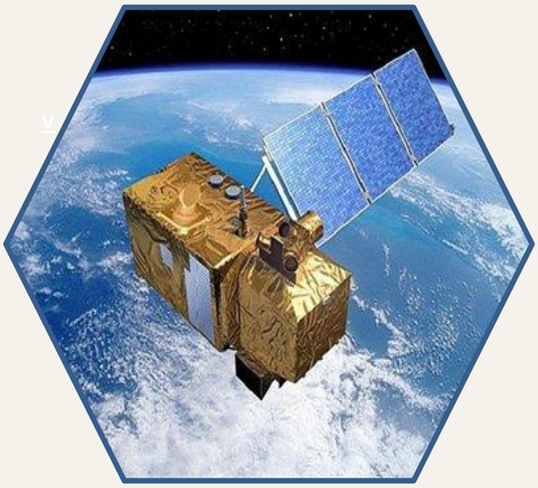
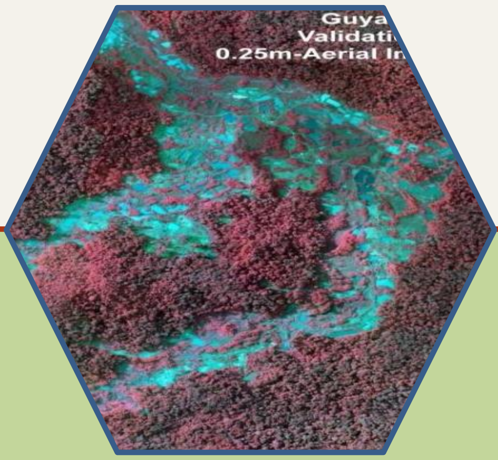
GUYANA

REDD+ Monitoring Reporting and Verification (MRV) System Report

Year 2023





August 2024

DISCLAIMER

GFC makes its best effort to provide accurate and complete information while executing the assignment. GFC assumes no liability or responsibility for any outcome of the Report.

PREFACE

In 2009 Guyana developed a framework for a national MRVS. This framework was created as a “Roadmap[1]” outlining progressive steps over a 3-year period to build towards a full MRVS being implemented. The MRVS was established to provide a national system to monitor, report and verify forest carbon emissions from deforestation and forest degradation in Guyana.

The first year of the MRVS roadmap 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, Phase 2 of the roadmap was developed. Phase 2 sought to consolidate and expand capacities for national REDD+ monitoring and MRV. This supported Guyana in meeting the evolving international reporting requirements from the UNFCCC while continuing to fulfil additional reporting requirements. In 2020, Guyana developed its Phase 3 roadmap. This charted the path forward for the next phase of the MRVS to a fully operational forest carbon reporting platform, suitable for a potential market-based mechanism and meeting all UNFCCC recommendations.

Today the system has advanced and is reporting on annual forest carbon emissions and removals by activities caused by deforestation and forest degradation. 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, particularly forest management. Over the past decade, Guyana’s MRV system has generated a wealth of data that can be used to understand the multiple uses of forests.

To date, thirteen national assessments (2010 to 2023) have been conducted, including the one outlined in this Report. This Report covers the period from January to December 2023.

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

Guyana Forestry Commission

[1] http://www.forestry.gov.gy/Downloads/Guyana_MRV_workshop_report_Nov09.pdf

SUMMARY

In 2020 the Monitoring Reporting and Verification System (MRVS) moved into its third phase in line with tasks set out in the MRVS roadmap. This report presents the findings of the thirteenth national assessment, which covers the period from January 2023 to 31 December 2023.

The MRVS reports, at a national level, deforestation and degradation by change driver and changes within the Intact Forest Landscape (IFL). Deforestation is monitored using satellite imagery, with estimates of degradation resulting from mining and infrastructure computed by drawing a GIS buffer around deforested areas and applying a specific emission factor. Emissions from shifting cultivation and timber harvesting and illegal logging are also reported. The MRVS provides a robust measure of both deforestation and degradation that aligns with Guyana's desire to pursue a low or no-cost REDD+ implementation option – this was an integral part of the Phase 2 objective whilst moving toward total emissions accounting.

Deforestation between 1 January 2023 and 31 December 2023 is 9,353 ha. This equates to an annualised deforestation rate of 0.053%.

As with previous assessments, the Durham University (DU) team has verified the GFC's deforestation area using a statistically representative independent sample. The area of deforestation reported by DU closely aligns with the values reported by the GFC (see Appendix 1).

A summary of the key reporting measures is presented in the following Tables. The total CO_2 emissions for 2023 is 13,936,482 tCO_2e.

Table S1: MRVS Results 2023

Deforestation				
Driver	***Area (ha)***	***Area (%)***	***EF (tCO_2/ha)***	***Emissions (t CO_2)***
Mining and Mining Infrastructure	5,853	62%	1,051	6,153,258.90
Forestry Infrastructure	339	4%	1,051	356,390.70
Infrastructure	541	6%	1,051	568,753.30
Agriculture	475	5%	1,110	527,440.00
Settlements	201	2%	1,051	211,311.30
Fire	1,513	16%	1,053	1,593,189.00
Shifting Cultivation	431	5%	1,106	476,686.00
Deforestation Total	**9,353**			**9,887,029.20**
Forest Degradation				
Driver	***Units***	***Area (See unit)***	***EF (tCO_2/ha)***	***Emissions (t CO_2)***
Timber Harvest Volume	m3	676,030	5.32	3,596,482
Illegal logging	m3	2,209	5.32	11,752
Skid Trails	km	2,556	171.84	439,235
Mining and Infrastructure Roads	ha	1,696	8.1	13,736
Degradation Total				**4,049,453**
Total emissions from Deforestation and Degradation				**13,936,482**

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SUPPORTING APPENDICES

ACKNOWLEDGEMENTS

Along with the Guyana Forestry Commission (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 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.
- Winrock International for work on the forest carbon monitoring system.
- Other Partners

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.

2. OVERVIEW OF GUYANA'S LAND CLASSES

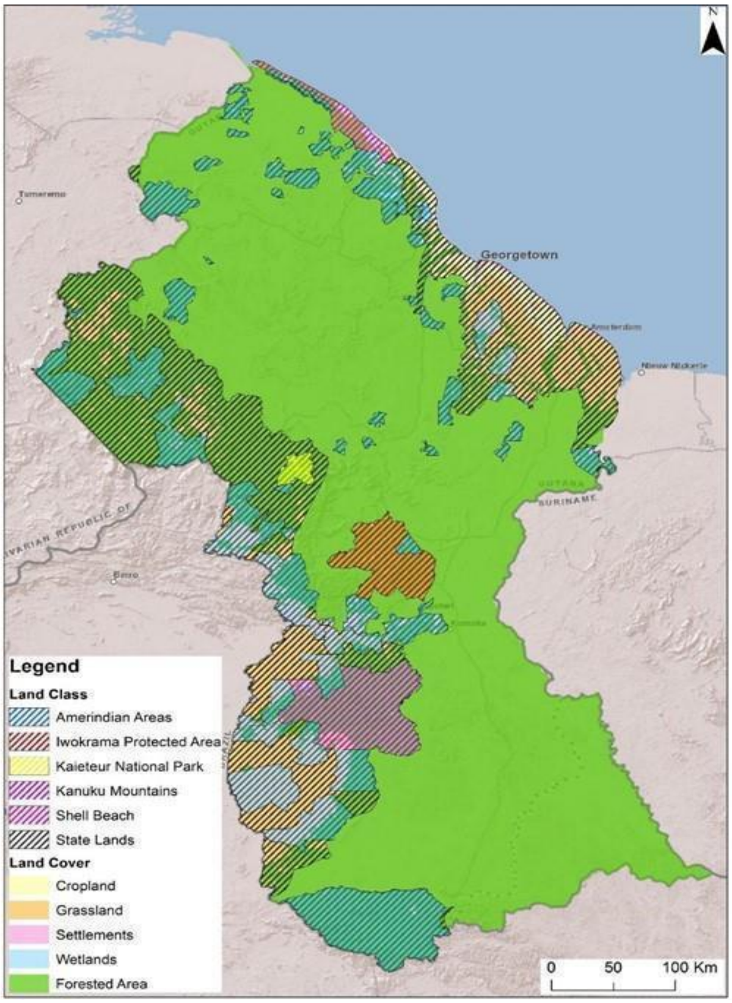


Figure 2-1 Guyana's Land Classes

There are four main tenure classifications in Guyana; the largest is State Forest at 60% of the total land area, followed by State Lands (19%), Amerindian lands (16%), and Protected Areas (5%). At the commencement of the MRVS, 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 the Forest Change SOP. The location of these areas is shown below.

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 is 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 1.1 million ha designated as Protected Areas. Kanashen village is a part of the Protected Area but is listed under Amerindian Lands. With this added to Protected Areas, the total is 1.7M hectares.

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.

Table 2-1 shows Guyana's land area by the adopted IPCC land cover classes, at the start of reporting year.

Land Classes	Forest	Non-Forest					
		Cropland	Grass-land	Settle-ments	Wet-lands	Other Land	Total
	(Area '000 ha)						
State Forest Area	12,013	127	289	30	127	11	12,597
Titled Amerindian Lands (*incl. newly titled lands*)	2,285	332	644	9	26	10	3,306
State Lands	2,428	443	926	44	132	99	4,072
Protected Area	1,088	4	34	0	13	1	1,139
Total Area	17,815	906	1,893	82	298	120	21,114

Table 2-1 Tenure by Adopted IPCC Land Cover Classes 2023

3. DEFINING AND MONITORING FOREST CHANGE

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.

The national forest cover as of 1990, based on this definition, and is used as a start point.

3.1 Guyana's Forest Monitoring System

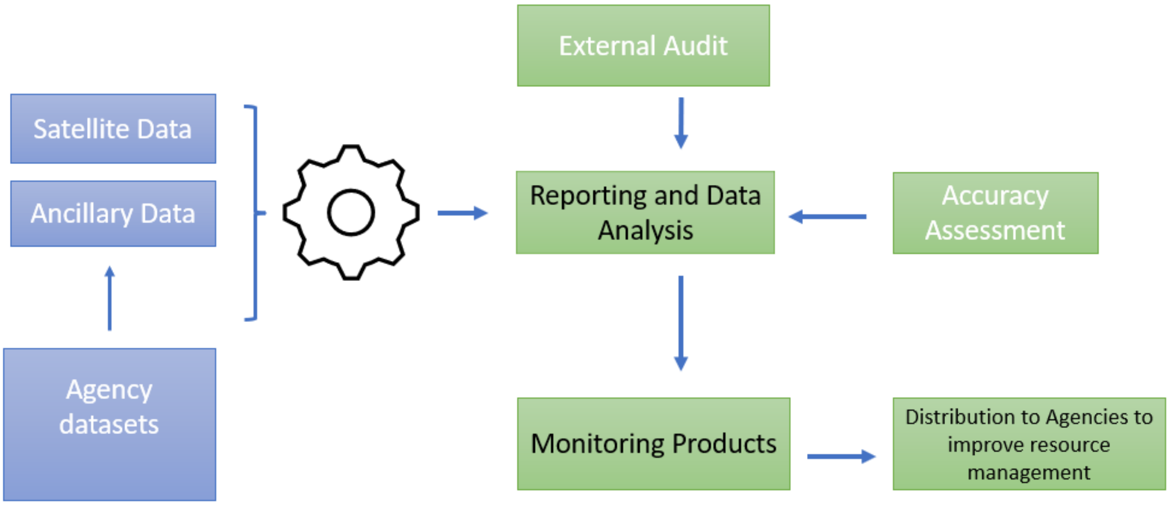
The process developed aims to enable areas of change (>1 ha) to be tracked spatially through time by the driver (i.e., mining, infrastructure, or forestry). The approach adopted seeks to provide a spatial record of temporal land-use change across forested land (commensurate to an IPCC Approach 3). Mapping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

Central to the system are satellite data and the datasets provided by Guyana's agencies. GFC's Forest Area Assessment Unit (FAAU) interprets and analyses these data and generates maps and associated spatial layers required to meet annual reporting requirements. Two external audits are included in the process. The first is the accuracy assessment; since inception, this analysis has been conducted externally by a team from Durham University.

