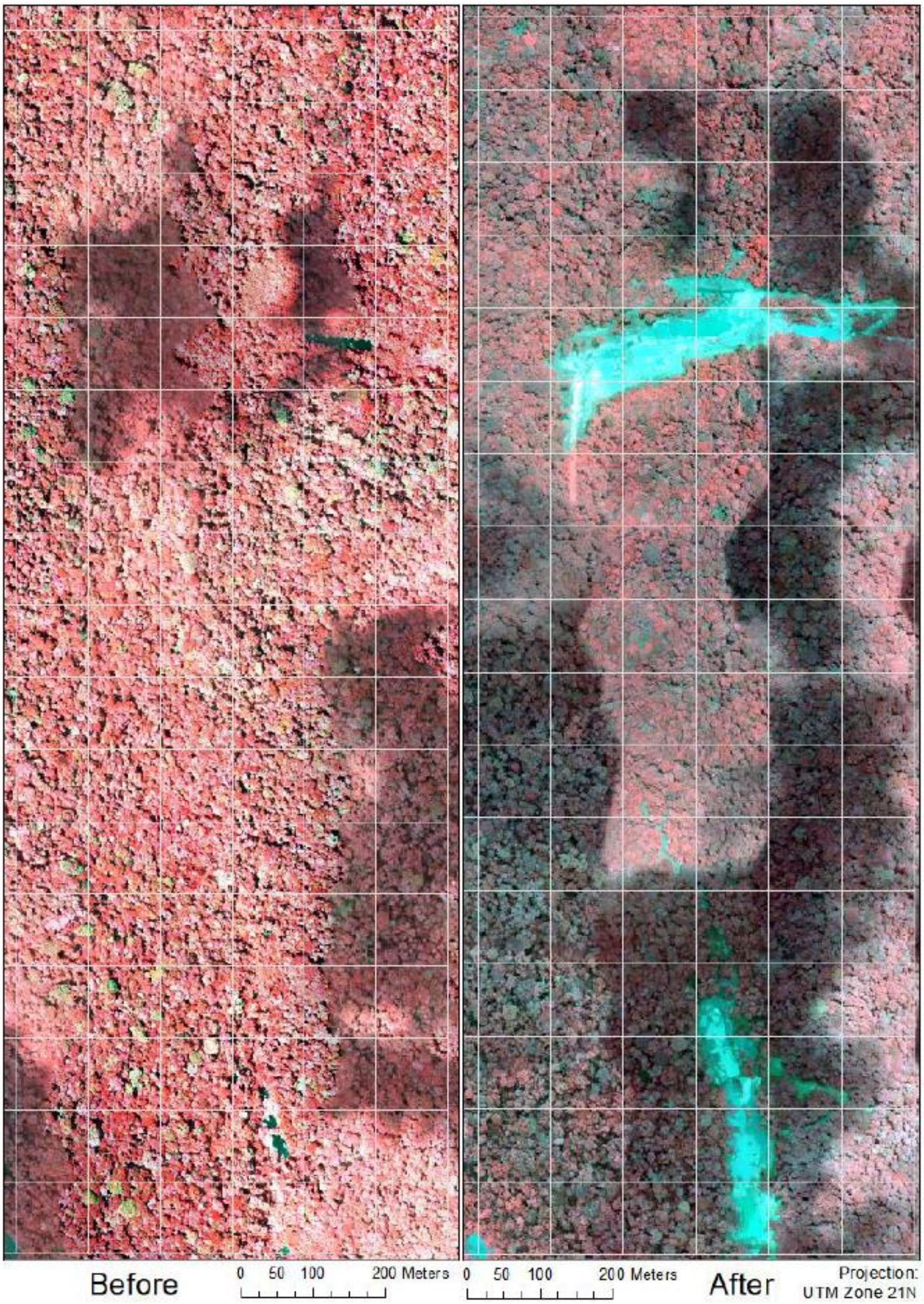

Figure 6.1 – GeoVantage aerial imagery displayed as a false colour composite was acquired in 2018 and repeated in 2019 showing the initial and final state of the forest. This sample area shows areas of deforestation and forest degradation where the driver for change is artisanal gold mining.

