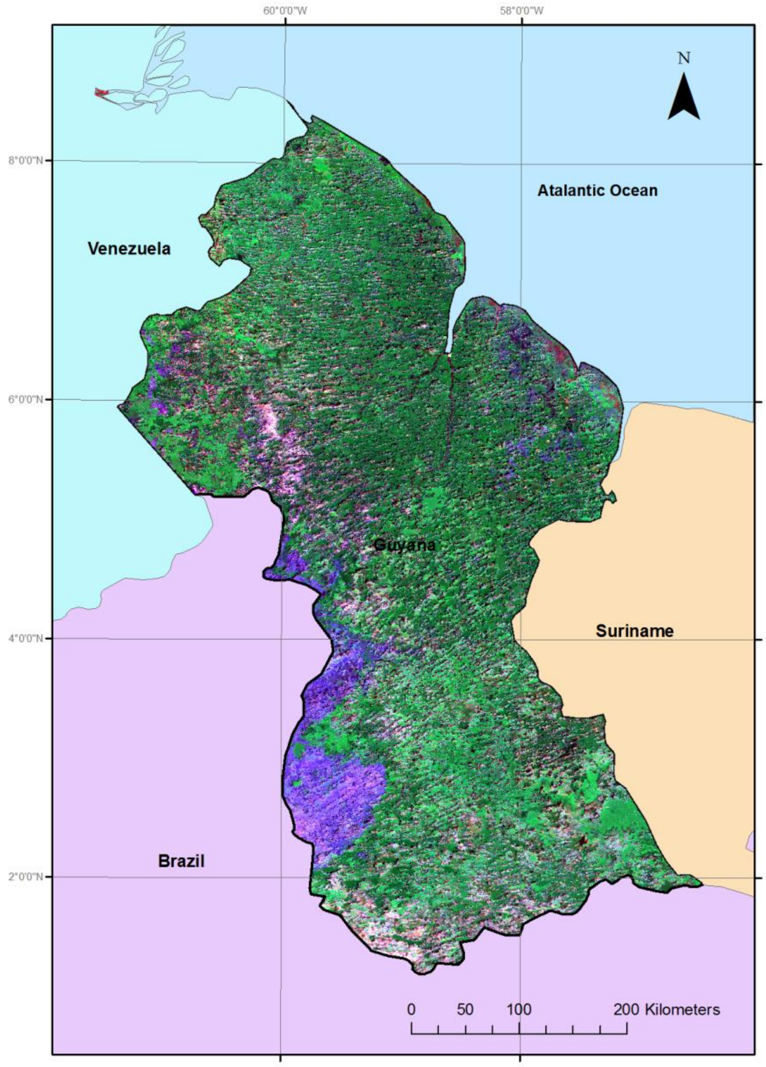


Guyana Forestry Commission

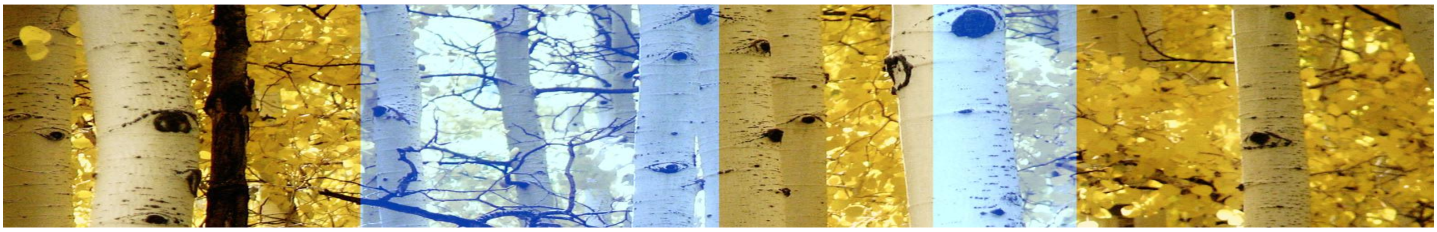
Guyana REDD+ Monitoring Reporting & Verification System (MRVS)

Interim Measures Report

01 October 2010 – 31 December 2011

Version 3

26 July, 2012



DISCLAIMER

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PREFACE

The Joint Concept Note (JCN) between the Government of Guyana and the Government of Norway identifies the stepwise and progressive development of the Guyana Monitoring Reporting and Verification System (MRVS) as an "Indicator of Enabling Activity" as outlined in the JCN, Section 2. The JCN also outlines that the mechanism for financial payments for services to Guyana. These payments areresult-based with deforestation and forest degradation measured against an agreed level.

In 2009, Guyana developed a national framework for an MRVS. This framework was developed as a "Roadmap[1]" that outlines progressive steps over a 3 year period that will 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 started at 2010 and required a number of initial reporting activities to commence. These were designed to assist in shaping the next steps planned for 2011 and 2012.

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, two national annual assessments have been conducted, including the one outlined in this Report. The first assessment period covered Year 1 (01 October, 2009 to 30 September, 2010) and the second (Year 2) covering the period 01 October, 2010 to 31 December, 2011.

The agreement between Guyana and Norway embarks on one of the first national-scale REDD-plus initiatives in the world. Given the nature of this cooperation agreement, and the implications that initial results and lessons learned will have it is important the MRVS is seen as a continuous learning process that is progressively improved. This process also assists to inform other countries seeking to take this same path

This report aims to fulfil in part, the deliverables of Specific Activity Areas 1-3 of the forest area assessment initiative of Guyana's MRVS, as provided by Induforand the GFC. The contract for this work under Year 2 of the MRVS Roadmap, extends to July 2012. At the completion of this contract all specific activities identified in the Terms of Reference will be completed, specifically item 4 (an independentAccuracy Assessment) as well as the associated capacity building activities.

In tandem with the work summarised in this report, an accompanying and closely connected programme of work is being implemented by GFC, with the assistance of a specialist firm (Winrock International), to develop a national forest carbon measurement system.

This programme will establish for Guyana, 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 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. Both aspects of work are initial parts of Year 2 of the Guyana MRVS Road Map.

As the MRVS is being developed, the reporting in this period, like in the case of Year 1 will be based on several agreed REDD+ Interim Indicators. The Report therefore aims to fulfill the requirements of a number of "Interim Indicators for REDD+ Performance in Guyana" for the period 01 October, 2010 to 31 December, 2011, as identified by the JCN Table 2. In other words,

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

the reporting on these intermediate indictors will allow for reporting to take place in the interim, while the full MRVS is under development.

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 its Low Carbon Development Strategy (LCDS).

The methods and results of the assessment for the period 01 October, 2010 to 31 December, 2011 will be subject to independent third party verification and is a requirement for the results-based financial support for 2012. As required by the JCN, the verification will take place for the second time in 2012, and will be conducted annually for the duration of the Guyana / Norway Partnership.

This third version of the Report has been produced taking into consideration stakeholder feedback received during a public release period executed over 15 June, 2012 to 6 July, 2012, as well as feedback and corrective actions resulting from the recently conducted (13-20 July), independent verification by Det Norkse Veritas.

This report is issued jointly by Indufor Asia Pacific Ltd (Indufor) and the Guyana Forestry Commission (GFC).

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Comment from Norwegian Ministry of the Environment

Please allow us to take this opportunity to thank you for receiving our comments on this report. Guyana has made impressive progress in developing the MRVS, as well as in taking action in order to keep deforestation and forest degradation at levels low. If the results of this report are confirmed, forest based emissions in Guyana seem to have stabilized at an impressively low level. We thank you again for your cooperation, and wish you the best of luck in the continuation of your work.

Response to comment

Guyana also sees the progressive improvements in the work on forest area assessment, as part of the MRVS roadmap process.

We plan to further work on some existing areas, such as degradation mapping, as well as to introduce new areas under the forest area assessment work in 2012/2013. A number of these have been summarised in Section 1.6 of IMR Version 1.

Comment from The Amerindian Action Movement of Guyana

The members of the Amerindian Action Movement of Guyana (TAAMOG) are pleased and happy over the release of the second performance report on interim measures for Reducing Emissions for Deforestation Plus (REDD+), under Guyana's Monitoring Reporting and Verification System (MRVS).