The final layer is input from external auditors who review and verify methods and analytical processes that meet specified reporting requirements.

An overview of the processes, datasets and outputs of the MRVS is given in Figure 3-1. It shows how the different parts of the MRV system are linked and used to generate annual forest change reports.

Figure 3-1 Overview of Guyana's MRVs



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, agriculture, infrastructure, or fire).

The datasets used for the change analysis have evolved. 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 was used.

From 2017, data from the Sentinel (2A/2B) multispectral imagery has been the primary dataset for monitoring deforestation, supplemented by Landsat and fire monitoring datasets.

3.3 Agency Datasets

Several Government agencies involved in managing and allocating 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

Level	Agency	Role	Data Held
Ministry of Natural Resources	Guyana Forestry Commission (GFC)	Management of forest resources	Resource management-related datasets
	Guyana Geology & 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.

4. ACTIVITIES REPORTED

The following Table 4-1 divides the reporting into either deforestation or degradation. Also summarised is an overview of drivers and associated deforestation or degradation activities reported within 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 combined with its visual appearance.

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

Reporting Class	Activity	Driver	Criteria	Supporting Info	Spatially Mapped	End Land Use Class
Deforestation	Roads	Infrastructure	Roads > 10m	Mapped layers, satellite imagery	Yes	Settlements
	Settlements	Settlements	Areas of new human Settlement >1 ha	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
	Agriculture[2]	Deforestation	Deforestation sites >1 ha incl. shifting cultivation occurring outside the village buffer extent	Registered agricultural leases, satellite imagery	Yes	Bareland or crop land
		Fire	Deforestation sites > 1 ha	FIRMs fire points, Spatial trends satellite imagery	Yes	Bareland or crop land
Degradation	Forestry	SFM	Harvested timber volumes and illegal logging totals.	Annual harvest plans, GIS extent of timber concessions	No[3]	Degraded forest by type
	Mining	Degradation	Buffer approach based on mapped mining and infrastructure deforestation areas.	Existing infrastructure incl. deforestation sites post-2011, satellite imagery was used to map the extent. Since replaced with a buffering approach that is computed on mapped deforestation areas.	Yes	Degraded forest by type

5. DEFORESTATION

Guyana's monitoring system is designed to map change events in the year of their occurrence and then monitor any changes over that area each year. If an area (polygon) remains constant, the land-use class and change driver are updated to stay 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.

5.1 Deforestation Definition

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

[3] Only mapped if log landings or market clearance area results in deforestation and the area is > 1 ha

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:

1. Forestry (clearance activities such as roads and log landings)
2. Mining (ground excavation associated with small, medium and large-scale mining)
3. Infrastructure such as roads (included are forestry and mining roads)
4. Agricultural conversion
5. Fire (all considered anthropogenic and depending on intensity and frequency can lead to deforestation).
6. Settlements change, such as new housing developments.

5.2 Deforestation Analysis Methods

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 1:8,000. If a 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 the 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 of the mapping team and is responsible for reviewing each tile as it is completed. Additional 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.

Natural events are considered non-anthropogenic change. They 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.

6. DEGRADATION

Overtime Guyana has developed country-specific methods for accounting for degradation. The method covers the primary sources of degradation including;

1. Forest management-related losses including selective harvesting of timber, logging damage and illegal harvesting. Reporting of these sources started in 2011.
2. Forest degradation surrounding mining sites and road infrastructure.

A short summary of each is included below.

6.1 Forest Management

Forest management includes selective logging activities in natural or semi-natural forests. This measure intends to ensure sustainable forest management with net-zero emissions or positive carbon balance in the long term. The requirement is that areas under sustainable forest management (SFM) be rigorously monitored, and activities documented, such as harvest estimates. The following information is documented by the GFC and available for review.

- Production by forest concession
- Total production.

The reporting requirements include data on extracted timber volumes available for verification. The Gain/Loss method is used as described by the IPCC for forests remaining forests. In addition to harvested volume, a default expansion factor is used to account for losses due to harvesting, i.e., collateral damage.

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 multiple stakeholder groups, and used in national reporting.

The methodology presented used is a module in an approved (double-verified) set of modules for REDD projects posted on the Verified Carbon Standard (VCS) set of methodologies.

For the year CO2 forest management related emissions were 4,035,717 tCO_2e.

6.2 Illegal logging

Reporting on illegal logging activities is done via the GFC's 36 forest stations located strategically countrywide and by field monitoring and audit teams through the execution of both routine and random monitoring exercises.

The rate of illegal logging for the assessment year is informed by a custom-designed database updated monthly and subject to routine internal audits. This database records infractions of illegal logging across Guyana. 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.

For the year CO2 illegal related emissions were 11,752 tCO_2e.

Forest degradation surrounding mining sites and infrastructure is mapped spatially and uses the deforested extent for the mapping year and buffers each site by 100 m. To avoid double counting the buffers are clipped to exclude previous years' degradation buffers. Any buffers that extend into the non-forest layer are also ignored.

7. DEFORESTATION TRENDS

The results presented summarise the forest change from deforestation and forest degradation. 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 of 1990. The forest cover estimated as of 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 a review of higher resolution satellite images. The outcome has been that the forest/non-forest boundaries were improved, but the forest area also changed-particularly at two points in time 2012 and 2014. In 2018, the forest area was revised to remove areas of historic shifting cultivation that surrounded settlements. This change was made based on a further study that concluded that these areas should be considered non-forest which aligns with Guyana's forest definition. In 2022, a further correction was made to the forest area after a review of the historical mapping dating back to 1990 when Landsat imagery was used. This amendment screened the forest change mapping for overlaps, duplication and attribution inconsistencies. This revision identified a further 169,000 ha of non-forest within the GIS. This area was removed from the forest area to give a revised 2022 start forest area of 17 821.55 ha.

Table 7-1 summarises the total change and change percentage for the entire country as a percentage of forest remaining.

Table 7-1 National Area Deforested 1990 to Current

Reporting Period	Assessment Year	Period (year)	Satellite Image Resolution	Start Forest Area	Forest Loss	
				('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	*18 019.35	12.74	0.071
Year 10	2020	1	10 m & 30 m	*18 001.79	10.23	0.057
Year 11	2021	1	10 m & 30 m	17 986.23	7.63	0.042
Year 12	2022	1	10 m & 30 m	17 821.55	6.47	0.036
Year 13	2023	1	10 m & 30 m	17 815.08	9.35	0.053

**Continual forest area updates based on remapping, using high spatial and temporal resolution imagery and removal of historical forest loss that have not regenerated to meet Guyana's Forest definition.*

Overall, Guyana's deforestation rate is low if compared to the rest of South America. The national trend shows that annual deforestation falls between 6,000 to 13,000 ha. Table 7-2Error! Reference source not found. provides a breakdown by forest change drivers, in the representation provided the area values are rounded. From 2022 onwards the area of shifting cultivation that have occurred outside of pre-defined buffers have been included. Inclusion of these areas reconciles the MRVS areas, so these conform with the ART Trees format.

The temporal analysis offers valuable insight into deforestation trends relative to 1990. A more meaningful comparison is provided if the rates of change are divided by driver and annualised.

Table 7-2 Annualised Forest Loss by Period & Driver from 1990 Onwards

Reference Period	Change Period	Reporting Period	Annualised Loss by Driver						Annual Loss
			Forestry	Agriculture	Mining	Infrastructure	Fire	Settlements	
		Year	Annual Area (ha)						(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	10 483	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
	2020	1	195	489	6 452	103	2 933	60	10 232
MRV Phase 3	2021	1	228	216	6 825	117	139	105	7 630
	2022	1	156	437	5 264	111	333	169	6 470
	2023	1	339	906	5 853	541	1 513	201	9 353

** Forest loss areas rounded*

The following table provides a summary of change drivers across each land class.

Table 7-3 Current Area Change by Driver & Land Class

Land Classes	Forest Loss by Driver & Land Class						Total Loss	Proportion of Total (%)
	Forestry	Agriculture	Mining	Infrastructure	Fire	Settlement		
State Forest Area	239	128	5 185	250	427	126	6 355	66%
Titled Amerindian Lands (*including newly titled lands*)	14	274	381	11	338	6	1 025	11%
State Lands / other	60	561	397	282	656	73	2 030	21%
Protected Area	27	7	10	0	102	2	148	2%
Total Area	339	906	5 853	541	1 513	201	9 353	100%

7.1 Trends by Driver

Mining

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 (13,664 ha), which marked a point where the gold price was the highest since 1980.

Forestry

The reported value of 339 ha is increased when compared to the previous year. As in the case of earlier assessments, forest roads are attributed to a forestry driver rather than attributing this change to Infrastructure.

Infrastructure

Infrastructure developments contributed 541 ha which is an increase over historical levels (40 to 342 ha). The area of clearance is in a similar location. The main difference is related to road construction activities and tends to be near townships. There have been a few new hinterland roads constructed to enhance access to villages.