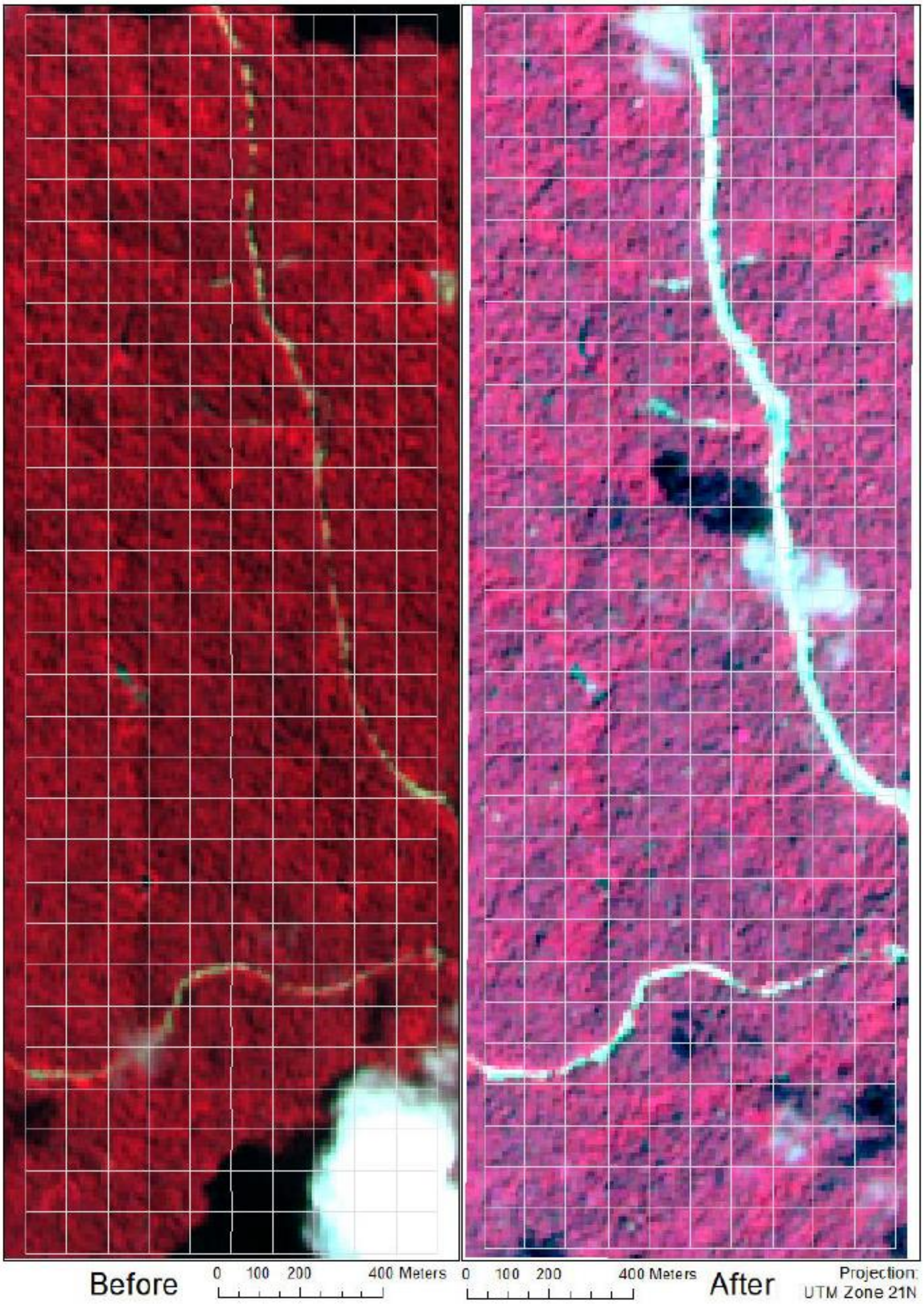

Figure 6.2 – Sentinel 2 MSI data displayed as a false colour composite was acquired in 2018 and again in 2019. This sample areas highlights where forest degradation has taken place resulting from widening of road infrastructure. The roads are easily seen on this Sentinel 2 imagery but the resolution makes precise estimation of area change difficult. The following figure shows the same area imaged with GeoVantage aerial imagery.

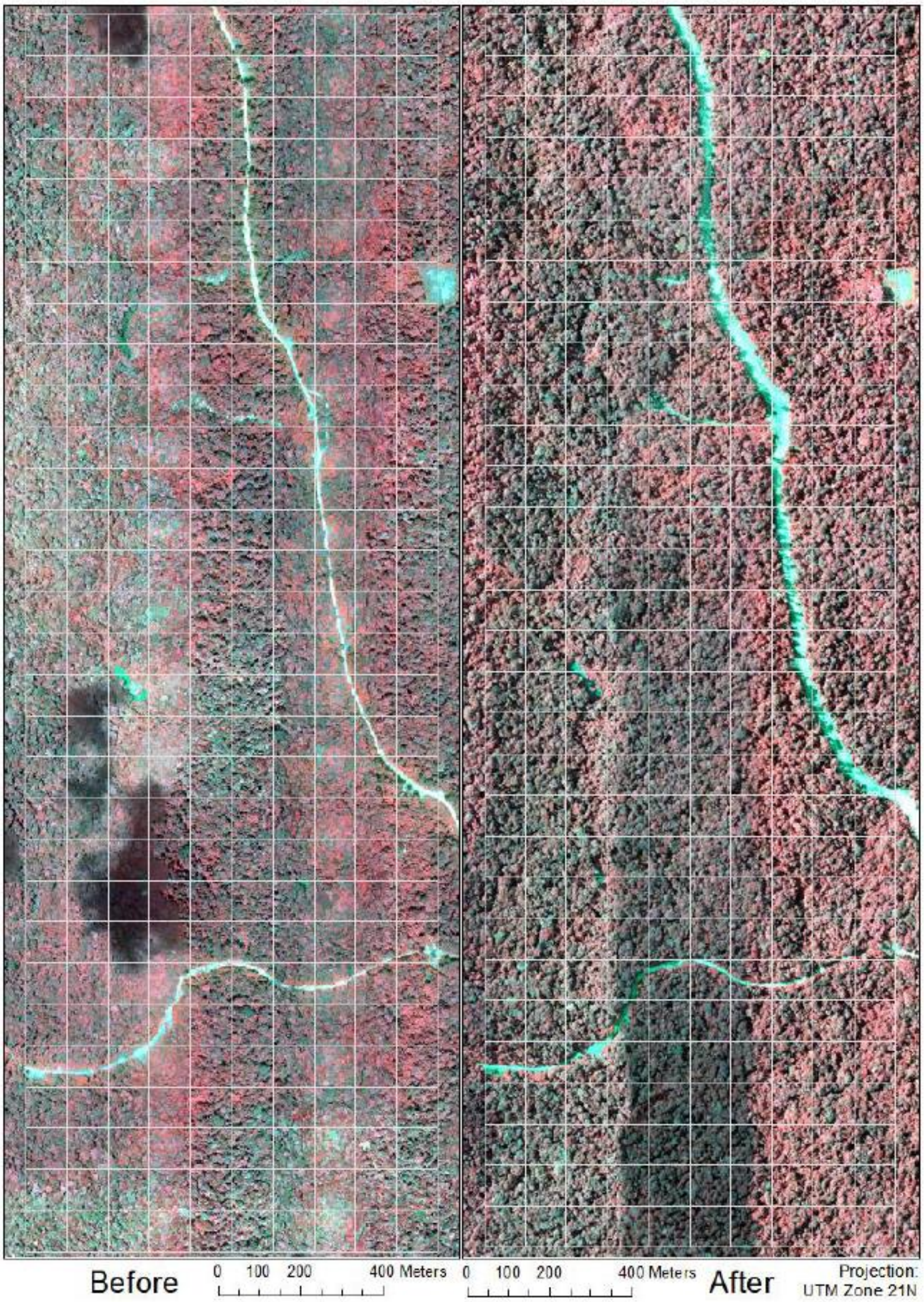

Figure 6.3 – GeoVantage aerial image acquired in 2018 and again in 2019, highlighting where forest degradation has taken place resulting from widening of road infrastructure. The roads are easily seen on aerial imagery and it is straightforward to measure the amount of forest loss due to road widening..