We are of the view that the second performance report is technically sound which will meet the expectations of the Guyana-Norway partnership model in the fight against Global Climate Change

Response to comment

The GFC in collaboration with its consultants have made efforts to improve on the year 1 mapping (2009/2010) in a number of areas. One of the major areas of improvement is in terms of including a more precise method for degradation monitoring, and another is in the use of a higher resolution satellite imagery option (5m), for forest area assessment. There are areas for future improvement in year 3 and these will be next steps in the forest area assessment work.

Guyana sees the work on the MRVS as a national model for the country as well as for other countries involved in work on climate change. We hope to bring important lessons from this undertaking which will include both successes and challenges faced.

The Report has been formatted to report on both of these. A number of challenges that are faced, including issues of persistent cloud and finding appropriate and feasible methods to monitor forest degradation,etc, have been identified in the report.

SUMMARY

In March 2011, a revised Joint Concept Note (JCN) under the Guyana/Norway Agreement was issued, and replaces the JCN of 2009. The revised JCN provides an update on 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 Monitoring Reporting and Verification System (MRVS) is established[2].

The basis for comparison of the area-based interim measures is the 30 September 2009 Benchmark Map[3]. The first reporting period (termed Year 1) is set from 01 October, 2009 to 30 September, 2010 with second reporting period (Year 2) covering 01 October 2010 to 31 December 2011, a fifteen (15) month period.

For the Benchmark and Year 1 analyses, medium resolution satellite images were used to calculate the forest area, in accordance with Guyana's national definition of forest for REDD+, as at 1990.

The total forested area at this point was estimated as 18.39 million hectares (ha) (with an indicative accuracy of 97.1%), of which 15.5 million ha is administered by the State.

Forest change between 2010 and 2011, was determined using high resolution (5 m) RapidEye imagery over Year 1 change areas. In other words, the change reported in this Assessment captures only the change that took place in the 15 month period under review – Year 2. The use of 5 m RapidEye imagery is a significant improvement over Year 1, as for a large part of Guyana which accounts for most of the allocated forest area, it offers resolution at 5 m as compared to 30 m primarily used in Year 1. This allows for more refined reporting of change areas. For the remaining areas in Year 2 assessment (areas not covered by Rapideye), Landsat TM and ETM+ were used.

Over areas of persistent cloud, ASAR radar images obtained for January to December 2011 and MODIS (250 m resolution) taken as close to the end of the period (31 December 2011) were also assessed to check for change under areas of cloud. This allows for spatial tracking of forest change areas through time as outlined under Approach 3 of the IPCC Good Practice Guidelines.

Forest change of forest to non-forest excluding degradation[4] between October 2010 and December 2011 (15 months) is estimated at 9 889 hectares[5]. Over the Year 2 reporting period, this equates to a total deforestation rate of 0.054%. This rate of change is largely similar, and a small percentage lower than Year 1 - October 2009 to September 2011 (12 months) which was reported as 0.056%. The results of the independent accuracy assessment conducted by the University of Durham (UoD) also calculated a similar rate of change for Year 2 (0.053%).

At the end of the Year 2 period, the area of forest remaining is estimated at 18.378 million ha. The accuracy of the mapping as calculated by the UoD is 96.8% (See Appendix 10).

Significant progress was made in Year 2, in mapping forest degradation. The area of degradation as measured by direct interpretation (based on a degradation study) of the 5 m RapidEye satellite imagery is 5 460 ha.

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[2] 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.

[3] 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.

[4] Changes in forest area due to forest degradation are not required to be reported in the interim period.

[5] This is inclusive of the Amaila falls road constructed as part of the pending hydro dam development.

It is envisaged that the reference measure as well as the interim performance indicators will only apply while aspects of the MRVS are being developed and will be phased out and replaced by a full forest carbon accounting systems developed using methodologies that are proven.

For the fifteen months Year 2 period (2010 to 2011) deforestation has remained relatively constant at 9 889 ha/yr. This is equivalent to a deforestation rate of 0.054%/yr for the period, which is very similar, and actually a marginal percentage lower, to the Year 1 rate (12 months) of 0.056%/yr.

The main deforestation driver for the current forest year reported (Year 2) is mining which accounts for 94% of the deforestation in this period. It should be noted that the driver of mining, includes mining infrastructure. A majority (96%) of deforestation is observed in the State Forest Area. Additionally the temporal analysis of forest change post 1990 indicates that most of the change is clustered around existing road infrastructure and navigable rivers. This provides a useful basis for planning an on-going monitoring programme that focuses on key hotspot areas.

The findings of this assessment will enable targets for REDD+ activities to be designed, that aim to bring about the largest positive impact in maintaining forest cover while enabling continued sustainable development and improved livelihood for Guyanese.

A summary of the key reporting measures and a brief description for these interim measures are outlined in Table S1. Table S2, identifies those measures that have not yet been accounted for in the MRVS. In this report, the analysis covers the benchmark period (1990-2009), the first year (Year 1) and second year (Year 2) of reporting

Outputs and results are also provided for the intact forest landscape – IFL (Ref. measure. 2). A change has been made to the IFL layer based on additional spatial information provided by the Guyana Geology and Mines Commission (GGMC) on reconnaissance areas. This dataset was not available in 2010 and was made available in 2011. This has resulted in a decrease in the eligible IFL area from 7.6 million ha to 5.59 million ha.

Relevant measures are also reported for forest management indicators (measure Ref. 3 and 4). Where applicable, a reference measure has been included. For measures such as forest degradation, this is the first time this has been formally calculated using remote sensing. For the Year 1 assessment a generic 500 m buffer to all new, Year 1 infrastructure (i.e. mining sites and roads), was applied.

It is envisaged that as the MRVS is expanded, reporting methods will be developed to account for emissions from shifting cultivation and activities that result in carbon sinks i.e. SFM or enrichment plantings.

Table S1: Interim Measures

Measure Ref.	Reporting Measure	Indicator	Reporting Unit	Reference Measure	Year 1Period	Year 2 (01 Oct 2010 to 31 Dec, 2011) 15 months	Difference Y2 and Benchmarkand Y2 and Y1 for Indicators 2, 2b, & 5
1	Deforestation Indicator	Rate of conversion of forest area as compared to the agreed reference level.	*Rate of change (%)/yr^{-1}*	0.275%[6]	0.056%	0.054%	-0.002
2	Degradation Indicators	National area of Intact Forest Landscape (IFL). Change in IFL post Year 1, following consideration of exclusion areas.	*Million ha*	N/A	7.60 (refined to5.59)	5.59	0
2b		Determine the extent of degradation associated with new infrastructure such as mining, roads, settlements post the benchmark period.	*ha*	N/A	92 413[7]	5 460	-86 939
3	Forest Management	Timber volumes post 2008 as verified by independent forest monitoring (IFM). These are compared to the mean volume from 2003-2008 (and *reference level prorated for a period of 15 months).*	*t CO_2*	4 251 583[8]	N/A	3 685 376[9]	-566 207
4	Emissions resulting from illegal logging activities	In the absence of hard data on volumes of illegally harvested wood, a default factor of 15% (as compared to the legally harvested volume)*(and reference level prorated for a period of 15 months).*	*t CO_2*	547 179	N/A	18 289[10]	-528 890
5	Emissions resulting from anthropogenic forest fires	Area of forest burnt each year should decrease compared to current amount.	*ha/yr^{-1}*	NA	1 706[11]	28	-1 678

[6]JCN March 2011 Pages 6 and 11.

[7]This indicator as is required by the Joint Concept Note of the Agreement between Guyana and Norway, includes a buffering of 500 km on all sides of all **new (this is defined by all features that occur for the first time in the period under assessment - Year 1)** detected deforestation activities including road and infrastructure developments, forestry, and mining. This area does not necessarily reflect degradation of forest in a practical sense but it is a provision as required by the interim indicator of the Joint Concept Note. Degradation will be comprehensively informed when the full MRVS is operational. This is therefore a conservative way of measuring of degradation in the interim.