Agricultural Development

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

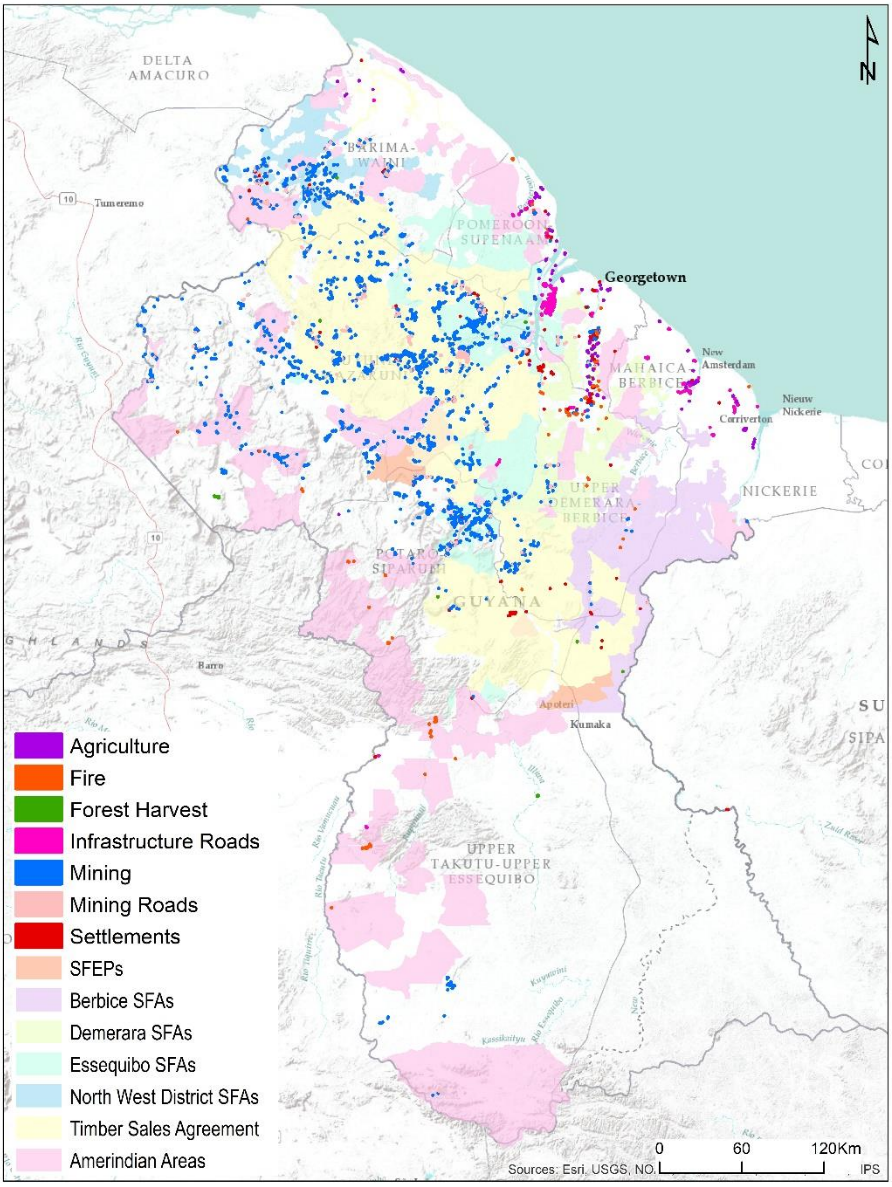
Biomass Burning - Fire

Fire events follow historical trends though significantly higher in year 2023, where events occur in the white sand forest area surrounding Linden and extend towards the eastern border of Guyana. Significant fire events are tied to prolonged dry spells and are most observed in the drier sand and grassland areas.

7.2 Tracking Historic and Current Trends

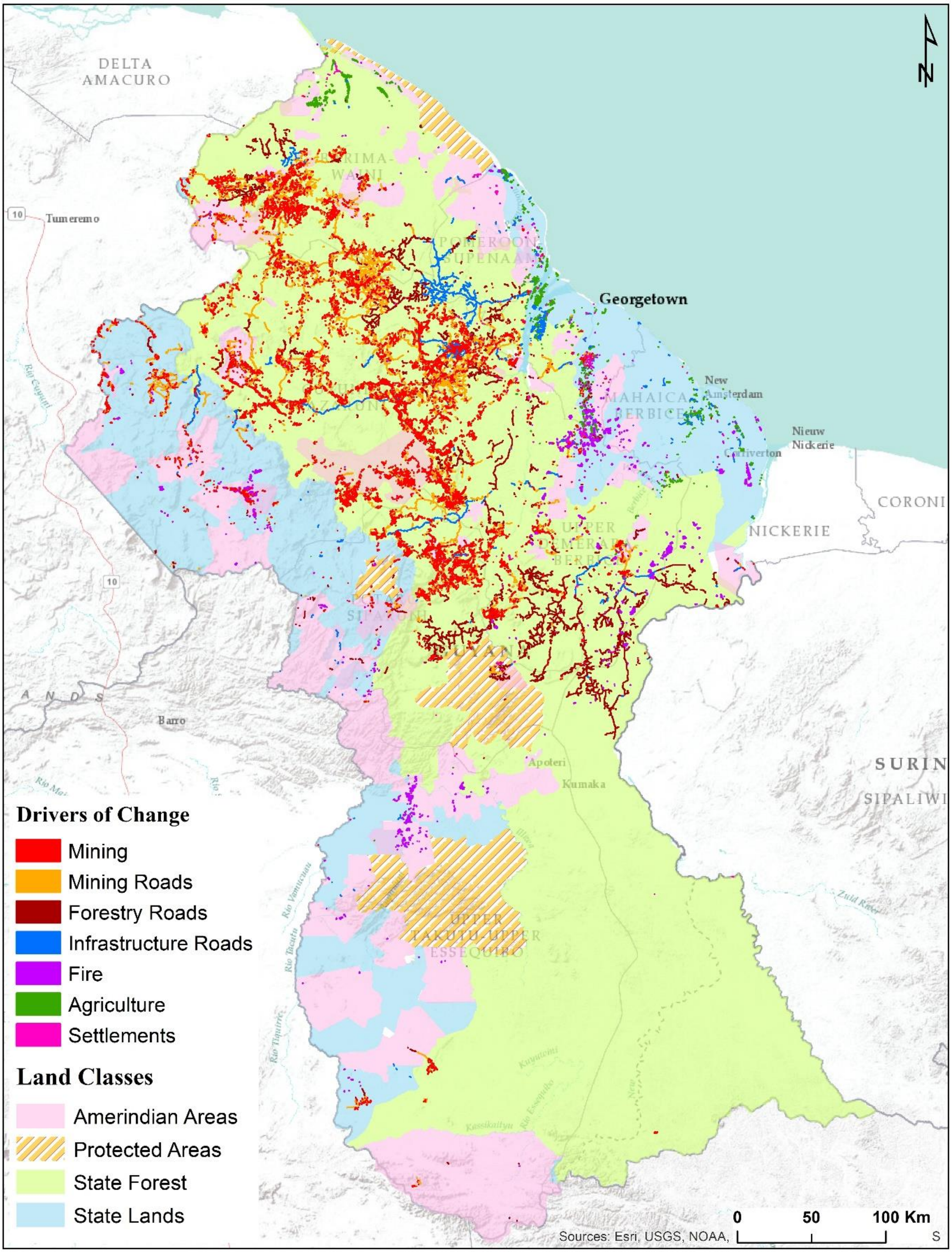
The following maps highlight current and historical deforestation within regions, by change driver and reporting period. Figure 7-1**Error! Reference source not found.** shows an example of the forest change results for 2023. It shows that most of the change is clustered[4] and that new areas tend to be developed near existing activities. Most deforestation activities occur close to or inside the footprint of historical change areas in the north and west.

Figure 7-1: 2023 Deforestation by Driver



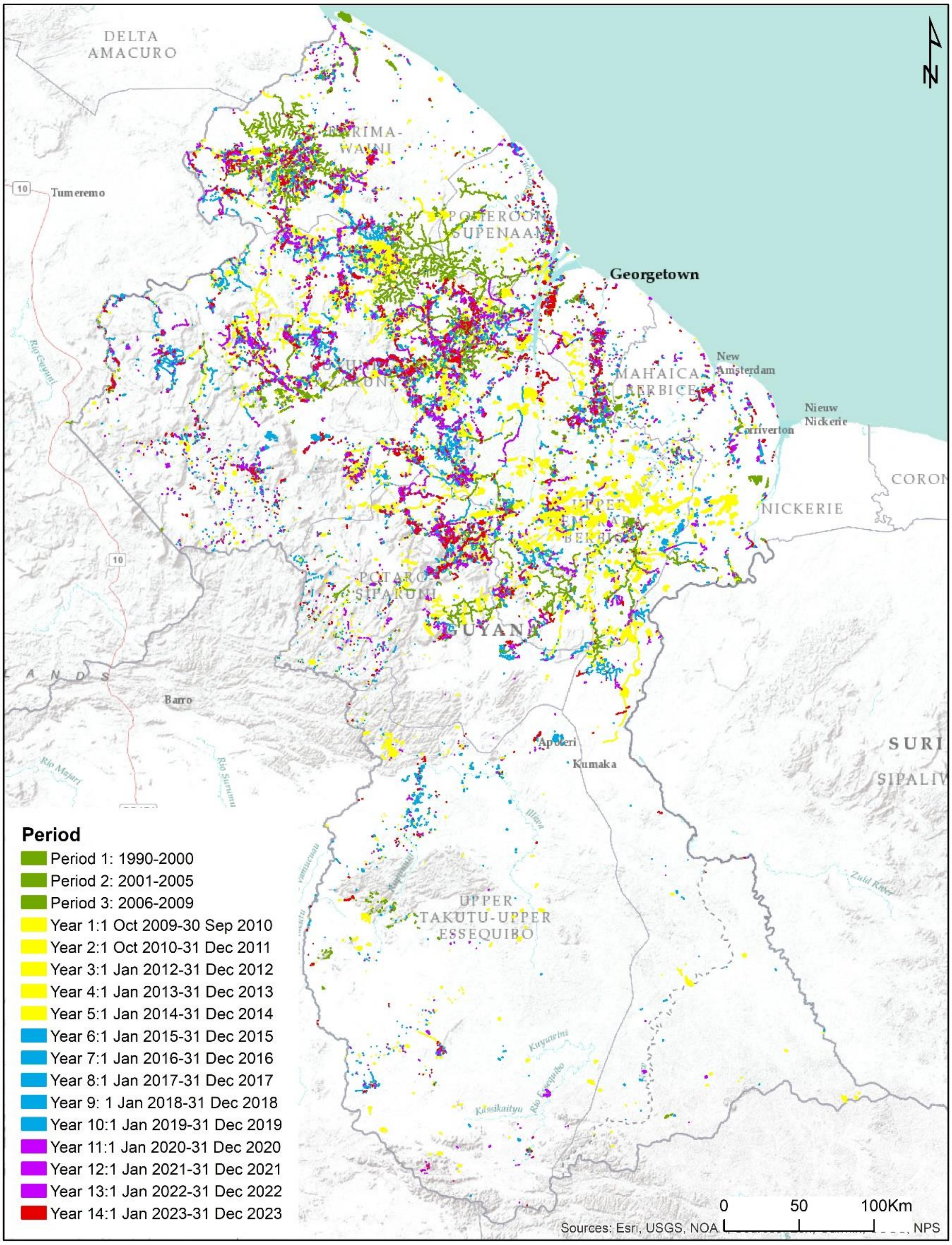
4 For the purposes of display the areas of deforestation have been buffered to make them more visible.

Figure 7-2 (A): 2023 Deforestation by Area



The final map divides the deforestation by monitoring period. The map shows 32 years of change spanning from 1990 to 2023.

Figure 7.2 (B): Deforestation Map Showing Historical Change Trends



7.3 Intact Forest Landscapes

A working definition of IFL was first prepared in 2006[5] by a team of research and environmental groups. By definition, the Intact Forest Landscapes represented large tracts of forest unaltered or fragmented by human impact.

As a REDD+ early mover, IFL was inserted into the Guyana-Norway Agreement to provide a verifiable means of tracking changes within IFL areas. 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. All changes that occur within the IFL are tracked and accounted for. For reference, these changes are included in the dashboard.

The IFL baseline area for Guyana is 7.97 million ha. In 2023 approximately 185 ha was deforested within the IFL area.

The final table reports change to the intact forest landscape relative to the benchmark value. IFL provides a simple measure of forest 'intactness,' i.e., the area of forest within a countries boundary that remains untouched by human impacts.