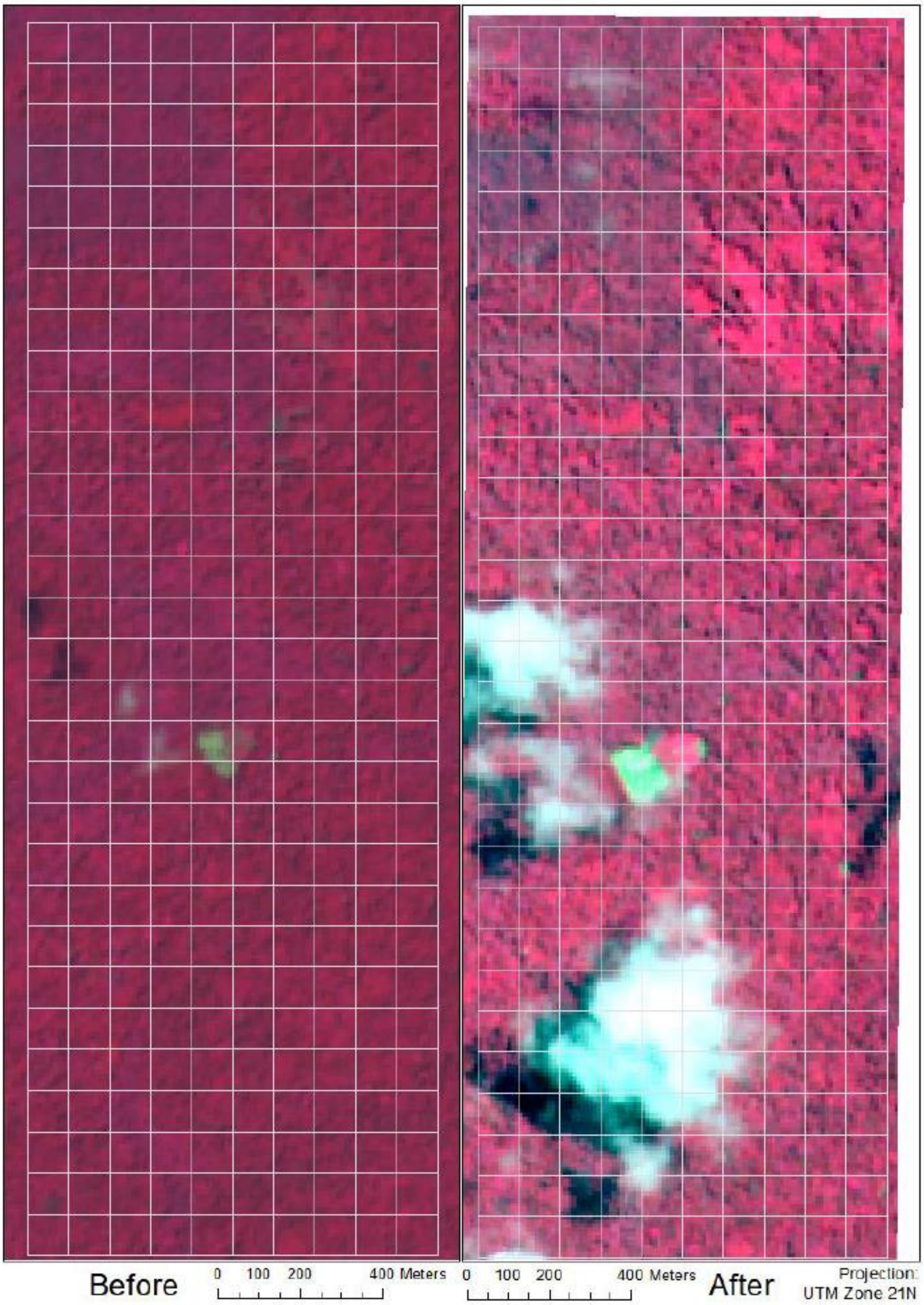

Figure 6.3 – Sentinel 2 MSI data displayed as a false colour composite was acquired in 2018 and again in 2019. This sample area shows change associated with shifting cultivation.