[8] Assessment completed based in Winrock International Report to the Guyana Forestry Commission, December 2011: ***Collateral Damage and Wood Products from Logging Practices in Guyana.*** This methodology only applies to emissions and not any removals due to re-growth of the logged forest. This has been updated from Version 1 of the report.

[9]Computed for the period 01 October, 2010 to 31 December, 2011. This has been updated from Version 1 of the report.

[10]Rate of illegal logging for the forest year 01 October 2010 to 31 December2011 is informed by a custom designed database that is updated monthly, and subject to routine internal audits.

[11] Degradation from forest fires is taken from an average over the past 20 years.

Table S2: Impending Interim Measures

The following measures are currently not included in the MRVS. The intention is that these measures will be phased in and monitored once the MRVS becomes operational.

Measure Ref.	Reporting Measure	Indicator	Reporting Unit	Reference Measure	Year 1 Period	Year 2 (Oct 1 2010 to Dec 31, 2011) 15 months	Difference Y2 and Benchmark or Y1 for Indicators 2, 2b & 5
6	Emissions resulting from subsistence forestry, land use and shifting cultivation lands (i.e. slash and burn agriculture).	Emissions resulting from communities to meet their local needs may increase as a result of inter alia a shorter fallow cycle or area expansion.	Not considered relevant in the interim period.	N/A	N/A	N/A	N/A
7	Encouragement of increasing carbon sink capacity of non-forest and forest land	Changes from non-forest land to forest (i.e. through plantations, land use change) or within forest land (sustainable forest management, enrichment planting)	Not considered relevant in the interim period.	N/A	N/A	N/A	N/A

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The continued support and oversight of the members of the MRVS Steering Committee and the Multi-Stakeholder Steering Committee of the LCDS are also especially acknowledged.

The GFC team would also like to acknowledge the following colleagues 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.
- Prof. Dr. Martin Herold and the GOFC-GOLD office for the support in the development of the MRVS Roadmap and framework for the outputs in this assessment
- National Institute for Space Research, Brasil (INPE) for responding to technical questions and also providing IRS satellite imagery.
- The Forest Carbon Tracking Task force (GEO FCT) for providing processed radar images and in particular Prof Dirk Hoekman of the Department of Environmental Sciences, Wageningen University, the Netherlands.
- ESRI for providing support in GIS software and overall technical support.
- The Clinton Climate Initiative for strategic guidance in the development of the MRVS framework.
- Winrock International and Applied Geosolutions for guidance in a number of areas of the MRVS development.
- Conservation International for their role in supporting the implementation of this, as well as other aspects of the Guyana MRVS.
- USAID for providing capacity support in the area of GIS and Remote Sensing training.
- Other Partners

GLOSSARY

The following terms and abbreviations are used throughout the report.

AGLB	Above Ground Live Biomass
ASAR	Phased Array Type C-band Synthetic Aperture Radar
AWiFS	Advanced Wide Field Sensor
CLAS	Carnegie Landsat Analysis System
DMC	Disaster Monitoring Constellation
DN	Digital Number
DTM	Digital Terrain Model
ESRI	Environmental Systems Research Institute
EVI	Enhanced Vegetation Index
FCPF	Forest Carbon Partnership Facility
FIRMS	Fire Information for Resource Management System
FRIU	Forest Resource Information Unit (GFC)
FTP	File Transfer Protocol
GEMI	Global Environmental Monitoring Index
Geo FCT	The Forest Carbon Tracking Task force
GFC	Guyana Forestry Commission
GGMC	Guyana Geology and Mines Commission
GIS	Geographic Information System
GLCF	Global Land Cover Facility
GL&SC	Guyana Lands & Surveys Commission
GOFC-GOLD	Global Observation of Forest and Land Cover Dynamics
GPS	Global Positioning System
GV	Green Vegetation
INPE	National Institute for Space Research in Brazil (Instituto Nacional de Pesquisas Espaciais)
IPCC	Inter Governmental Panel on Climate Change
IRS (LISS)	Indian Remote Sensing Linear Self Scanning Sensor
ITTO	International Tropical Timber Organisation
LAI	Leaf Area Index
LCDS	Low Carbon Development Strategy
LULUCF	Land Use, Land Use Change and Forestry
MERIS	Medium Resolution Imaging Spectrometer
MMU	Minimum Mapping Unit
MODIS	Moderate Resolution Imaging Spectroradiometer
MOU	Memorandum of Understanding
MRSid	Multi-resolution Seamless Image Database
MRVS	Monitoring Reporting and Verification System
MS	Multispectral
MSAVI	Modified Soil Adjusted Vegetation Index
NARI	National Agricultural Research Institute, Guyana
NAS	Network Attached Storage
NDAVI	Normalised Difference Vegetation Index
NIR	Near Infrared
Pan	Panchromatic
Radar	Radio Detection and Ranging
REDD+	Reducing Emissions from Deforestation and Forest Degradation Plus

SAIL	Scattering by Arbitrarily Inclined Leaves
SAVI	Soil Adjusted Vegetation Index
SFA	State Forest Area
SMA	Spectral Mixture Analysis
SPOT	Satellite Pour l'Observation de la Terre
SRTM	Shuttle Radar Topography Mission
SWIR	Short Wave Infrared
UNFCCC	United Nations Framework Convention on Climate Change
UNREDD	United Nations REDD Programme
USGS	United States Geological Survey
VNIR	Visible and Near Infrared
WWF	Worldwide Fund for Nature

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 the 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 Guyana Low Carbon Development Strategy

The Government of Guyana has embarked on a national programme that aims to protect and maintain its forests in an effort to reduce global carbon emissions and at the same time attract resources to foster growth and development along a low carbon emissions path. As at September 2009 Guyana has approximately 87% of its land area covered by forests, approximately 18.5 million ha. Historically, relatively low deforestation rates of between 0.1% to 0.3%, have been reported for Guyana. Guyana's Low Carbon Development Strategy has expressed Guyana's commitment to providing a model on how to address the second most important source of carbon dioxide emissions world-wide, coming from deforestation and forest degradation and which is estimated at approximately 18% of global emissions.

Guyana's forest resources have the potential to make a large contribution to the emission-reduction efforts targeted by the Kyoto Protocol (as part of the United Nations Framework Convention on Climate Change, UNFCCC).

Guyana currently records a comparatively lower deforestation rate, reported in its Interim Measures MRVS Report, as ranging between 0.02% and 0.056% 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 REDD+ programme's focus on avoided deforestation and degradation is expected to widen to include efforts to improve aspects of sustainable forest management, forest conservation, and forest enhancement as reflected in the Bali Action Plan, paragraph 1 (b) (iii). Once these three additional elements are incorporated, REDD is then referred to as REDD+. The willingness of the Governments of Guyana and Norway to cooperate in creating a usable, relevant framework for REDD and REDD+ is therefore a promising sign for development of best practices for the Guyanese forestry sector as well as broader emission reduction goals.

The activity undertaken, forms part of the second year of the three-phase Road Map developed for Guyana's MRVS.

The objective of this initial MRVS Road Map activity is to undertake 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.

Additionally, in accordance with the requirement of the Guyana, Norway Cooperation agreement, an assessment on a number of REDD+ Interim Indicators for the current year period of 01 October 2010 to 31 December 2011 is also required as a follow on to the previous (Year 1) report for the period 01 October 2009 to 30 September 2010.

The results of the assessment for the period 01 October 2010 to 31 December 2011 are presented in this Report.

1.3 Establishing Forested Area

Land classified as forest follows the definition as outlined in the Marrakech Accords In accordance with the Marrakech Accords (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 previous 2010 report prepared by GFC and Pöyry provides a detailed description of this process.

In summary, this process involved:

- Determination of the 1990 forest area using medium resolution satellite images (Landsat) by excluding non-forest areas (including existing infrastructure) as at 1990.
- From this point forward accounting for forest to non-forest land use change that have occurred between 1990 and 2010 using a temporal series of satellite data.

The 2010 Interim measures report estimated that as at the benchmark period (30 September 2009) the total forest area that met the above definition was 18.39 million ha (± 0.4130 million ha).