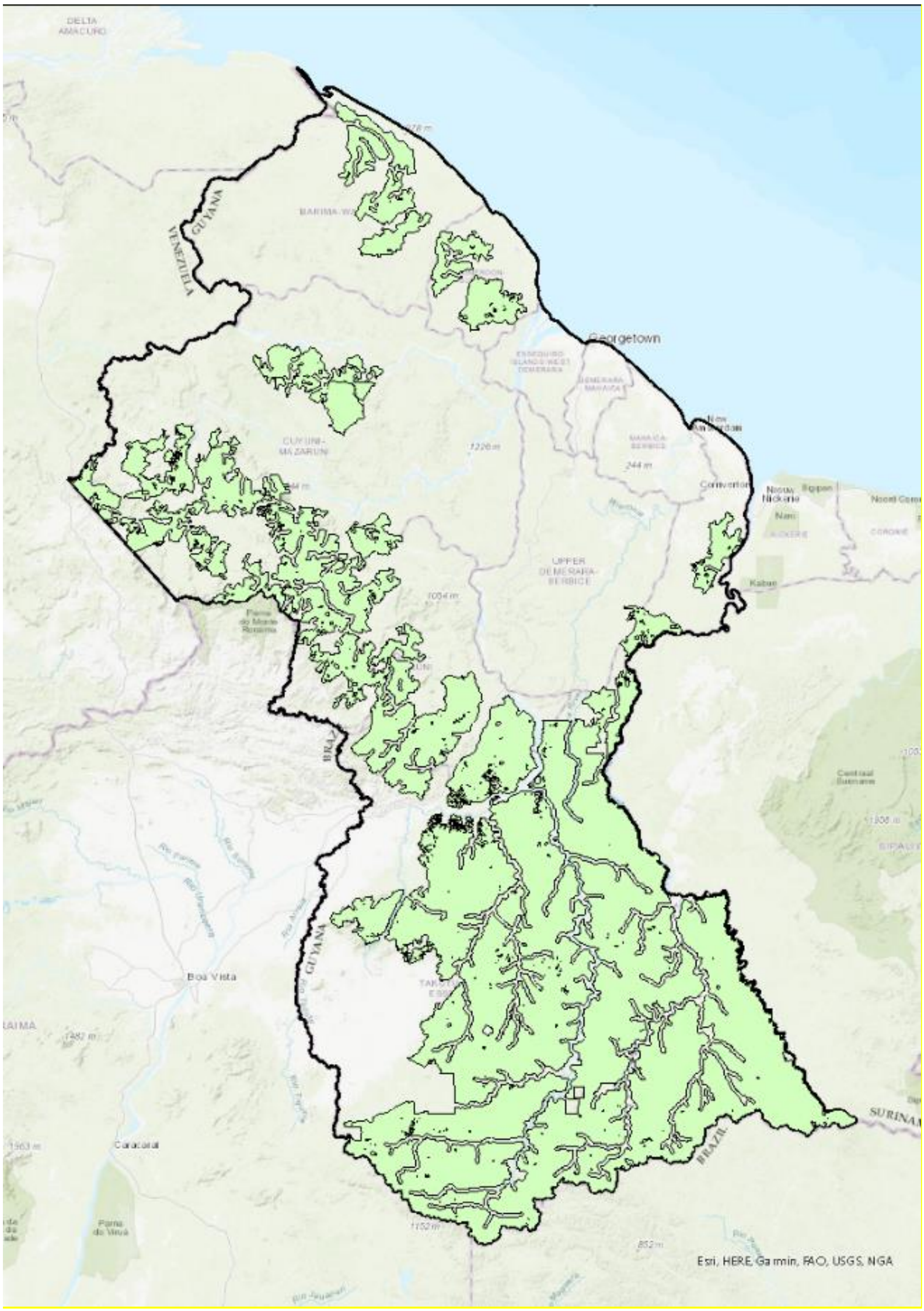
Table S3 MRVS Results 2023 – Intact Forest Landscape

IFL Area	Benchmark	Annual change		
		2021	2022	2023
	Area million (ha)	Change (ha)		
	7.97	240	340	185

The findings of this assessment will assist in designing REDD+ activities that aim to maintain forest cover while enabling continued sustainable development and improved livelihoods for Guyanese.

[5] http://www.intactforests.org/

Figure 7-3: Extent of Guyana's IFL



Appendix 1: Accuracy Assessment Report

Accuracy Assessment Report Year 13 (2023) Guyana REDD+ MRVS

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26 April 2024

8. EXECUTIVE SUMMARY

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 2023. Specifically, the terms of reference asked that confidence limits be attached to forest area estimates.

The methods used in this report follow the recommendations set out in the GFOI and GOFC-GOLD good practice 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 2023. Landsat 8 & 9, ESA Sentinel-2, Planet-PlanetScope and Skysat imagery was used to assess change.

A change analysis using two-stage stratified 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.

The estimate of the total area of change in the 12-month Year 13 period - Forest and degraded forest to Non-forest is 8,250 ha with a standard error of 1,229 ha and a 97.5% confidence interval (5,842 ha; 10,658 ha)

Changes totalling 1 ha were detected within the boundary of the Intact Forest Landscape. These are interpreted as caused by shifting agriculture.

The sample-based estimates for land cover class areas for December 2023 are as follows:

a) Forest = 18,390,591 ha

b) Degraded forest = 1000,337 ha

c) Non-forest = 2,589,853 ha

d) Forest/Degraded Forest to Non Forest Change = 8,250 ha

e) Note that the total area of Guyana in the sample-based estimates is 21,125,900 ha.

9. AREAS OF ACTIVITY

1.1 To assess Year 13 (Year 2023) deforestation, taking note of IPCC Good Practice Guidelines and GFOI and GOFC/GOLD good practice guidelines.

1.2 To outline a methodology for accuracy assessment including an outline of the (1) sample design, (2) response design, and (3) analysis design[6]. For the design component, reference data to be used should be identified, and literature cited for methods proposed. The design must ensure representativeness of the scenes selected for analysis. The sampling specifications used must be stated.

1.3 To support independent verification of the REDD+ interim measures and national estimates of Gross Deforestation 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 12 as an area change total and by driver.

1.4 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 on 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.

1.5 For 2023 (Year 13), 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.

1.6 To use the sample data to estimate the extent of forest degradation for Year 13 for the whole of Guyana and to report error margins/confidence bands and provide verification of the forest degradation rate for Year 13 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.

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

10. AREA REPRESENTATION

The total land area for Guyana is 21,123,486 hectares, calculated from the national boundary Shapefile provided by GFC in 2014. However, the sample areas are based on a 1 km2 mesh that extends slightly over the national boundary Shapefile in some areas and so the sampling area for the Country is 21,125,900 ha. The digital maps contained in the report were obtained from the Guyana Forestry Commission (GFC), the Guyana Land and Surveys Commission (GL&SC). All maps use the WGS 84 datum and are projected to UTM Zone 21N.

10.1 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 / IAP 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 forest area and forest loss assessments in this report do not look at the GFC / IAP mapping, it is an independent analysis. Details of the GFC / IAP mapping are explained in the Standard Operating Procedure for Forest Change Assessment for ART TREES. 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 and to quantify the precision of the estimate of deforestation observed in the Year 12 period. A second task is to identify the processes (drivers) that are responsible for deforestation and forest degradation, and, where possible to estimate the precision of area estimates.

11. SAMPLING DESIGN FOR VERIFYING YEAR 13 FOREST CHANGE

11.1 Change sample design

The Year 13 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 12 (Dec 2022), 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 and Guidelines, Penman et al., 2003). 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 (Olofsson et al 2013).

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, 9, 10, 11 and 12, the GFC Forest Area Assessment Unit (FAAU) used Landsat and Sentinel-2 imagery as the primary mapping tool. The Y13 response design used Planet PlanetScope & Skysat, 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 assessment was based on interpretation of Sentinel-2 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, normally 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 2000-2022 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 Guyana Forestry Commission's Standard Operating Procedure for Forest Change Assessment for ART TREES outlines approaches used to minimize 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).

11.2 Response Design

Table 3.1 summarises the data available to validate the deforestation and forest degradation change estimates for 2023, that is the end of 2022 (year 12) and the end of 2023 (Year 13). 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)

Satellite	Time period	Resolution (m)	Spectral	Revisit	Radiometric
Skysat	Sept-Dec '22 & '23	Varies sub-metre	B, G, R, NIR	Sub-daily	16-bit
Planet	Aug-Dec 2022 and 2023	3m	B, G, R, NIR	Sub-daily	12-bit
Sentinel-2	Aug-Dec 2022 and 2023	10m	B, G, R, NIR	5 days	12-bit
Landsat 8,9	Aug-Dec 2022 and 2023	30 m	B, G, R, NIR, SWIR	8 days	12-bit

A critical component of any accuracy assessment is the need for appropriate reference data (Herold *et al.*, 2006; Powell *et al.*, 2004). It is often the case that reference data itself contains errors and is not a gold standard and at least one study reports large differences of the order of 5-10% between field- based and remotely sensed reference data (Foody, 2004, 2010; Powell *et al.* 2004). Therefore, a key aspect of the response design is to use reference data that allow forest / non- forest land cover to be classified with certainty. Year 13 deforestation and degradation was mapped by the IAP/GFC team from Sentinel-2 imagery and PlanetScope monthly mosaics, while the accuracy assessment primarily used PlanetScope, and Skysat imagery supplemented by the detailed reinterpretation of Sentinel-2 satellite imagery in parts of Guyana that were within the Low-Risk stratum.

For 2023, as with the period 2016-22, forest degradation was not mapped wall-to-wall across Guyana. The level of degradation was estimated from a change analysis of reference data using a two-stage stratified sample with randomisation of the first stage sample transects. The change analysis interpreted land cover at two time periods using the best available reference data - primarily PlanetScope, and Skysat imagery supplemented by reinterpretation of Sentinel-2.

The degradation analysis was carried out by the Durham mapping team (three persons) using a rules-based approach that is described in the Standard Operation Procedure for degradation assessment. Note that the definition of forest degradation requires the interpreter to make a quantitative assessment of the area of forest lost and to record the loss as a proportion of each hectare sample analysed. Even though the interpreter has access to the area 'measure tool' within ArcMap, any misinterpretation or miscalculation of change is most likely to arise from human-error or interpretation using poor quality imagery or areas partially obscured by cloud or cloud shadow. In addition to assessing evidence for land cover change, the interpreter is required to assign a driver to every sample area that exhibits change. The choice of change driver is selected from a drop-down menu of known reasons for deforestation and forest degradation. However, the process of selecting a change driver is subjective and depends on the knowledge of the interpreter and the level of care taken in interpreting the imagery and with following the definitions / rules and respecting the exclusions (e.g. Table 3.2) specified in the SOP.

Table 3-2 – Year 13 Deforestation and Forest Degradation Assessment Exclusions

Reference	Criteria
1	Land use change that occurred prior to 1 January 2023 or after 31 December 2023
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.

11.3 Planet: PlanetScope and Skysat

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). While in 2020 the PlanetScope imagery was found to be of varied quality with different radiometric integrity displayed by different sensors, and on some occasions the imagery was offset, in 2021 and 2023 the PlanetScope imagery was substantially better both radiometrically and geometrically, but not perfect. 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[7].

Skysat: The Skysat mission comprises a constellation of 21 satellites offering sub-metre spatial resolution, in three groups: Skysat-1 and -2 [A/B Generation] with 0.86m Panchromatic and 1.0m multispectral resolution; Skysat-3 until -15 [C Generation, sun-synchronous] with 0.65m Pan and 0.81m MS resolution; and Skysat-16 until -21 [C-Generation, non-sun-synchronous] with 0.57m Pan and 0.75m MS resolution. The sub-daily revisit time that these satellites provide can increase the chances to acquire cloud-free imagery.

11.4 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, but only Level-1C (orthorectified product) is provided to users. The Sentinel Toolbox[8] 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. For the periods Aug-Dec 2022 and Aug-Dec 2023, Google Earth Engine was used to select the best cloud-free images that matched the target sampling period. These were clipped to the buffered PSUs and downloaded. The S2 provided via GEE was level 1C, and cloudiness was calculated using the pre-processed Cloud Score+ dataset available on Google Earth Engine (Pasquarella et al., 2023).