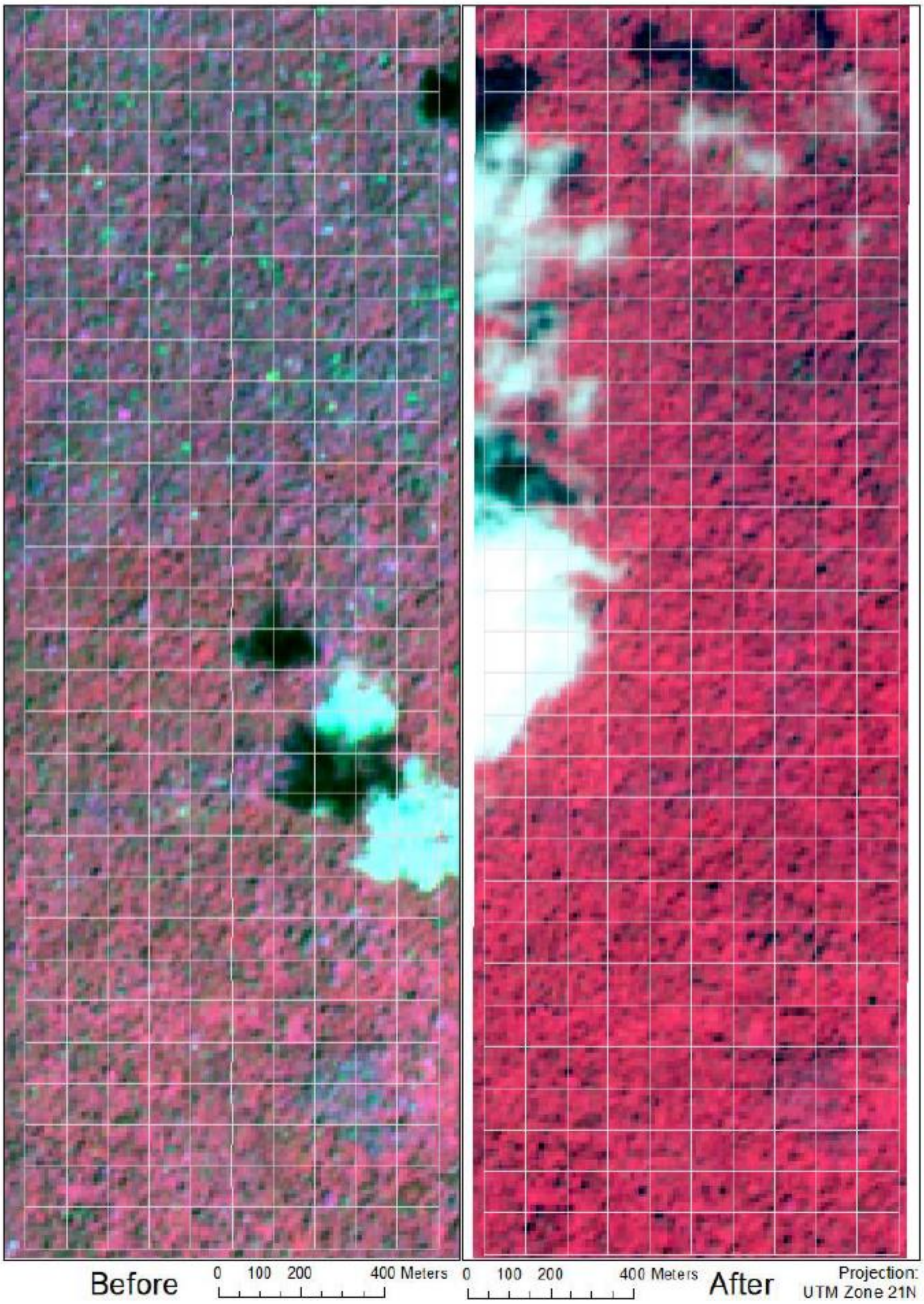

Figure 6.4 – The false colour composite images above are Sentinel-2 data taken one year apart over an area where fire was the degradation change driver in 2018. The 2019 image appears to show recovery but it is impossible to interpret the level of recovery with tthe Sentinel 2 imagery alone. This figure highlights how difficult it can be to identify and correctly classify change (loss and recovery) associated with transient fires.

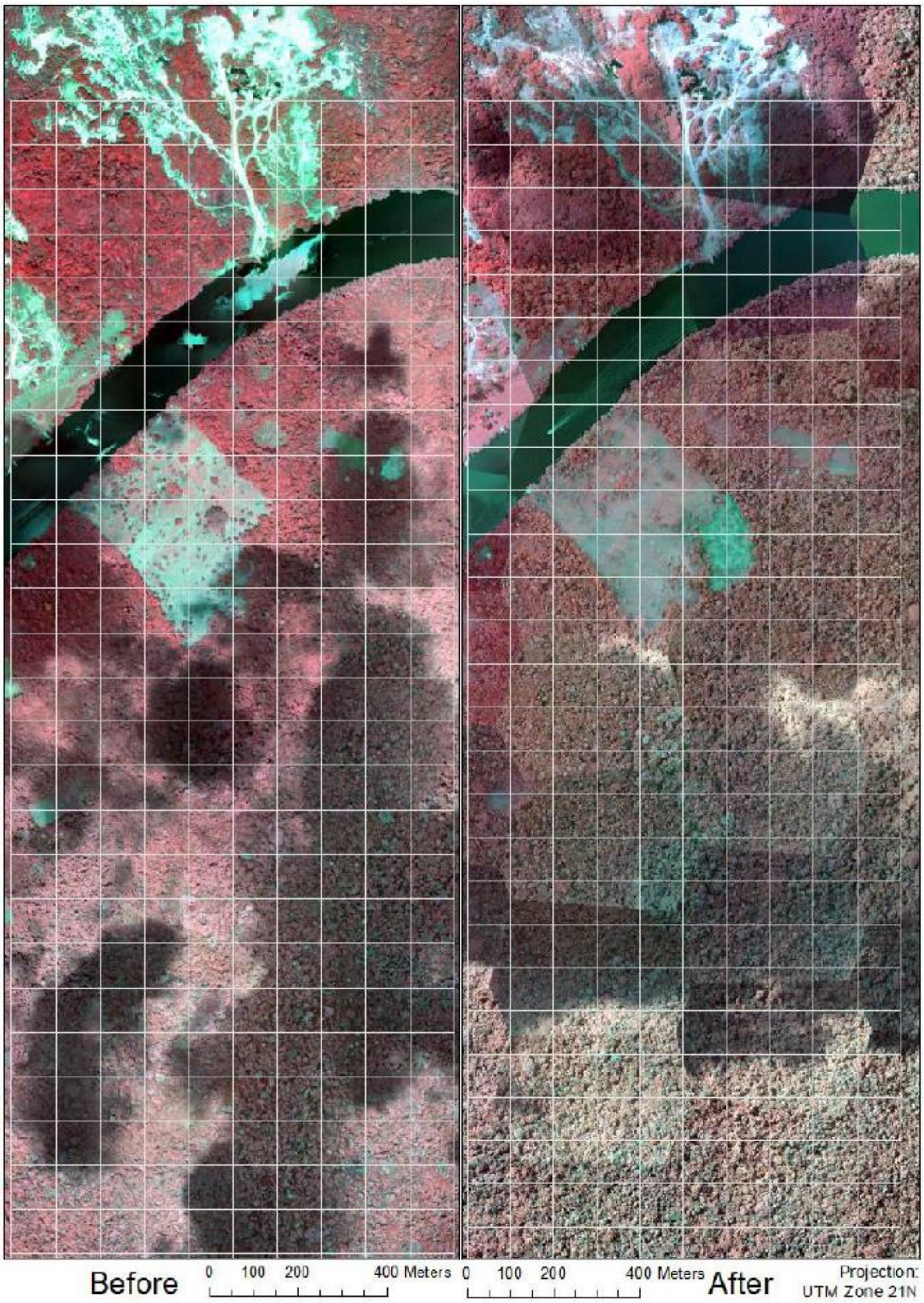

Figure 6.5 – This sample area is an example where the spatial resolution of the imagery plays an important role in the interpretation of the land cover. The aerial GeoVantage false colour infrared imagery allows the interpreter to measure expansion of agricultural areas with confidence at the scale of the 1 ha minimum mapping unit.