This figure was further verified by the University of Durham (UoD) with an indicative accuracy of (97.1%).

The 2011 (Year 2) assessment has used a forest area (includes State Land, State Forest and Amerindian Villages) of 18.39 million ha as the starting point. Any new land cover change for the Year 2 period has been subtracted from this initial area. The Year 2 period spans from October 2010 to December 2011.

1.4 Overview of National Process for MRVS Implementation and Update on Progress

The Roadmap for Guyana's MRVS was developed through a multi-stakeholder consultative process involving a wide cross section of stakeholders. This multi-stakeholder process was facilitated through two MRVS workshop that were held in 14 September 2009 and 27-29 October 2009.

The Roadmap was designed to consider a number of necessary steps and different types of gaps (data, eligibility, capacity, and institutional, and methodological) to be addressed in different phases with a focus on the building of national capacities. The associated timeline of the Roadmap is 2010/11 for Phase 1, 2011/12 for Phase 2 and post 2012/13 for the implementation phase. This timing reflects the current planning and maybe accelerated if desired and based on lessons learned and progress made, as well as development in the international negotiation arena.

A REDD Secretariat has been established at the Guyana Forestry Commission to coordinate and execute all REDD+ work and operates in close collaboration with key partners including the Office of Climate Change and non-Governmental stakeholders. As part of the development of the MRVS, a MRVS Steering Committee was convened in November 2009 and tasked with the overall responsibility of strategic oversight of the implementation of all MRVS activities. Some of the other tasks include:

- Ensuring that scope aligns with the agreed requirements of projects
- Providing advice on the means by which key stakeholder groups are kept informed of progress in the development of the MRVS

- Contribution of inputs from the respective agencies that each member is a part of, to ensure close cohesion and coordination of MRVS activities implementation.

The Steering Committee comprises representation from;

- Government (Office of Climate Change (OCC)
- Guyana Lands & Surveys Commission (GL&CS)
- Guyana Geology & Mines Commission (GGMC)
- Ministry of Amerindian Affairs (MOAA)
- Environmental Protection Agency (EPA)
- Guyana Forestry Commission (GFC)
- Private sector (Forest Producers Association (FPA), Guyana Gold and Diamond Miners Association (GGDMA)
- Education sector (University of Guyana(UG))
- Civil society (National Toshaos Council (NTC)) organisations.

Within the MRVS Steering Committee, a Technical Sub-Committee was established to advise the Steering Committee on the more technical areas of the MRVS such as GIS & Remote Sensing related areas. This Technical Sub-Committee comprises representation from technical officers of the EPA, GL&SC, GGMC and GFC.

The current composition of the MRVS Steering Committee ensures that there is input from the major sectors involved in the process as well as for provision of data and technical advice into the process of the development of the MRVS. In contributing to the work of the MRVS Steering Committee, the GL&SC is the agency responsible for administration of State Lands in Guyana as well as for the granting of agricultural leases; this agency therefore provides information on land use and boundaries of Amerindian villages and is a key partner in the demarcation process.

The GGMC is the overall regulatory body for the mining sector in Guyana. As such, this agency provides to the MRVS SC, information on land use within the mining sector as well as potential areas identified for mining in the future. These mining activities mainly occur within the State Forest Estate (SFE) as well.

The Environmental Protection Agency is responsible for the promotion, facilitation and coordination of effective environmental management and protection; and the sustainable use of Guyana's natural resources. The GFC is responsible for the management and regulation of Guyana's State Forest Estate and overseeing the implementation of REDD + activities in Guyana.

The Ministry of Amerindian Affairs has the responsibility of enhancing the quality of life of Amerindian People in Guyana through the formulation and implementation of policies and programmes that facilitate cultural, social and economic development, promote equity and advance the rights of Amerindian people. Given that the MRVS would be developed with a capacity building approach and be community centered, the MoAA is an appropriate inclusion.

With the further inclusion of UG, FPA and GGDMA, the views of not only the private sector but those of the tertiary education and research facility (UG) are reflected. With the combination of the state regulatory agencies, private sector and civil society on the MRVS Steering Committee, this allows a planned and coordinated approach to the overall development of the MRVS. There is also another important consideration, in that there is stakeholder involvement in the process through the addition of entities such as the National Toshaos' Council.

As of 31 December 2011, a total of nine meetings of the MRVS Steering Committee had been held. Among the main discussion points at these meetings were the following:

- Results of Assessment Period 1 – 01 October 2009 to 30 September 2010.

- Revised Joint Concept Note (March 2011) accompanying the MoU between Guyana and Norway; including recently completed processes in Year 1 regarding Independent Verification and Accuracy Assessment.
- Discussion on forest carbon stock assessment and link to forest area assessment.
- Community MRVS as one part of the MRVS demonstration activities planned.
- Forest carbon stock assessment
- Options of satellite imagery for forest area change assessment, and recommendations to conduct assessment using RapidEye 5 m imagery for Year 2.

Over the period 01 October 2010 to 31 December 2011, activities in the MRVS Roadmap continued to be implemented. The MRVS Roadmap aims at producing an accountable and verifiable system and this will be the main means through which performance will be measured. It is being designed to measure and monitor changes to forest carbon stock due to anthropogenic sources. This system will assess various drivers of deforestation and forest degradation, and the impacts that these have on forest area and carbon stocks and inform Policy actions and other interventions. In 2011, work continued on a number of key areas in the development of the MRVS, more specifically in the areas of estimation of forest area change assessment, forest carbon stock assessment for Guyana as well as in the initiation of work on REDD+ demonstration activities. These activities have been executed in keeping with the internationally accepted guidance of the IPCC as well as others such as the GOFC GOLD Sourcebook, while maintaining a capacity building approach throughout, to ensure the sustainability of the MRVS.

In March 2011, a revised Joint Concept Note (JCN) under the Guyana/Norway Agreement was issued, and replaces the JCN of 2009. The revised JCN provided an update on 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 with some amount of refinement, drawing mainly on results from the first year assessment.

In the first quarter of 2011, the first annual assessment was completed for the period 01 October 2009 to 30 September 2010. A full historic assessment was also completed of forest area assessment and change monitoring by different drivers and activities causing deforestation, and covered the period 1990 to September 30, 2010. This report (Interim Measures Report, March 2011) is available on the GFC's website. Further, reporting was also completed on the agreed REDD+ Interim Indicators as set out in the JCN and includes the establishment of several benchmark levels for the various REDD+ Interim Indicators that will be used as the basis for future reporting references. This assessment concluded on areas such as forest/non forest cover for four time periods, including the annual assessment period ending September 2010. The completed assessment was conducted with assistance from technical experts, and integrated key capacity building aspects as part of the process of building institutional capability, for the conducting of similar work in the future. The Interim Measures Report which summarizes the approach, method, and results for the historic and annual assessment by drivers, was subject to independent accuracy assessment and independent third party verification.

Among the main results of the Interim Measures Report, Accuracy Assessment and Independent Verification, several recommendations were tabled for incorporation in the second reporting period. These have been identified as priority actions for continuous development of the MRVS in this Year 2 period, and in upcoming reporting periods, beginning with the immediate next period (01 October 2010 to 31 December 2011). National capacity building commenced during the execution of the first assessment period and will progressively build in the future assessment periods.

Throughout 2011, Guyana has sought, through various local and international fora, to learn from, and share experiences with other organisations and countries that are involved in this initiative. Guyana has worked closely with local and international organizations to facilitate the smooth and successful development, implementation and maintenance of the activities detailed in the MRVS Road Map. Guyana has also actively pursued efforts towards building local capacity through both local and international sessions, targeting the key technical experts that are actively involved in REDD+ implementation & MRVS in Guyana, not only at the level of the GFC and other relevant

Government agencies, but also through civil society groups such as the National Toshaos Council and committees such as the MRVS Steering Committee as well as the University of Guyana. It is expected that these initiatives will continue into 2012, as the implementation of activities in the MRVS Road Map continues.