GFC acquired multiple Sentinel-2 scenes to cover the whole land area of Guyana for Aug-Dec 2022 and Aug-Dec 2023. Multiple scenes area required to cope with cloud cover.

11.5 Sampling Design for Change Analysis

The sampling design refers to the methods used to select the locations at which the reference data are obtained. As the area of the country is large, and deforestation is observed to be clustered around

[7] http://www.planet.com/explorer (last accessed: December 2021)

[8] https://earth.esa.int/web/sentinel/toolboxes/sentinel-2 (last accessed: December 2021)

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 that using simple random sampling (Stehman and Czaplewski, 1998; Stehman, 2009; Potapov *et al.*, 2014).

To assess the area and rate of deforestation, a two-stage sampling strategy with stratification of the primary units was adopted. As the deforestation events are dynamic, it has been necessary to re-stratify approximately every three years. The stratification in Y11 was based on historical deforestation events prior to Y11. As such, 100% of the mapped deforestation in Y10 fell within the High-Risk stratum. In Y11, about 90% of the mapped deforestation fell within the High-Risk stratum. In Y12, about 75% of the mapped deforestation fell within the High-Risk stratum. Because of this trend, a re-stratification was needed in Y13 that would increase the probability of capturing the deforestation within the High-Risk stratum samples.

Regarding the size of the second stage sample unit, the minimum area that can be ordered from the VHR imagery archive is one sq.km, and so this is the minimum size adopted (i.e. not smaller than one sq.km). As for a larger size, 95% of Guyana's deforestation takes place in plots less than 10ha in size (see figure 1). Therefore, the size of one sq.km seems sufficient.

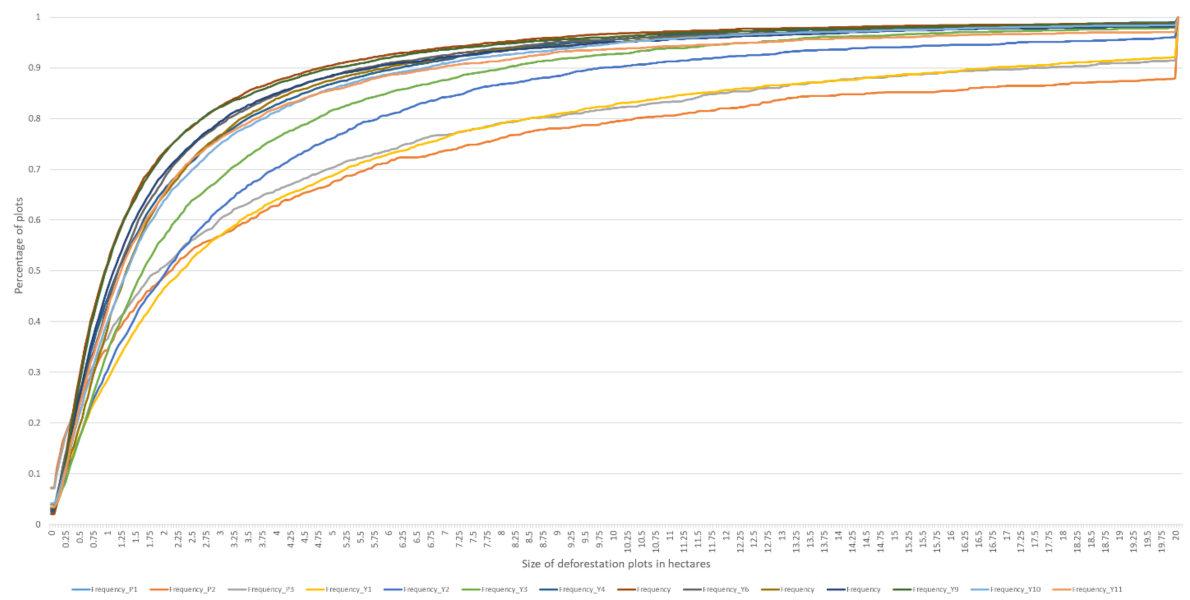

Figure 2 – With the exception of the three first periods and Y1, all other periods have 90% of the detected deforestation plots at an area of less than 10ha, while Y3-9 and Y11 have 95% of the plots below 10ha.

Regarding the shape of the strata unit, the satellite imagery pixels are square. For this, rectangular or square would be the right shapes to avoid sub-pixels especially when assessing change with imagery from Sentinel-2 (10m pixel size), or Landsat (30m pixel size). As there is no reason for a particular orientation in the shape, the square shape seems appropriate.

First, a square grid of 1 km by 1 km in size was created within the spatial extent of the country's national boundary[9]. Gridding resulted in 211,259 squares (see figure 2); note that only rectangles with a centroid within the Guyana national boundary were selected.

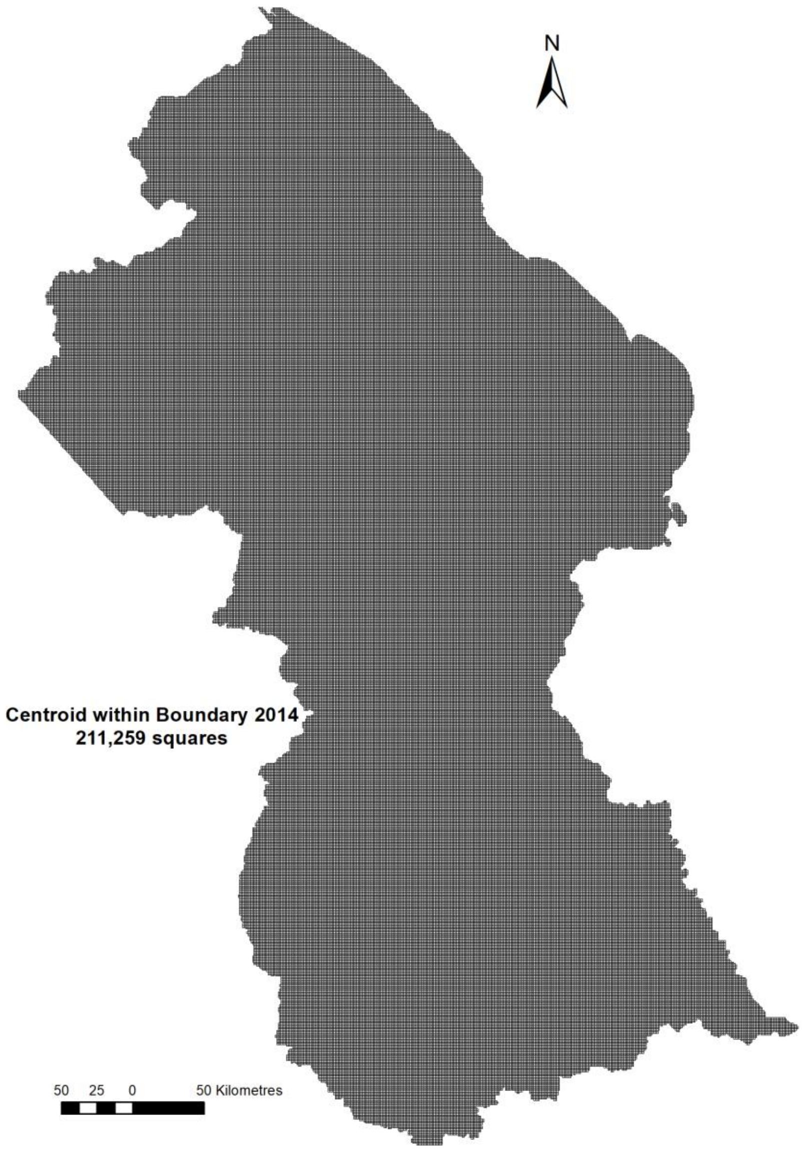

Figure 2 – Guyana broken down to 211,259 one sq.km squares. This forms the basis for the stratification.

Strata are based on actual observations of deforestation (particularly Years 1 to 12[10]). 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 000000110000 intersects deforestation events that were recorded in Years 7 and 8. By using this record, it is easy to identify areas of persistent deforestation (see figure 3).

[9] According to the Interim Measures Report November 2015, the national boundary (that was used for the stratification) was defined with the aid of updated RapidEye ground control points, which resulted in an increase in spatial accuracy of the imagery.

[10] Note that in GFC mapping Y13 is the Jan-Dec 2022 period, while the Jan-Dec 2021 period is mapped as Y12.

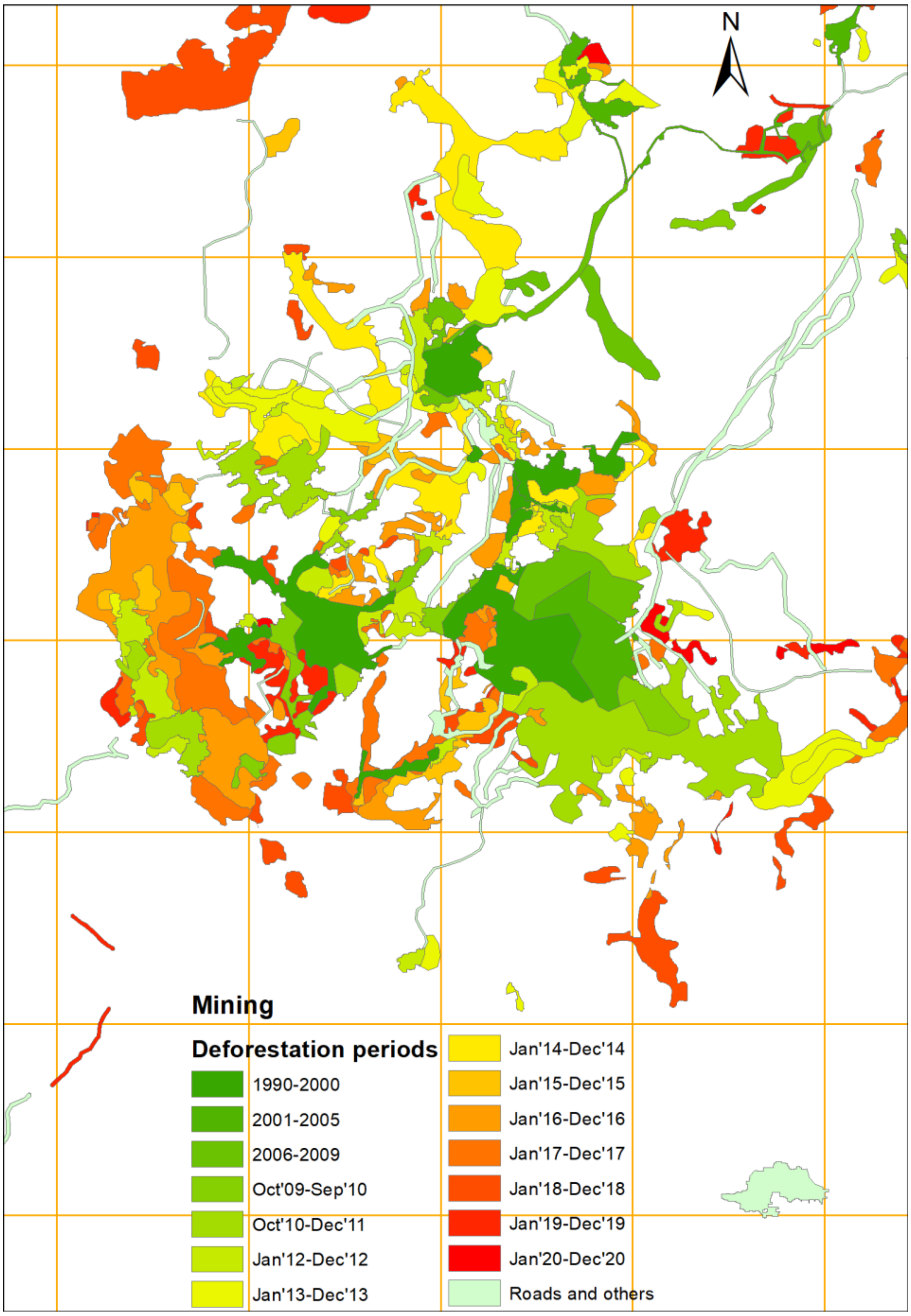

Figure 3 – This is an example of an area where deforestation happens almost every year. In this particular example, the change driver is mining. Most of the deforested areas are adjacent to each other, that is, new deforestation events appear clustered close to already deforested land.