6.2 Drivers of Deforestation

The results from the stratified sample estimates confirm GFCs conclusion that mining and mining-related infrastructure, including settlements, is the overwhelming driver for deforestation (84%), see Table 6.1.

Table 6.1	Drivers of Deforestation and Degradation			
Driver	Deforestation area in ha	Percentage of total deforestation	Degradation area in ha	Percentage of total degradation
Agriculture	497	6 %	256	3 %
Mining	5,219	64 %	5,010	51 %
Mining Roads / Settlements			241	2 %
Fire	2,485	30 %		
Shifting agriculture			3,880	39 %
Unknown			497	5 %
Total (ha)	8,202		9,883	

6.3 Forest Degradation

In the Years 2-5 degradation statistics were derived from wall-to-wall mapping by GFC using a combination of RapidEye 5m pixel size and Landsat 30 m pixel size imagery. In year 6 covering 24 months, 2015-2016 RapidEye imagery was not available, and it was not possible to derive forest degradation maps from Landsat and some Sentinel-2 MSI data alone. Therefore, the level of forest degradation was estimated from the change sample reference data using an interpretation of aerial imagery supplemented with PlanetScope and Sentinel-2 MSI data. A similar approach was used for 2018, except the interpretation was carried out by the GFC Mapping Team rather than by the independent accuracy assessment team. For 2019 the Covid-19 pandemic meant that the interpretation was carried out by the accuracy assessment team at Durham University.

The key questions are:

i) have the Durham University interpreters been able to identify forest degradation consistently given the strict definitions outlined in the Standard Operating Procedure?
ii) are the reference data of sufficient quality to allow forest degradation to be determined on a consistent basis?
iii) can the drivers of degradation be determined accurately and consistently?

GeoVantage aerial image data were used for accuracy assessment, but this imagery was not available to the GFC mapping team for the Y9 period, and so the quantitative assessment of forest degradation was undertaken from the change sample analysis alone where GeoVantage and PlanetScope imagery was a key tool for identifying and quantifying forest degradation.

Table 6.1 shows the deforestation and forest degradation data broken down by driver for the assessment sample. The data show that 84% of deforestation is associated with mining and mining infrastructure. It must be noted:

(i) that drivers of change are easier to identify on GeoVantage and PlanetScope imagery than on Sentinel-2 and

(ii) that GeoVantage and PlanetScope was not available for the Low Risk stratum giving a possible bias in driver classification by stratum.

The breakdown of forest degradation by driver is also shown in Table 6.2. This also reveals that mining is the dominant driver for forest degradation in Year 9. A complete breakdown of all the change observed from the reference data in Year 8 and Year 9 is shown in the tables of Appendix A of the report. Using a change sample is clearly the most efficient and powerful way to detect change over a year. The levels of precision achieved are not likely to be much improved by taking a larger sample.

Table 6.2 Drivers of Degradation by year, units in hectares per year

Drivers of degradation	Indicator	Adopted Ref. Measure	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Degradation Indicator	Determine the extent of degradation associated with new infrastructure such as mining, roads, settlements[6]	4 368	4 352	4 251	5,679	3,512	2,599	5,251
Emissions resulting from anthropogenic forest fires	Area of forest burnt each year should decrease.	706[1]	395	265	762	804	0	0
Emissions resulting from subsistence forestry, land use and shifting cultivation lands	Emissions resulting from communities to meet their local needs may increase as a result of inter alia a shorter fallow cycle or area expansion.	-	765	167	93	281	1,654	4,136
Natural / Unknown					802	0	0	497
Total (ha)					7,336	4,764	4,253	9,883.30

[6] Degradation from forest fires is taken from an average over the past 20 years. This value is inclusive of all degradation drivers except for rotational shifting agriculture

7 SUMMARY AND CONCLUSIONS

a. We conclude that the estimates of deforestation based on the mapping undertaken by GFC based mainly on the interpretation of Sentinel-2 MSI imagery may be overestimated.

b. The methods used by GFC, and assisted by IAP, follow the good practice recommendations set out in the GOFC-GOLD guidelines and considerable effort has been made to acquire cloud-free imagery towards the end of the census period October-December 2019 (Year 9).

c. The estimate of the total area of change in the 12-month Year 9 period from forest to non-forest and degraded forest to non-forest is 8,202 ha, with a standard error of 1,413 ha and a 97.5% confidence interval (5,433 ha; 10,972 ha).

d. The estimate of the annual rate of deforestation that occurred over the Year 9 (12 months) period is 0.0645% with a standard error of 0.00789% and a 97.5% confidence interval (0.0491%; 0.0800%).

e. The estimate the total area of change in the 12-month Year 9 period from forest to degraded forest between Y8 and Y9 is 9,883 ha, with a standard error of 1,614 ha and a 97.5% confidence interval (6,720 ha; 13,046 ha).

f. Three changes, totalling 2.00 ha were detected within the boundary of the Intact Forest Landscape. These are interpreted as caused by shifting agriculture.