Work also progressed in the area of forest carbon stock assessment and in the design of the forest carbon monitoring system. In this area, the GFC is working with Winrock International in executing the main activities. To date, the following main areas have been advanced:

- Design the Forest Carbon Monitoring System and execute preliminary field work
- Data collection for: biomass measurements, destructive sampling, logging impact assessment and re-growth assessment
- Forest carbon mapping and stratification
- Standard Operating Procedures design
- Carbon conversion and expansion factors for Guyana
- Training and capacity building

Other activities that will be completed include design of a long term monitoring plan for forest carbon and assessment of drivers/processes impacting on carbon impact, emission factors and key category analyses.

Additionally, work also advanced in the area of REDD+ demonstration project, with the launch of a Community MRVS project. This is a collaborative project with civil society and donor partners, working with the GFC.

Further technical assessments have been completed in the area of reference level setting, exploration of ecosystem services within the MRVS, and forest degradation. Over the next 12 months, efforts will be geared towards the overall integration and reporting through an IPCC structured national look-up table.

In tandem with these efforts, other activities from the strategic and policy arenas were also advanced during the reporting period. A framework for Independent Forest Monitoring (IFM) was developed. The first scoping missions took place in September – December 2011 with findings published on the GFC website, and the audit set for third quarter 2012. At the same time, discussions have continued on EU FLEGT and implementation of several sections of the REDD+ Governance Development Plan has advanced.

1.5 Overview of Capacity Building Efforts in Guyana's MRVS Implementation

In the design of the MRVS Roadmap as well as the resulting Terms of Reference for the various aspects of technical work that are being conducted, building local capacity is identified as a priority. As such, there is significant emphasis in the Roadmap on identifying gaps that exist in current capacities, and for each design phase of activity implementation, to take into consideration the need to fill these gaps.

The Year 2 forest area assessment utilised an approach that allows for inherent local capacity building throughout the process. In addition to formal sessions with GFC's staff, a training manual was also developed. In June/July 2012 another formal session, this time extended to other Governmental bodies and the University of Guyana, will be executed, and will aim at providing training on each step of the assessment. In a number of areas, inclusive of accuracy assessment, the staff of GFC's Forest Resources Information Unit participated in the execution of the tasks.

Over this reporting period, GFC effectively doubled the staffing within its Forest Resources Information Unit (GIS/RS Focal Unit of the GFC), and updated its GIS/RS software and database environment, and its hardware capabilities. These have resulted in the creation of an improved enabling environment for GFC's increased participation in the Year 2 assessment.

Over the reporting period several GIS/RS related training programmes were conducted. These were supported by various international partners. Through a collaborative effort between ESRI and The Clinton Foundation, training was provided to a number of Governmental partners and academic institutions in the areas of: Data Management in the Multiuser Geodatabase (DMGD) and Managing Editing Workflows in a Multiuser Geodatabase (MEGD). The delivery of this programme was conducted at the University of Guyana and included 17 lesson sessions. Through this collaboration as well, several GIS software and multiple user licenses, were provided to the GFC, other institutions and the University of Guyana.

Working with another international partner, a longer term training programme was also executed. Over the period May 2011 to May 2012, a modular training programme was conducted with GFC's technical staff on areas of GIS Fundamentals, Advanced GIS and Remote Sensing.

Through cooperation with the Amazon Cooperation Treaty Organization (ACTO) and the National Institute for Space Research (INPE in Brazil), GFC participated in a training course on the use of forest monitoring systems in the Amazon countries. This course examined areas including: mapping, monitoring and control of deforestation and forest cover in the Amazon using the TERRA AMAZON System and other tools developed by INPE for this purpose; cartography, geo-processing, image processing and remote sensing; generating updated databases with information on the status of forest cover in each participating country; and the sharing of experiences on technical methodologies and concepts related to the use of deforestation monitoring systems. This initiative allowed for the building of local capacity in the area of INPE´s Amazon Terra System including: (i) System of Deforestation Detection in Real-Time -DETER and (ii) Calculation Program for Deforestation in the Amazon-Digital -PRODES.

In other MRVS related areas in collaboration with Winrock International, training/workshop sessions were also facilitated. They include sessions at the University of Guyana and at GFC in the areas of climate change, ecosystem services, and others.

1.6 Planned MRVS Development Areas

There are several areas that will be developed and improved during the period that interim measures are recorded. This includes development of monitoring systems to facilitate reporting on impending measures such as shifting cultivation and afforestation.

The transition from medium resolution (30 m) Landsat to high resolution RapidEye images (5 m) has increased the opportunity to better delineate and detect land use change. If a similar approach is followed in year 3 then further automation of the process will be investigated.

It is worth noting that currently that there are very few operational medium resolution satellite systems that are freely available, or obtained images frequently enough to allow national reporting of change. To reduce the risk of inadequate coverage GFC is considering investing in the tasking of satellite systems such as RapidEye.

In following this approach then further investment in data analysis and reporting tools and methodologies to monitor change are required.

All of the following specific areas of development require that on-going high resolution be obtained:

- Development of methods to monitor and map shifting cultivation. The focus of this will be to monitor the temporal change of shifting cultivation plots.
- Spatial mapping of forest harvesting activities and potential development of linkages to log extraction information.
- Development of methods to map afforestation resulting from regenerating non-forest areas. A study to evaluate the ability of multi-temporal high resolution data to detect regeneration.
- Improvements in existing data layers such as the non-forest layer (naturally occurring) and historical pre-Year 2 change layers.
- Development of GIS-based reporting tools to allow further automation of forest change reporting.

- Integration of carbon measurements with spatial datasets to create activity-specific look-up values.
- Development of the MRVS to ensure repeatability in calculations and improved documentation of datasets and processes.

Further training will also be undertaken with a full-time Remote Sensing specialist embedded in GFC's Forest Resources Information Unit (FRIU).

2. LAND ELIGIBLE UNDER GUYANA'S LCDS

Under the Memorandum of Understanding (MOU) between Guyana and Norway, not all land is included in Guyana's Low Carbon Development Strategy (LCDS). Only lands under the ownership of the State are initially included in the LCDS. In 2011, additional land was transferred from State Lands and State Forest Area to titled Amerindian lands as part of Guyana's land titling process. Tenure arrangement in Guyana can be classified broadly into five main categories as presented in Table 2-1.

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 study, these are lands that are not included as part of the State Forest Estate that are under the mandate of the State. In this assessment, this category predominantly includes State Lands, with isolated pockets of privately held land, but not including titled Amerindian villages.

Iwokrama

The Iwokrama Programme Site, as defined by the Laws of Guyana, Chapter 20:04, is an area of approximately 371 000 ha of Guyana's tropical rainforest that has been dedicated by the Government of Guyana for purposes of conservation and research, by the Iwokrama International Centre. This area includes Fairview Amerindian Village. The area presented in Table 2-1 is 350 000 ha as it excludes Fairview which is included under Amerindian titled land.

Kaieteur National Park

As defined by the Laws of Guyana, Chapter 20:02, the Kaieteur National Park is an area of land constituted as a National Park, that allows for the preservation of natural scenery, fauna and flora.

Titled Amerindian Land

As provided for in the Amerindian Act 2006, these are 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 provides a summary of land eligible for inclusion under the MoU with Norway.