These areas provide a good indication of the patterns of deforestation for each change driver. For example, in figure 3, the mining operations remove forest mostly adjacent to the operations, year-by-year. While placing the mining areas within the High-Risk stratum, there should be a consideration of how deep into the inaccessible forest a mining operation may proceed within the year. Figure 1 illustrated an expectation that 95% of the areas of forest loss will be less than 10 ha. After placing a *minimum bounding geometry* around deforestation with mining as driver, the maximum width for these less-than-10-ha areas was 895 m. Therefore, for mining areas, to capture expanding deforestation, a buffer of 900m can reasonably be applied and so include more squares in the High-Risk stratum.

When deforestation events have been observed for the last two years, then the sample square was assigned to the High Risk (HR) stratum. A buffer of 900m was then applied to include more sample squares in the High-Risk stratum. All other sample squares were assigned to Low Risk (LR) stratum.

This resulted in the classification of sample squares into three strata: 28,225 HR, 174,082 LR, and 8,952 0R (zero risk) (see figure 3.1 – left). Proportionally, aiming for a total of 1,000 randomly sampled squares, 126HR and 874LR were selected. However, the minimum order of VHR data (Skysat) resulted to 140 scenes. For this, 156HR and 874LR were the final selection (see figure 3.1 – right).

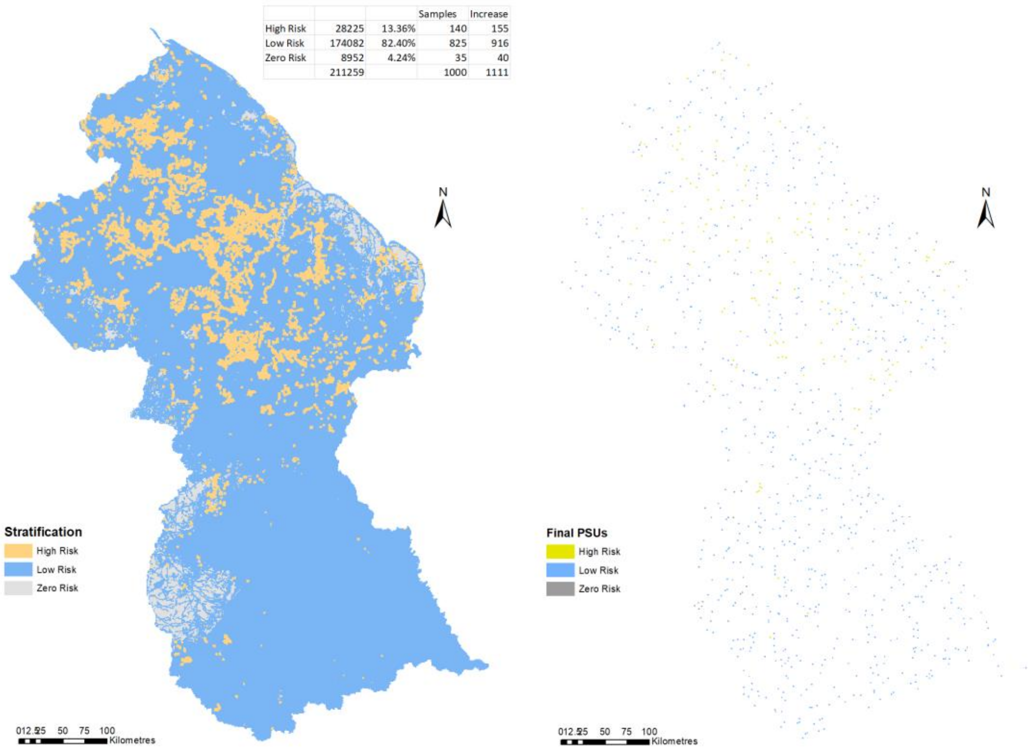

Figure 3.1 – High and Zero Risk strata (left) and final random sampling of the strata (right image).

Within each first-stage sample, a systematic grid of 100 hectares was generated. The centre point of the each of the first-stage samples was generated randomly. In total 107,300 one-hectare samples became available for accuracy assessment.

For each primary sampling unit (PSU), the land cover class (e.g. Forest or Non-Forest, Degradation or Non- Degradation) is determined for the Year 13 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 13 land cover change included high resolution satellite imagery (see Table 3.1). Also available were GIS data indicating mining, forestry and agricultural concessions.

Year 13 Change Assessment involved the collection of 1073 equally sized primary sample units (each with 100 ha) with a direct correspondence with Year 12. The reference data selected for the change assessment in Year 13 was a combination of PlanetScope, Skysat and Sentinel-2 imagery for the High-Risk stratum, and Sentinel-2 and Landsat imagery for the Low Risk stratum.

11.6 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 13 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 validation team consists of two qualified and experienced image interpreters. 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. The procedure uses an ArcMap Change-Assessment Toolbar and follows 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.

11.7 Decision Tree for 2023 (Year 13) 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 12 and 13 are assessed.
2. Areas of shifting cultivation are classified as “Pioneer” and “Rotational” even if they are smaller in size than the minimum mapping unit (1 ha). “Pioneer” areas are evaluated as deforestation and “Rotational” as forest degradation.
3. Areas of water bodies are classified as non-forest.
4. Areas of cloud and shadow or missing data are labelled as Omitted.
5. Areas representing Year 14 change (post Dec 2023) were also omitted from the analysis as this change postdates the Year 13 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 2022 imagery (Skysat, PlanetScope, Sentinel-2 or Landsat) and 2023 imagery (Skysat, PlanetScope, Sentinel-2 or 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.

12. STATISTICAL METHODOLOGY

12.1 Change Sample Estimates

We treat the design as a stratified cluster design. The clusters are squares. The strata are HR and LR. A simple random sample of squares from each stratum is taken. Then, within each rectangle, all hectares are systematically evaluated, and all change is measured quantitatively. This sample design primarily used Skysat and PlanetScope imagery supplemented by reinterpretation of Sentinel-2 satellite imagery in parts of Guyana that were within the Low-Risk stratum.

The reference data consisted of 1073 primary sample units stratified into HR (2,822,500 ha), LR (17,408,200 ha), and Zero Risk (895,200 ha) areas as described in the sampling design (Section 11) 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; (3) the sampling fraction in each stratum is proportional to the total population and that the relative sample size reflects, in this case, a ratio of 65:35 between HR and LR stratum respectively.

The total number of 1 ha samples analysed in the whole survey was 107,300. Of this total only 194 were omitted due to cloud cover or cloud shadow in the reference imagery. The proportion of the total omitted is 0.0018 which represents 0.2 % of the sample. This is much reduced on the 2.8% from the previous year. Key inputs to the analysis are the total number of samples in each stratum. These are 2,822,500 ha (15,500 sampled hectares) for HR, 17,408,200 (91,800 sampled hectares) for LR, and 895,200 ha (200 sampled hectares).

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

12.2 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[11] 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

$$(W, Y) = (w_{hij}, y_{hij})$$

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

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

Where

$h = 1,2, \dots \dots \dots, H$ 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

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

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

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

Where $\hat{\hat{Y}}$ is the estimate of the mean, $StdErr\left(\hat{\hat{Y}}\right)$ 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

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

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

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

13. RESULTS

13.1 Estimates of forest cover in 2022 (Year 12)

We can ignore that we have Year 13 information and obtain estimates of Year 12 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 Dec 2022 (Year 12) is 18,399,957 ha, standard error 20,256 ha, and 97.5% confidence interval (18,360,257; 118,439,657) 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 2021 is 0.8972, standard error 0.001, 97.5% confidence interval (0.8953, 0.8999). Note that proportions add to one.

Table 5.1 Analysis of Y12 (2022) hectares of all classes

	Area	SE	2.5%	97.5%
Degraded forest	99,220	4,285	90,822	107,619
Non-degraded forest	18,399,957	20,256	18,360,257	18,439,657
Non-forest	2,589,853	19,876	2,550,898	2,628,809

Table 5.2 Analysis of Y12 (2022) proportions of all classes

	Mean	SE	2.5%	97.5%
Degraded forest	0.0047	0.0004	0.0043	0.0051
Non-degraded forest	0.8725	0.0100	0.8706	0.8744
Non-forest	0.1228	0.0009	0.1210	0.1247

13.2 Estimates of forest cover in 2023 (Year 13)

We now repeat these analyses for Year 13. 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 13 is 18,390,591 hectares, standard error 20,290 hectares, and 97.5% confidence interval (18,350,824; 18,430,358) hectares. Table 5.4 shows proportions instead of totals. Otherwise, the interpretation is as for Year 12.

Table 5.3 Analysis of Y13 (2023) hectares of all classes

	Area	SE	2.5%	97.5%
Degraded forest	100,337	4,309	91,892	108,782
Non-degraded forest	18,390,591	20,290	18,350,824	18,430,358
Non-forest	2,598,103	19,907	2,559,086	2,637,121

Table 5.4 Analysis of Y13 (2023) proportions of all classes				
	Mean	SE	2.5%	97.5%
Degraded forest	0.0048	0.0002	0.0044	0.0052
Non-degraded forest	0.8720	0.001	0.8702	0.8739
Non-forest	0.1232	0.0004	0.1250	0.1250

13.3 Estimates of change from Year 12 to Year 13

We analyse change from Year 12 to Year 13 as follows. We have matched pairs of sample data, where the hectares seen in Year 12 are seen again in Year 13. 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 12. If the classification had been Forest (non-degraded), the possibilities are Forest in Year 12 and Year 13, Forest in Year 12 and Degraded in Year 13, and Forest in Year 12 and Non-Forest in Year 13. Therefore, these will result in a total of nine possible combinations of change.

Table 5.5 Totals of Class Changes from Forest for 2022-2023 areas in hectares				
Stratum / Class	Forest loss	SE	2.50%	97.50%
Forest/Degraded to NonForest (not including 'natural' change drivers)	8,250	1,229	5,842	10,658

In Table 5.5 we estimate the area of Guyana which was classified as Forest, including degraded forest in Year 12 and Non-Forest in Year 13. The estimate is 8,250 hectares, standard error 1,229 hectares, 97.5% confidence interval (5,842 ha; 10,658 ha). Appendix 1 gives the same information as Table 5.5 but disaggregated by stratum and by proportions rather than totals.

In Year 13 the GFC mapping team found no change from Non-Forest to Forest or Degraded Forest to Forest (i.e. reforestation). Note that it would be difficult to identify reforestation with any certainty in the LR stratum because only Sentinel- 2 data are available. Nevertheless, no reforestation was found in the HR stratum using the high resolution Skysat, PlanetScope or Sentinel-2 imagery. Note that, although not a formal requirement of the accuracy assessment, 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 0.25 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 4,054 hectares, standard error 864 hectares, 97.5% confidence interval (2,360 ha; 5,747 ha).