PSU – 167; SSU - 115, Forest-Degradation, Shifting cultivation, 0.45 ha
PSU – 324; SSU - 211, Forest-Degradation, Shifting cultivation, 0.80 ha
PSU – 324; SSU - 231, Forest-Degradation, Shifting cultivation, 0.75 ha

g. The GeoVantage (aerial survey) provided sufficient detail (spatial resolution) to assess the Sentinel-2 deforestation mapping as provided by GFC. It would be difficult to make a precise assessment of degradation without access to high-resolution imagery. Sentinel-2 MSI or Landsat ALI data are not sufficient for this purpose.

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9 APPENDIX A: STATISTICAL TABLES

Table A1 – ANALYSIS OF 2018 Hectares OF ALL CLASSES

	Hectares	SE	2.50 %	97.50 %
2018 Degradation	273344.1	8014.122	257636.7	289051.5
2018 Forest	18465620	21243.89	18423983	18507258
2018 NonForest	1976515	20180.53	1936962	2016069

Table A2 - ANALYSIS OF 2018 Hectares OF ALL CLASSES BY STRATUM

	Hectares	SE	2.50 %	97.50 %
HR:2018 Degradation	167536.8	6128.4	155525.4	179548.2
LR:2018 Degradation	36449.9	2605.7	31342.9	41556.9
MR:2018 Degradation	69357.4	4458.7	60618.5	78096.3
HR:2018 Forest	3633991	14052.2	3606450	3661533
LR:2018 Forest	9857918	9408	9839479	9876358
MR:2018 Forest	4973711	12858	4948509	4998912
HR:2018 NonForest	941552.1	13242.5	915597.3	967506.9
LR:2018 NonForest	460950.9	9073.5	443167.2	478734.6
MR:2018 NonForest	574012.5	12229.6	550042.9	597982

Table A3 - ANALYSIS OF 2018 Proportions OF ALL CLASSES

	Mean	SE	2.50%	97.50%
2018 Degradation	0.0132	4.00E-04	0.0124	0.014
2018 Forest	0.8914	1.00E-03	0.8894	0.8934
2018 NonForest	0.0954	1.00E-03	0.0935	0.0973

Table A4- ANALYSIS OF 2018 Proportions OF ALL CLASSES BY STRATUM

	Mean	SE	2.50%	97.50%
HR:2018 Degradation	0.0353	0.0013	0.0328	0.0379
LR:2018 Degradation	0.0035	0.0003	0.003	0.004
MR:2018 Degradation	0.0123	0.0008	0.0108	0.0139
HR:2018 Forest	0.7662	0.003	0.7604	0.772
LR:2018 Forest	0.952	0.0009	0.9502	0.9537
MR:2018 Forest	0.8855	0.0023	0.881	0.8899
HR:2018 NonForest	0.1985	0.0028	0.193	0.204
LR:2018 NonForest	0.0445	0.0009	0.0428	0.0462
MR:2018 NonForest	0.1022	0.0022	0.0979	0.1065

Table A4 - ANALYSIS OF 2019 Hectares OF ALL CLASSES

	Hectares	SE	2.50%	97.50%
2019 Degradation	282762.7	8162.241	266765	298760.4
2019 Forest	18447535	21313.72	18405761	18489309
2019 NonForest	1985182	20214.59	1945562	2024802

Table A6 - ANALYSIS OF 2019 Hectares OF ALL CLASSES BY STRATUM

Stratum / Class	Hectares	SE	2.50%	97.50%
HR:2019 Degradation	171254.7	6193.5	159115.7	183393.6
LR:2019 Degradation	36636.8	2612.3	31516.8	41756.8
MR:2019 Degradation	74871.2	4630.2	65796.1	83946.3
HR:2019 Forest	3623535	14097.9	3595903	3651166
LR:2019 Forest	9857545	9411.4	9839099	9875991
MR:2019 Forest	4966456	12920.9	4941131	4991780
HR:2019 NonForest	948290.7	13278	922266.3	974315.1
LR:2019 NonForest	461137.8	9075.2	443350.6	478924.9
MR:2019 NonForest	575753.6	12246	551751.9	599755.4

Table A5 - ANALYSIS OF 2019 Proportions OF ALL CLASSES

	Mean	SE	2.50%	97.50%
2019 Degradation	0.0136	4.00E-04	0.0129	0.0144
2019 Forest	0.8905	1.00E-03	0.8885	0.8925
2019 NonForest	0.0958	1.00E-03	0.0939	0.0977

Table A8 - ANALYSIS OF 2019 Proportions OF ALL CLASSES BY STRATUM

Stratum / Class	Mean	SE	2.50%	97.50%
HR:2019 Degradation	0.0361	0.0013	0.0335	0.0387
LR:2019 Degradation	0.0035	0.0003	0.003	0.004
MR:2019 Degradation	0.0133	0.0008	0.0117	0.0149
HR:2019 Forest	0.764	0.003	0.7581	0.7698
LR:2019 Forest	0.9519	0.0009	0.9501	0.9537
MR:2019 Forest	0.8842	0.0023	0.8797	0.8887
HR:2019 NonForest	0.1999	0.0028	0.1944	0.2054
LR:2019 NonForest	0.0445	0.0009	0.0428	0.0462
MR:2019 NonForest	0.1025	0.0022	0.0982	0.1068

Table A9 - ANALYSIS OF 2018-2019 TOTALS OF CLASS CHANGES

	Hectares	SE	2.50 %	97.50 %
2018-2019 Degradation.Degradation	272879.4	8007.9	257184.2	288574.5
2018-2019 Forest.Degradation	9883.3	1613.9	6720.1	13046.5
2018-2019 Forest.Forest	18447535	21313.7	18405761	18489309
2018-2019 Degradation.NonForest	464.7	328.6	-179.3	1108.8
2018-2019 Forest.NonForest	8202	1412.8	5432.9	10971.1
2018-2019 NonForest.NonForest	1976515	20180.5	1936962	2016069