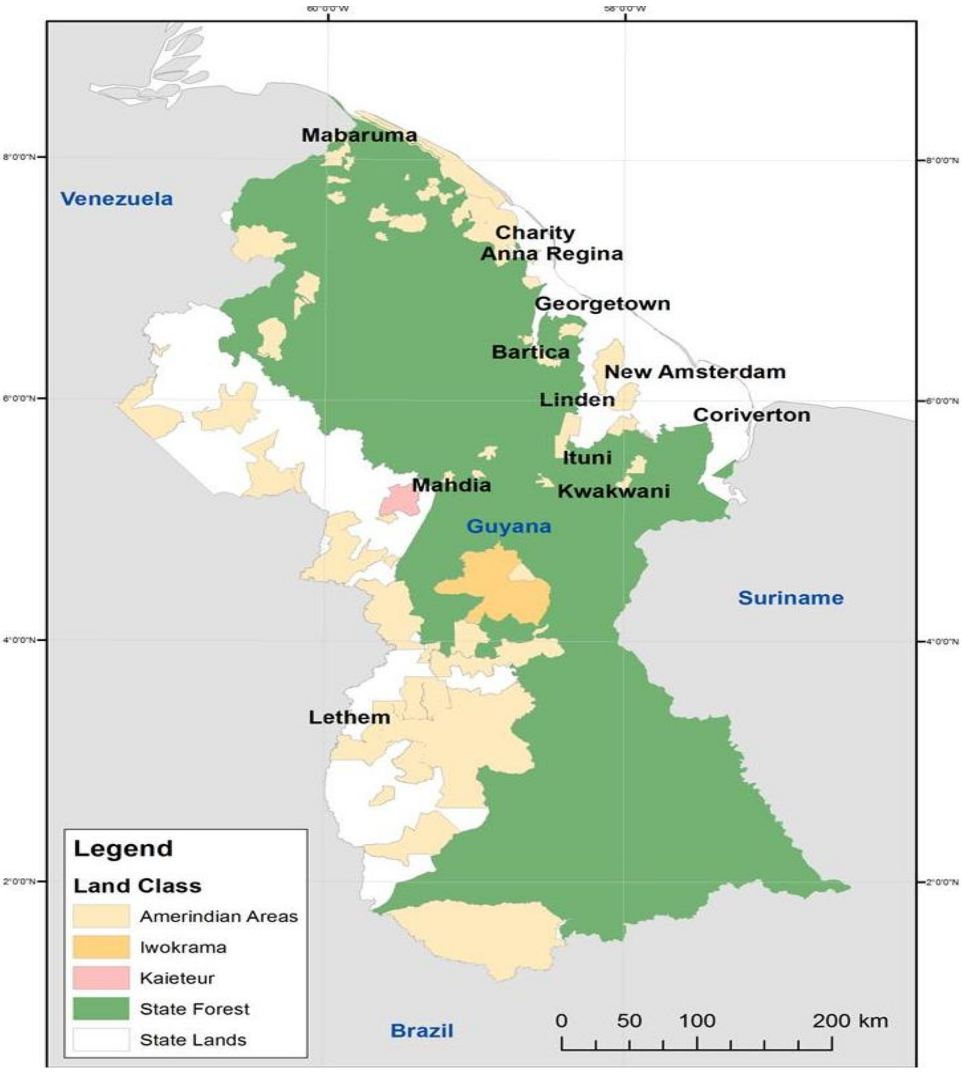
The eligible area of forest which includes the State Forest Area (SFA) and state lands under LCDS as calculated from the mapping analysis is estimated at 15.42 million ha. This excludes Iwokrama, Kaieteur National Park and titled Amerindian Land. Combined, these forested areas make up 2.95 million ha.

Table 2-1: Land Class by Forest and Non Forest Area 2011[12]

Land Class	LCDS Status	Non Forest	Forest	Total
		(Area '000 ha)		
State Forest Area	Included	460	12 342	12 801
State Land[13]	Included	1 692	3 084	4 776
Iwokrama[14]	Excluded	7	343	350
Kaieteur National Park	Excluded	0.6	62	63
Titled Amerindian Land	Excluded until Opt in	591	2 547	3 138
Total Area (ha)		2 751	18 378	21 129

The distribution of these areas is shown in Map 2-1.

Map 2-1: LCDS Eligible Areas



[12] Guyana's forest definition has been applied to distinguish forest and non-forest areas in categories listed.
[13] This category predominantly includes State Lands, with isolated pockets of privately held land, but not including titled Amerindian villages.
[14] The Iwokrama area quoted excludes Amerindian titled land 'Fairview'. The legislative geographic area size of Iwokrama is 371 682 hectares.

3. FOREST & LAND COVER DATASETS

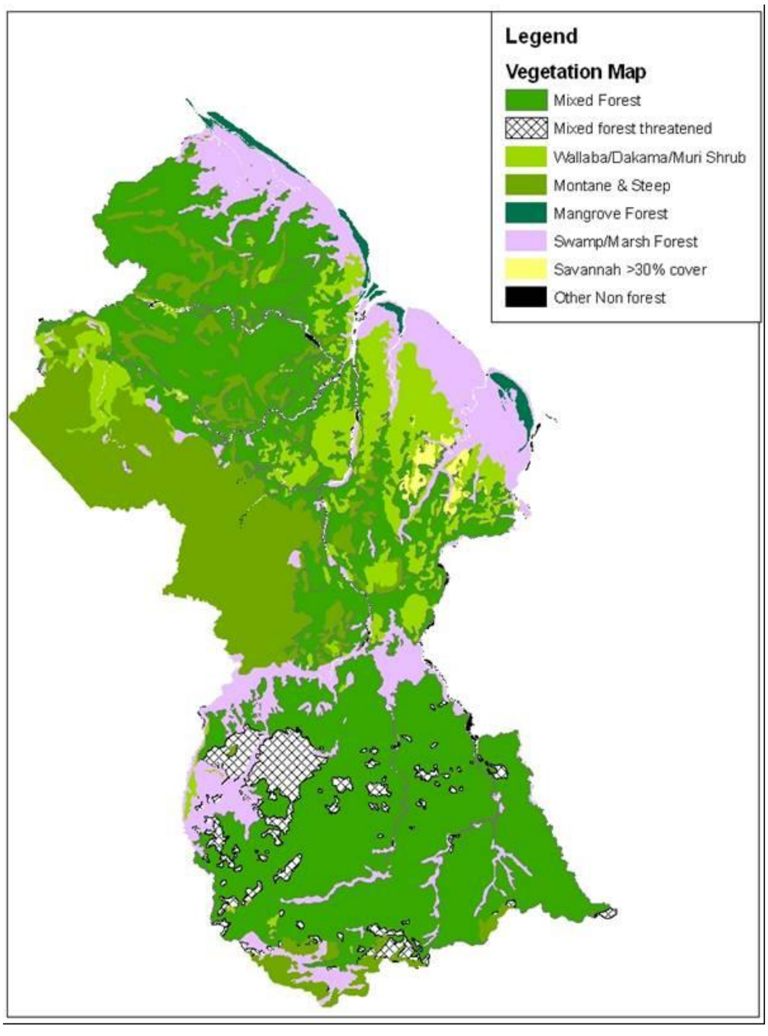
For the interim measures report the total land area is divided by forest and non-forest components as determined at 30 September 2009 (Benchmark). This has been created from interpretation of the Landsat time series.

In developing the MRVS, it is important that forest and non-forest components are identified and mapped so that changes between the two classes can be monitored. For areas identified as forested, further stratification is required to divide forest types by their potential carbon storage capacity. The stratification process is still on-going, but as a starting point two datasets have been considered. Both maps were produced in 2001 by Dr. Hans ter Steege, University of Utrecht, Netherlands, in collaboration with the GFC Forest Resources Information Unit.

The first provides a detailed forest vegetation map for the entire State Forest Area (SFA) and was created from various existing vegetation maps and updated using interpretations of historical aerial photographs, satellite radar imagery from the Japanese Earth Remote Sensing satellite (JERS 1). The maps completeness was supported by analysis of field data collected during the Commission's forest inventories.

At the same time a national forest and land use classification map at a scale of 1:1 000 000 scale was produced (Map 3-1). This is based mainly on national soil survey data made available by the National Agricultural Research Institute (NARI).

Map 3-1: Simplified National Vegetation Map 1:1 000 000 Scale



Using these maps as a starting point GFC has modified this classification to produce a preliminary classification. This conforms to the six broad land use categories in accordance with IPCC reporting guidelines (Table:3-1). A description of the land use categories is provided in Appendix 3.