13.4 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 12 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 and degraded forest in Year 12 changed to non-forest in Year 13 is 8,250 hectares with a standard error of 1,229 hectares, 97.5% confidence interval (5,842 ha; 10,658 ha). These changes translate into a mean rate of deforestation on 0.022 % with a SE of 0.003 % with a 97.5% confidence interval for the rate of change of 0.015 % to 0.028 %, see Table 5.6.

Table 5.6 Mean Deforestation annual rate per hectare (%)

	Mean	SE	2.5%	97.5%
Year 13 (2023) Forest loss	0.029	0.005	0.018	0.039

13.5 Deforestation rate comparison

Table 5.7 shows the Year 12 to Year 13 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 and HR strata. Year 13 shows the lowest rate of change according to the sample-based change estimates.

Table 5.7 Comparison of Forest Change Estimates Source

	Area change (ha)	Change Rate (%)	SE Rate (%)
GFC / Indufor GIS Map Estimate	9,353	0.053	
Change Sample Estimate (not including 'natural')	8,250	0.029	0.005

13.6 Drivers of Deforestation

Table 5.8 shows the deforestation data broken down by driver for the assessment sample. This shows that 70.7% of deforestation is associated with mining, 17.9% with settlement infrastructure, 9.1% with shirting agriculture and 2.3% unknown or natural change. The results confirm GFCs conclusion that mining and mining-related infrastructure including settlements is the overwhelming driver for deforestation in Year 13 (2023).

Table 5.8 Drivers of Deforestation excluding 'natural'				
Driver	Area in ha	SE	2.5%	97.5%
Agriculture				
Mining	5,835	834	3815	7,855
Settlements	1,473	520	452	2,490
Fire				
Shifting agriculture	752	269	15	1,490
Unknown	190	190	-182	563
Total	8,250	1,229	5,842	10,685

14. DISCUSSION

The results are divided into three areas that warrant further discussion:

i. the strategy used to identify and quantify deforestation and estimate change area from imagery;
ii. estimation of the drivers of forest loss;
iii. quality of the imagery needed to undertake the assessment.

Quantifying deforestation level

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 slightly lower 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 imagery and so areas identified as deforestation might, in fact, be forest degradation and vice versa.
2. The overall amount of deforestation is very 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 0.89% of samples omitted because of cloud cover is lower in Y13 than the 2.8% observed in Y12 and this is likely due to the use of multiple sources of imagery (Landsat, Sentinel, PlanetScope and Planet-Skysat.
4. The accuracy assessment for deforestation did not check the GIS map product, rather it estimated forest loss from an independent probability-based sample.
5. The uncertainty in interpreting either change or the driver for change and is recorded on a four-interval percentage scale confidence score. The score was above 75% certainty in 85% of cases where change from Forest to Non-Forest was identified.

In figures 6.1-6.2, different examples are presented that illustrate the quality of the data and how it is used in the sample-based estimation process noting the rules as described in the standard operating procedures.

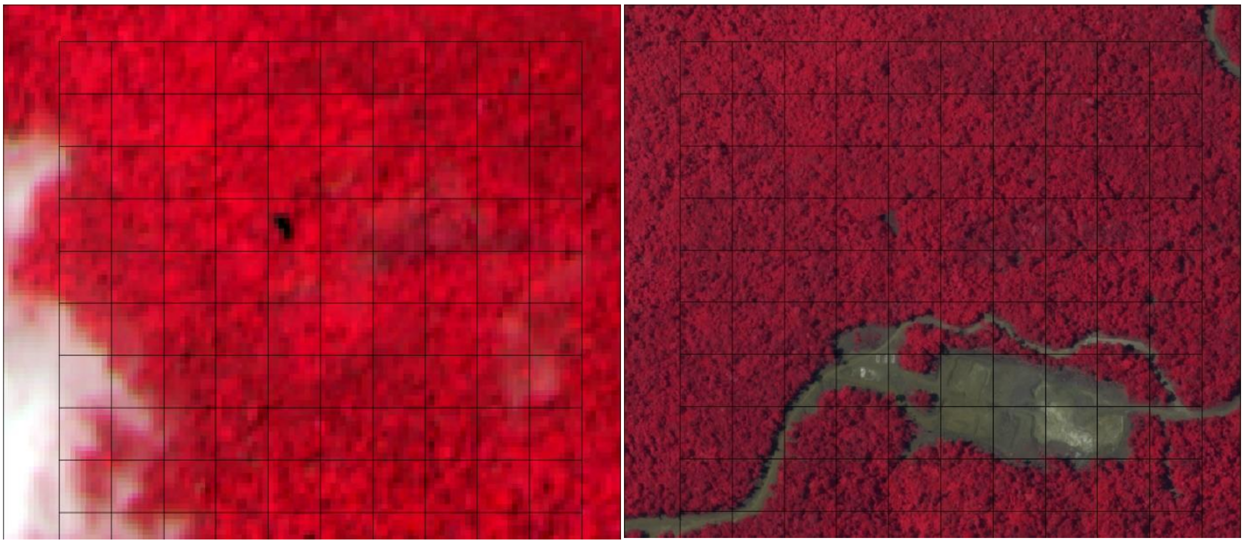

Figure 6.4 – Sentinel-2 imagery (20 October 2022) and Pan-sharpened Skysat imagery (25 September 2023) of PSU – 154 showing forest loss due to Mining.

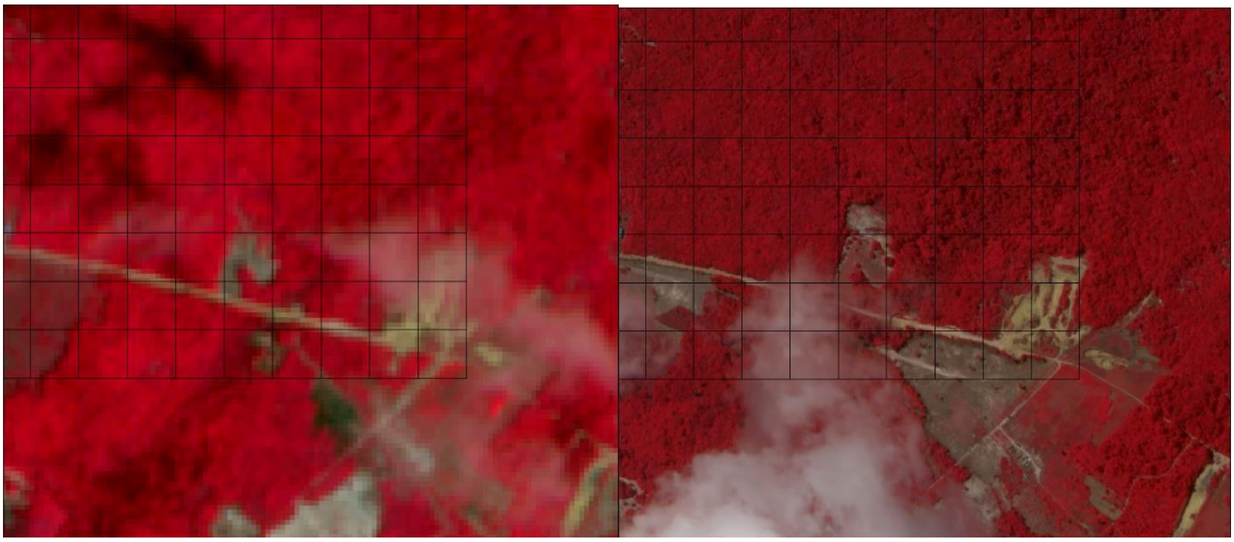

Figure 6.2 – Sentinel-2 imagery (22 October 2022) and Pan-sharpened Skysat imagery (09 September 2023) of PSU – 78 showing forest loss due to Settlement.

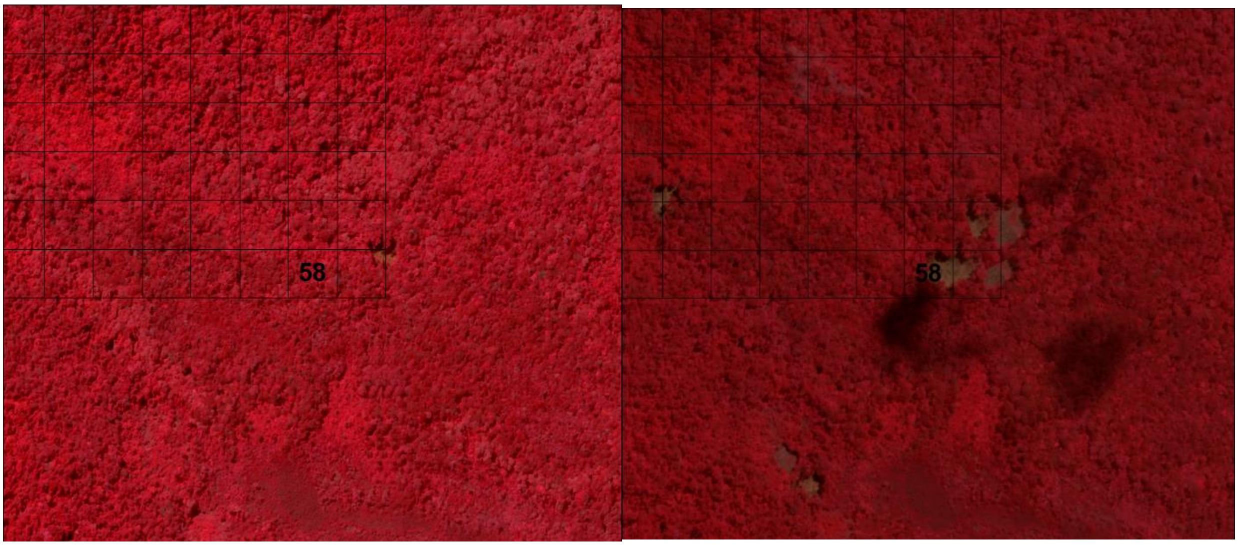

Figure 6.3 – Pan-sharpened Skysat imagery (04 September 2022) and Pan-sharpened Skysat imagery (04 September 2023) of PSU–063 showing forest loss due to shifting cultivation.

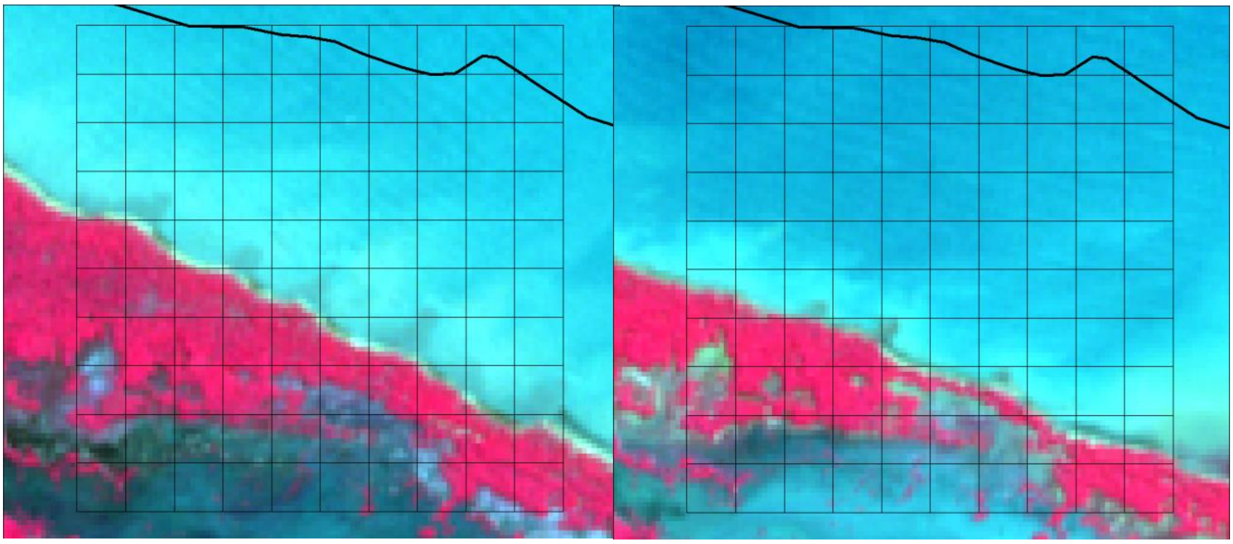

Figure 6.4 – Sentinel -2 imagery (15 August 2022) and Sentinel-2 imagery (05 August 2023) of PSU - 896 showing forest loss due to coastal Mangrove loss. The black line at the top shows the coastline in 2014.