Table A10 - ANALYSIS OF 2018-2019 TOTALS OF CLASS CHANGES BY STRATUM

Stratum / Class	Hectares	SE	2.50%	97.50%
HR:2018-2019 Degradation.Degradation	167072.1	6120.2	155076.7	179067.4
LR:2018-2019 Degradation.Degradation	36449.9	2605.7	31342.9	41556.9
MR:2018-2019Degradation.Degradation	69357.4	4458.7	60618.5	78096.3
HR:2018-2019 Forest.Degradation	4182.6	985.4	2251.2	6114
LR:2018-2019 Forest.Degradation	186.9	186.9	-179.4	553.3
MR:2018-2019 Forest.Degradation	5513.8	1264.4	3035.7	7991.9
HR:2018-2019 Forest.Forest	3623535	14097.9	3595903	3651166
LR:2018-2019 Forest.Forest	9857545	9411.4	9839099	9875991
MR:2018-2019 Forest.Forest	4966456	12920.9	4941131	4991780
HR:2018-2019 Degradation.NonForest	464.7	328.6	-179.3	1108.8
LR:2018-2019 Degradation.NonForest	0	0	0	0
MR:2018-2019 Degradation.NonForest	0	0	0	0
HR:2018-2019 Forest.NonForest	6273.9	1206.6	3908.9	8638.9
LR:2018-2019 Forest.NonForest	186.9	186.9	-179.4	553.3
MR:2018-2019 Forest.NonForest	1741.2	710.7	348.2	3134.2
HR:2018-2019 NonForest.NonForest	941552.1	13242.5	915597.3	967506.9

LR:2018-2019 NonForest.NonForest	460950.9	9073.5	443167.2	478734.6
MR:2018-2019 NonForest.NonForest	574012.5	12229.6	550042.9	597982

Table A11 - ANALYSIS OF 2018-2019 proportions OF CLASS CHANGES

	Mean	SE	2.5	%
2018-2019 Degradation.Degradation	0.01317	0.00039	0.01242	0.01393
2018-2019 Forest.Degradation	0.00048	0.00008	0.00032	0.00063
2018-2019 Forest.Forest	0.89052	0.00103	0.8885	0.89254
2018-2019 Degradation.NonForest	0.00002	0.00002	-0.00001	0.00005
2018-2019 Forest.NonForest	0.0004	0.00007	0.00026	0.00053
2018-2019 NonForest.NonForest	0.09541	0.00097	0.0935	0.09732

Table A12 - ANALYSIS OF 2018-2019 proportions OF CLASS CHANGES BY STRATUM

Stratum / Class	Mean	SE	2.50%	97.50%
HR:2018-2019 Degradation.Degradation	0.03522	0.00129	0.0327	0.03775
LR:2018-2019 Degradation.Degradation	0.00352	0.00025	0.00303	0.00401
MR:2018-2019 Degradation.Degradation	0.01235	0.00079	0.01079	0.0139
HR:2018-2019 Forest.Degradation	0.00088	0.00021	0.00047	0.00129
LR:2018-2019 Forest.Degradation	0.00002	0.00002	-0.00002	0.00005
MR:2018-2019 Forest.Degradation	0.00098	0.00023	0.00054	0.00142
HR:2018-2019 Forest.Forest	0.76396	0.00297	0.75814	0.76979
LR:2018-2019 Forest.Forest	0.95193	0.00091	0.95015	0.95371
MR:2018-2019 Forest.Forest	0.88417	0.0023	0.87966	0.88868
HR:2018-2019 Degradation.NonForest	0.0001	0.00007	-0.00004	0.00023
LR:2018-2019 Degradation.NonForest	0	0	0	0
MR:2018-2019 Degradation.NonForest	0	0	0	0
HR:2018-2019 Forest.NonForest	0.00132	0.00025	0.00082	0.00182
LR:2018-2019 Forest.NonForest	0.00002	0.00002	-0.00002	0.00005
MR:2018-2019 Forest.NonForest	0.00031	0.00013	0.00006	0.00056
HR:2018-2019 NonForest.NonForest	0.19851	0.00279	0.19304	0.20398

LR:2018-2019 NonForest.NonForest	0.04451	0.00088	0.0428	0.04623
MR:2018-2019 NonForest.NonForest	0.10219	0.00218	0.09792	0.10646

Table A13 - ANALYSIS OF 2018-2019 TOTALS OF CLASS CHANGES FROM FOREST/DEGRADED

	Hectares	SE	2.50%	97.50%
2018-2019 Forest/Degraded.Degradation	282762.7	8162.2	266765	298760.4
2018-2019 Forest/Degraded.Forest	18447535	21313.7	18405761	18489309
2018-2019 Forest/Degraded.NonForest	8666.8	1450.4	5823.9	11509.6
2018-2019 NonForest.NonForest	1976515	20180.5	1936962	2016069

Table A14 - ANALYSIS OF 2018-2019 TOTALS OF CLASS CHANGES BY STRATUM FROM FOREST/DEGRADED

Stratum / Class	Hectares	SE	2.50%	97.50%
HR:2018-2019 Forest/Degraded.Degradation	171254.7	6193.5	159115.7	183393.6
LR:2018-2019 Forest/Degraded.Degradation	36636.8	2612.3	31516.8	41756.8
MR:2018-2019 Forest/Degraded.Degradation	74871.2	4630.2	65796.1	83946.3
HR:2018-2019 Forest/Degraded.Forest	3623535	14097.9	3595903	3651166
LR:2018-2019 Forest/Degraded.Forest	9857545	9411.4	9839099	9875991
MR:2018-2019 Forest/Degraded.Forest	4966456	12920.9	4941131	4991780
HR:2018-2019 Forest/Degraded.NonForest	6738.7	1250.5	4287.8	9189.5
LR:2018-2019 Forest/Degraded.NonForest	186.9	186.9	-179.4	553.3
MR:2018-2019 Forest/Degraded.NonForest	1741.2	710.7	348.2	3134.2
HR:2018-2019 NonForest.NonForest	941552.1	13242.5	915597.3	967506.9
LR:2018-2019 NonForest.NonForest	460950.9	9073.5	443167.2	478734.6
MR:2018-2019 NonForest.NonForest	574012.5	12229.6	550042.9	597982