Table:3-1: Preliminary Land Use Categories

<table>
<tr><th>Class</th><th>Land use Category</th><th>Land Use Type</th><th>Comment</th></tr>
<tr><td rowspan="7">Forest Land</td><td rowspan="7">Forest Land</td><td>Mixed forest</td><td rowspan="7">Grouped as forest for Interim measure reporting with Guyana’s definition of forest applied for quantification within categories</td></tr>
<tr><td>Wallaba/Dakama/Muri Shrub Forest</td></tr>
<tr><td>Swamp/Marsh forest</td></tr>
<tr><td>Montane forest</td></tr>
<tr><td>Mangrove</td></tr>
<tr><td>Savannah >30% cover</td></tr>
<tr><td>Plantations</td></tr>
<tr><td rowspan="8">Non forest</td><td rowspan="2">Grassland</td><td>Savannah <30% cover</td><td rowspan="8">Grouped as Non forest for Interim measure reporting with Guyana’s definition of forest applied for quantification within categories</td></tr>
<tr><td>Grassland</td></tr>
<tr><td rowspan="2">Cropland</td><td>Cropland</td></tr>
<tr><td>Shifting Agriculture</td></tr>
<tr><td rowspan="2">Wetland</td><td>Wetland open water</td></tr>
<tr><td>Herbaceous wetland</td></tr>
<tr><td>Settlements</td><td>Settlements</td></tr>
<tr><td>Other land</td><td>Other land</td></tr>
</table>

The intention is to update and refine these maps as appropriate using satellite imagery. The revised map will incorporate change detected from 1990 to September 2009 and will form the basis of the forest stratification map which delineates forest strata by potential carbon stocks. This is an input required for the carbon forest monitoring system to determine the amount of CO_2 sequestered, or emitted.

4. 2010-11 MONITORING & SPATIAL DATASETS

The process developed at GFC aims to enable areas of change (>1 ha) to be tracked through time, by driver(i.e. mining, infrastructure and forestry). The approach adopted seeks to provide a spatial record of temporal land use change within forested land(commensurate to an Approach 3). Future monitoring will be expanded to include changes within non-forest areas.

For the previous assessment, the change analysis focuses on detection of forest change over four nominal periods as follows;

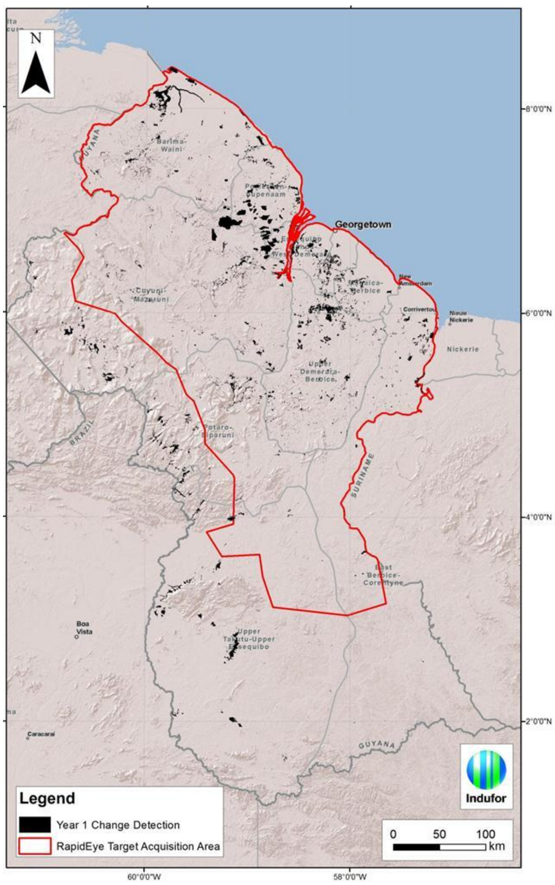
- 1990 to 2000 – Landsat 30 m
- 2001 to 2005 – Landsat 30 m
- 2006 to 2009 September - Landsat 30 m
- 2009 – 2010 October (Year 1) - Landsat 30 m and DMC (22 & 32 m)

It is from the first three time periods that the Benchmark forest map is created. The Benchmark map provides a snapshot of forest area as at 30 September 2009.

The 'Year 1' map covers the first year after the benchmark map. For this period all forest to non-forest changes from 2009 to 2010 September were mapped spatially and reported. The main dataset used over this period was 30 m Landsat imagery.

For the 2010-11 assessment, higher resolution 5 m imagery was tasked over previously identified change areas. The area covered was 12 million ha which equated to 56% of Guyana’s land area. The improved resolution enabled better identification of change boundaries, drivers of change and areas of forest degradation (Figure 1).

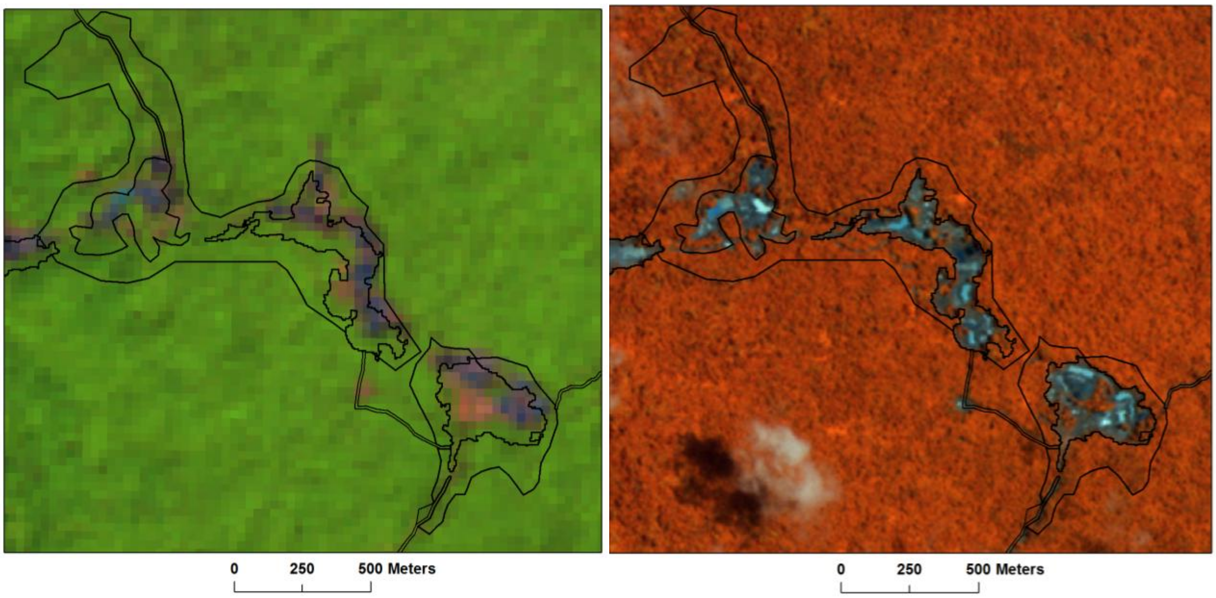
Figure 1: 2011 RapidEye Target Acquisition Area



Landsat imagery was used over the same area and also extended over the remainder of the country. This provides wall-to-wall coverage of Guyana that prioritises high resolution imagery over the most rapidly changing areas. Of particular note is that the area outside of the RapidEye tasked area is predominantly cloud-free.

The following example shows the difference in resolution between Landsat (left) and RapidEye (right) over a mining area. In the RapidEye the access roads, the extent and intensity of the mining operation are more apparent.