14.1 Image Datasets for Deforestation Mapping

The strategy for accuracy assessment in year 12 and Year 13 makes use of fine (sub-metre pixel size) and medium-fine (3-10 m) spatial resolution satellite imagery. Table 3.1 details the types of imagery used for the reference data set where the pixel size varies from sub-metre (SkySat) to 3m (PlanetScope) and 10m (Sentinel 2 MSI). It must be noted that acquiring suitable cloud-free satellite imagery presents a considerable challenge and a risk to the project. In previous years, contracts were awarded to two different suppliers for the fine resolution data, and their ability to deliver on these contracts varied between a 20% success rate for MAXAR and a 65% success rate for Planet for SkySat data[12]. For the 2023 assessment period, 100% of the Planet-SkySat data were acquired and delivered successfully for all Primary Sampling Units. In addition, Planet-PlanetScope satellite constellation data were available via the NICFI Data Program for Guyana that includes an agreement between Norway (NICFI) and Planet to provide Guyana with Level 2 access to original rather than mosaiced PlanetScope 'Visual Basemaps' image data.

Our assessment on the quality of the reference data can be summarised in the following statements:-

I. Drivers of change are easily identified on Skysat imagery although some offsets in the spatial referencing of Skysat imagery were observed which required additional care in interpretation,

II. Skysat and PlanetScope imagery were not available for the Low Risk stratum, thus giving a possible bias in driver classification by stratum.

III. Skysat images have a relatively small footprint and so several of the AA images were (visibly) mosaicked but this did not cause any difficulties with change sample interpretation.

IV. Sentinel-2 MSI data were, in general, of good radiometric and we found no geometric/positional quality problems.

[12] The larger (than Maxar) number of satellites in the Skysat constellation, combined with the non-sun synchronous orbits, provided more chances for cloud-free acquisitions.

V. There is noticeable variability in radiometric image quality of the PlanetScope acquisitions, noting that different instruments from the constellation of satellites were used in the analysis (PS2, PS2.SD, PSB.SD).

15. SUMMARY AND CONCLUSIONS

We conclude that the estimates of deforestation based on the mapping undertaken by GFC based largely on interpretation of Sentinel-2 MSI and PlanetScope imagery match closely with the independent change sample analysis undertaken by the Durham University mapping team using Skysat, PlanetScope and Sentinel-2 MSI data.

The methods used by GFC, and assisted by Indufor, follow the good practice recommendations set out in the GFOI and GOFC-GOLD good practice guidelines and considerable effort has been made to acquire cloud free imagery towards the end of the census period October-December 2022 (Year 13).

The estimate of Year 13 deforestation, derived independently from GFC, using a change sample analysis of the total area of change in the 12-month Year 13 period from forest to non-forest and degraded forest to non-forest is 8,250 ha, with a standard error of 1,229 ha.

The estimate of the annual rate of deforestation that occurred over the Year 13 (12 month) period is **0.029%** with a standard error of **0.005%**.

Only three changes were detected within samples that fell within the boundary of the **Intact Forest Landscape**. Two changes were interpreted as forest degradation associated with mining in the High-Risk stratum. Only one change sample (1 ha) was deforestation due to mining activity.

The Skysat and PlanetScope data provided sufficient detail (spatial resolution) to assess the Sentinel-2 MSI deforestation mapping as provided by GFC.

16. DATA CREDITS

Landsat data courtesy of USGS, via GEE.

Contains Copernicus Sentinel data 2015 to 2024, processed in Google Earth Engine.

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APPENDIX A: STATISTICAL TABLES

Appendix 2: IPCC Table

to: (end of year 2023)	forest land	cropland (managed)	grassland (managed)	wetland (managed)	settlement	other land	end of 2023
from: (start of year 2023)			*area (kha)*				
forest land (HPfC, MA)	4,422.98	0.55			1.00	3.59	**4,417.83**
forest land (HPfC, LA)	2,201.71	0.09			0.31	1.31	**2,200.00**
forest land (MPfC, MA)	1,209.55	0.11	**NO**	**NE**	0.11	0.85	**1,208.49**
forest land (MPfC, LA)	4,282.79	0.13			0.05	0.86	**4,281.76**
forest land (LPfC, MA)	199.09	0.01			0.00	0.07	**199.02**
forest land (LPfC, LA)	5,498.96	0.02			0.01	0.29	**5,498.64**
cropland (managed)							**906.42**
grassland (managed)							**1,770.38**
wetland (managed)			**NE**				**297.74**
settlement							**206.34**
other land							**127.04**
start of 2023	**17,815.09**	**905.51**	**1,770.38**	**297.75**	**204.87**	**120.07**	21,113.66
net change	9.35	-0.91			-1.48	-6.97	

NE – not estimated
NO – not occurring

Appendix 3: Image Catalogue

The following table provides a list of satellite images used to map forest loss for the 2023 mapping year.

Stack Name	Satellite/ Instrum.	Data Provider	Res (m)	Acqu. Year	Acqu. Month
20230805T141719_20230805T141714_T21NVF.tif	S2	ESA	10	2023	Aug
20230806T143731_20230806T143730_T20NQP.tif	S2	ESA	10	2023	Aug
20230806T143731_20230806T143730_T20NRP.tif	S2	ESA	10	2023	Aug
20230808T142719_20230808T142717_T20NQN.tif	S2	ESA	10	2023	Aug
20230808T142719_20230808T142717_T20NQP.tif	S2	ESA	10	2023	Aug
20230808T142719_20230808T142717_T20NRN.tif	S2	ESA	10	2023	Aug
20230808T142719_20230808T142717_T20NRP.tif	S2	ESA	10	2023	Aug
20230808T142719_20230808T142717_T21NTH.tif	S2	ESA	10	2023	Aug
20230808T142719_20230808T142717_T21NTJ.tif	S2	ESA	10	2023	Aug
20230813T142721_20230813T142800_T20NRJ.tif	S2	ESA	10	2023	Aug
20230813T142721_20230813T142800_T20NRN.tif	S2	ESA	10	2023	Aug
20230813T142721_20230813T142800_T20NRP.tif	S2	ESA	10	2023	Aug
20230813T142721_20230813T142800_T21NTD.tif	S2	ESA	10	2023	Aug
20230813T142721_20230813T142800_T21NTE.tif	S2	ESA	10	2023	Aug
20230813T142721_20230813T142800_T21NTF.tif	S2	ESA	10	2023	Aug
20230813T142721_20230813T142800_T21NTH.tif	S2	ESA	10	2023	Aug
20230813T142721_20230813T142800_T21NTJ.tif	S2	ESA	10	2023	Aug
20230813T142721_20230813T142800_T21NUJ.tif	S2	ESA	10	2023	Aug
20230823T142721_20230823T143116_T20NRJ.tif	S2	ESA	10	2023	Aug
20230825T141719_20230825T141714_T21NTC.tif	S2	ESA	10	2023	Aug
20230825T141719_20230825T141714_T21NUC.tif	S2	ESA	10	2023	Aug
20230825T141719_20230825T141714_T21NUD.tif	S2	ESA	10	2023	Aug
20230825T141719_20230825T141714_T21NUE.tif	S2	ESA	10	2023	Aug
20230825T141719_20230825T141714_T21NUF.tif	S2	ESA	10	2023	Aug
20230825T141719_20230825T141714_T21NUG.tif	S2	ESA	10	2023	Aug
20230825T141719_20230825T141714_T21NUH.tif	S2	ESA	10	2023	Aug
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20230902T142721_20230902T142717_T21NTH.tif	S2	ESA	10	2023	Sep
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20230927T142719_20230927T142849_T21NTB.tif	S2	ESA	10	2023	Sep
20230927T142719_20230927T142849_T21NTC.tif	S2	ESA	10	2023	Sep
20230927T142719_20230927T142849_T21NTD.tif	S2	ESA	10	2023	Sep
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20230927T142719_20230927T142849_T21NTG.tif	S2	ESA	10	2023	Sep
20230929T141711_20230929T141911_T21NUH.tif	S2	ESA	10	2023	Sep
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20231007T142709_20231007T142929_T20NRN.tif	S2	ESA	10	2023	Oct
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20231014T141709_20231014T142132_T21NUB.tif	S2	ESA	10	2023	Oct
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20231129T143739_20231129T143739_T20NQL.tif	S2	ESA	10	2023	Nov
20231201T142701_20231201T142704_T20NQL.tif	S2	ESA	10	2023	Dec
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LC08_231056_20230816.tif	L8	USGS	30	2023	Aug
LC08_231056_20231019.tif	L8	USGS	30	2023	Oct
LC08_231057_20231019.tif	L8	USGS	30	2023	Oct
LC08_232054_20230908.tif	L8	USGS	30	2023	Sep
LC08_232054_20230924.tif	L8	USGS	30	2023	Sep
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LC08_232055_20231026.tif	L8	USGS	30	2023	Oct
LC08_232055_20231111.tif	L8	USGS	30	2023	Nov
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LC09_231058_20231011.tif	L9	USGS	30	2023	Oct
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LC09_232056_20230831.tif	L9	USGS	30	2023	Aug
LC09_232056_20231002.tif	L9	USGS	30	2023	Oct
Planet Medres Normalized Analytic 2023-10 Mosaic	Plan- etScope	Planet	3	2023	Oct
Planet Medres Normalized Analytic 2023-11 Mosaic	Plan- etScope	Planet	3	2023	Nov
Planet Medres Normalized Analytic 2023-12 Mosaic	Plan- etScope	Planet	3	2023	Dec

Additional start sources:

Stack Name	Satellite/ Instrum.	Data Provider	Res (m)	Acqu. Year	Acqu. Month
Planet Medres Normalized Analytic 2020-10 Mosaic	Plan-etScope	Planet	3	2020	Oct
Planet Medres Normalized Analytic 2021-09 Mosaic	Plan-etScope	Planet	3	2021	Sep
Planet Medres Normalized Analytic 2021-10 Mosaic	Plan-etScope	Planet	3	2021	Oct
Planet Medres Normalized Analytic 2022-08 Mosaic	Plan-etScope	Planet	3	2022	Aug
Planet Medres Normalized Analytic 2022-10 Mosaic	Plan-etScope	Planet	3	2022	Oct
Planet Medres Normalized Analytic 2022-11 Mosaic	Plan-etScope	Planet	3	2022	Nov
Planet Medres Normalized Analytic 2022-12 Mosaic	Plan-etScope	Planet	3	2022	Dec