Table A15 - ANALYSIS OF 2018-2019 proportions OF CLASS CHANGES FROM FOREST/DEGRADED

Class	Mean	SE	2.50 %	97.50 %
2018-2019 Forest/Degraded.Degradation	0.01365	0.00039	0.01288	0.01442
2018-2019 Forest/Degraded.Forest	0.89052	0.00103	0.8885	0.89254
2018-2019 Forest/Degraded.NonForest	0.00042	0.00007	0.00028	0.00056
2018-2019 NonForest.NonForest	0.09541	0.00097	0.0935	0.09732

Table A16 - ANALYSIS OF 2018-2019 proportions OF CLASS CHANGES BY STRATUM FROM FOREST/DEGRADED

Stratum / Class	Mean	SE	2.50%	97.50%
HR:2018-2019 Forest/Degraded.Degradation	0.03611	0.00131	0.03355	0.03867
LR:2018-2019 Forest/Degraded.Degradation	0.00354	0.00025	0.00304	0.00403
MR:2018-2019 Forest/Degraded.Degradation	0.01333	0.00082	0.01171	0.01494
HR:2018-2019 Forest/Degraded.Forest	0.76396	0.00297	0.75814	0.76979
LR:2018-2019 Forest/Degraded.Forest	0.95193	0.00091	0.95015	0.95371
MR:2018-2019 Forest/Degraded.Forest	0.88417	0.0023	0.87966	0.88868
HR:2018-2019 Forest/Degraded.NonForest	0.00142	0.00026	0.0009	0.00194
LR:2018-2019 Forest/Degraded.NonForest	0.00002	0.00002	-0.00002	0.00005
MR:2018-2019 Forest/Degraded.NonForest	0.00031	0.00013	0.00006	0.00056
HR:2018-2019 NonForest.NonForest	0.19851	0.00279	0.19304	0.20398
LR:2018-2019 NonForest.NonForest	0.04451	0.00088	0.0428	0.04623
MR:2018-2019 NonForest.NonForest	0.10219	0.00218	0.09792	0.10646

Table A17 - ANALYSIS OF 2018-2019 TOTALS OF CLASS CHANGES FROM FOREST

Stratum / Class	Hectares	SE	2.50%	97.50%
2018-2019 Forest.Degradation	9883.3	1613.8	6720.4	13046.2
2018-2019 Forest.Forest	18447535	2143.6	18443334	18451736
2018-2019 Forest.NonForest	8202	1412.6	5433.3	10970.7

Table A18 - 2018-2019 TOTALS OF CLASS CHANGES FROM FOREST BY STRATUM

Stratum / Class	Hectares	SE	2.50%	97.50%
HR:2018-2019 Forest.Degradation	4182.6	985.3	2251.4	6113.8
LR:2018-2019 Forest.Degradation	186.9	186.9	-179.4	553.3
MR:2018-2019 Forest.Degradation	5513.8	1264.3	3035.8	7991.7
HR:2018-2019 Forest.Forest	3623535	1556.6	3620484	3626586
LR:2018-2019 Forest.Forest	9857545	264.3	9857026	9858063
MR:2018-2019 Forest.Forest	4966456	1450	4963614	4969298
HR:2018-2019 Forest.NonForest	6273.9	1206.4	3909.4	8638.4
LR:2018-2019 Forest.NonForest	186.9	186.9	-179.4	553.3
MR:2018-2019 Forest.NonForest	1741.2	710.7	348.2	3134.2

Table A19 - ANALYSIS OF 2018-2019 proportions OF CLASS CHANGES FROM FOREST

Stratum / Class	Mean	SE	2.50%	97.50%
2018-2019 Forest.Degradation	0.00054	0.00009	0.00036	0.00071
2018-2019 Forest.Forest	0.99902	0.00012	0.99879	0.99925
2018-2019 Forest.NonForest	0.00044	0.00008	0.00029	0.00059

Table A20 - ANALYSIS OF 2018-2019 proportions OF CLASS CHANGES FROM FOREST

Stratum / Class	Mean	SE	2.50%	97.50%
HR:2018-2019 Forest.Degradation	0.00115	0.00027	0.00062	0.00168
LR:2018-2019 Forest.Degradation	0.00002	0.00002	-0.00002	0.00006
MR:2018-2019 Forest.Degradation	0.00111	0.00025	0.00061	0.00161
HR:2018-2019 Forest.Forest	0.99712	0.00043	0.99628	0.99796
LR:2018-2019 Forest.Forest	0.99996	0.00003	0.99991	1.00001
MR:2018-2019 Forest.Forest	0.99854	0.00029	0.99797	0.99911
HR:2018-2019 Forest.NonForest	0.00173	0.00033	0.00108	0.00238
LR:2018-2019 Forest.NonForest	0.00002	0.00002	-0.00002	0.00006
MR:2018-2019 Forest.NonForest	0.00035	0.00014	0.00007	0.00063

This analysis is restricted to hectares known to be forest in 2018.

Table A21 - Mean Deforestation (to Degraded/NonForest) per hectare

	Mean	SE	2.50%	97.50%
loss	0.000645	7.89E-05	0.000491	0.0008

Table A22 - Mean Deforestation (to Degraded/NonForest) per hectare BY STRATUM

Stratum	Mean	SE	2.50%	97.50%
HR	0.001979	0.000303	0.001386	0.002573
LR	2.28E-05	1.66E-05	-9.8E-06	5.53E-05
MR	0.000904	0.000189	0.000534	0.001275

This analysis is the amount of deforestation in the area sampled, using the actual area of deforestation per sample.

Table A23 - Mean Area that is not Forest per hectare

	Mean	SE	2.50%	97.50%
Area	0.000524	0.000183	0.000165	0.000884

Table A24 - Mean Area that is not Forest per hectare BY STRATUM

Stratum	Mean	SE	2.50%	97.50%
HR	0.001174	0.000561	7.43E-05	0.002274
LR	0.000321	0.000163	1.80E-06	0.00064
MR	0.000509	0.000489	-4.49E-04	0.001466