Figure 2: Comparison of Coincident Landsat and RapidEye



The reasons for the inclusion of RapidEye in the year 2 monitoring programme were to:

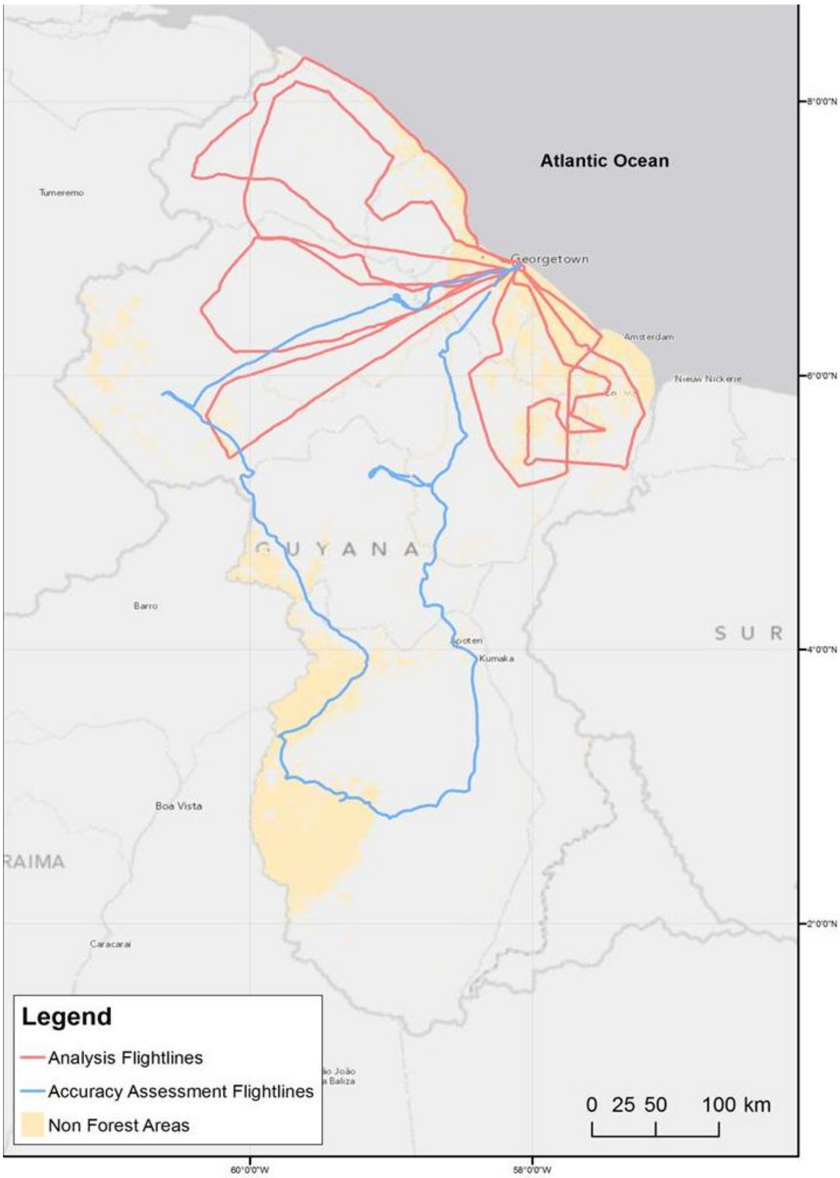
- Improve the delineation of change and identification of drivers
- Provide additional certainty in obtaining cloud-free coverage over Guyana for the August to December period.
- Diversification of remote sensing datasets suitable for monitoring change. This is particularly important given the failure of Landsat 5 in October 2011.
- Enable on-going land cover monitoring at a higher resolution to replace interim measures such as the Intact Forest Landscape.
- Develop methods for the processing of high resolution imagery prior to the implementation of the fully operational MRVS.
- Achieve a cost efficient and effective solution for monitoring forest change.

These points are key to Guyana's success in meeting its reporting obligations. It is clear that targeted acquisition of satellite data is important to ensure effective land use change monitoring as required to adhere to best practice. If a proactive approach is not adopted then there is a risk that a national level assessment could not be conducted either due to lack of suitable imagery or because of a delay in the provision of GeoFCT datasets.

To assist with classification of forest change drivers and confirm the appearance of different land cover types, several aerial inspections were conducted using a small fixed wing Cessna. During the flight oblique aerial photos were taken. These photos were linked to a GPS location and used for reference during the analysis. The following map shows the flight tracks and coverage since 2010 (Figure 3).

Additional aerial over-flights were also conducted during the Year 2 accuracy assessment. These provided coverage over the south of the country.

Figure 3: Combined Aerial Inspection Flight Lines2010 and 2011



Comment from Norwegian Ministry of the Environment

We note with great interest that data from several satellite sensors, as well as flight photos, have been used for the year 2 assessment. How has the interoperability between data sources been validated? Some more information on this could be added to the report.

Response to Comment

This is touched upon in this section of the IMR and also Section. 7

The primary datasets used in the change detection process include Landsat TM & ETM+ and RapidEye (over high activity areas). The mapping methods used are consistently applied and documented in the mapping guide (Appendix 9). All additional datasets are used to provide additional information to support the change detection decision. This is either to check areas covered by cloud (radar), or over-flights to confirm land cover types or change drivers.

A mapping improvement programme will be implemented in Year 3 as outlined in section 1.6. Improvements will focus on updating existing base layers such as non-forest and historic pre-Year 2 forest change. These updates are designed to improve the spatial accuracy of the MRVS.

4.1 Data Structure, Operators and Training

All spatial data is stored on the Network Attached Storage (NAS) at GFC and builds on the archived and manipulated data output from the Year 1 analysis. The NAS is managed by the IT team at GFC and is routinely backed up and stored off site.

The Year 1 data report recommended a central repository for all spatial information for inter-agency use. In 2012 GFC is looking to upgrade to ArcGIS server and in November 2011 the FRIU staff undertook ESRI training on working with relational databases as part of the Low Carbon Development Strategy (LCDS) assistance program. The implementation of a central repository for geographic data will provide an industry standard method for usage and manipulation of spatial data.

The relevant datasets that were used for the analysis have been documented and archived. This includes brief metadata description about the dataset, its location on the network and anticipated update frequency. Several datasets are actively used and reside on GFC's Forest Resource Information Unit (FRIU) network drive. These datasets are copied into a working folder at the beginning of each year. Care has been taken not to disrupt the structure of FRIU datasets and also to avoid duplication of datasets. GIS and remote sensing data and layers are stored on the dedicated NAS. Raw image datasets as provided by image providers are retained and have been catalogued using the analysis period they relate to, sensor, path and row, and processing information. New folders are created as these scenes are processed using ENVI image processing software and all associated files generated are also retained. All images are named using a common format that identifies the satellite, path and row, image date, provider, processing level (e.g. O = orthorectified) and any post-processing that has been done to register the imagery to a terrain corrected base mosaic. The current processed datasets are held in a GeoDatabase, and the satellite images are all full band stacks in either TIFF or IMG format.

GFC has recruited a number of staff in 2011, and now has eight GIS operators, a GIS manager and one remote sensing specialist. All desktop computers are running the latest version of ArcGIS (10) as provided by ESRI under the LCDS assistance program. Two copies of ENVI 4.7 have also been installed to enable image processing. Both are dongle versions and include maintenance contracts. The FRIU holds customised toolbars for automated processing imagery in ENVI and ArcGIS, where possible.

4.2 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.

Table 4-1 provides a summary of the various spatial datasets. The Ministry of Public Works is overseeing the development of the Amaila Hydropower Project. This planned hydroelectric project includes road construction and site clearance. To date only the access road has been constructed.

These datasets will be incorporated into the Year 2 analysis to assist in the detection of land use change events.

Table 4-1: Agency Datasets Held at GFC

Agency	Role	Data Held
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 lease information. Reconnaissance areas, large and medium scale mining areas including dredge locations.
Guyana Lands and Survey Commission (GL&SC)	Management of land titling and surveying of land	Land tenure, settlement extents and country boundary
Central Housing & Planning Authority	Management of Housing & Communities	Existing and planned housing information that are located in forested areas.

4.3 Guyana Forestry Commission

The GFC is responsible for advising the subject Minister on issues relating to forest policy, forestry laws and regulations. The Commission is also responsible for the administration and management of all State Forest land. The work of the Commission is guided by a National Forest Plan (2011) that has been developed to address the National Forest Policy (2011).

The Commission develops and monitors standards for forest sector operations, develops and implements forest protection and conservation strategies, oversees forest research and provides support and guidance to forest education and training.

The Forest Resource Information Unit (FRIU) holds a range of operational spatial data that are used to assist in the management of forest resources. A summary of the spatial layers is provided in Table 4-2.

4.4 Guyana Geology Mines Commission

The main functions of GGMC are to:

- Promote mineral development
- Provide technical assistance and advice in mining, mineral processing, mineral utilisation and marketing of mineral resources
- Conduct mineral exploration
- Research the areas of exploration, mining, and utilisation of minerals and mineral products.

The GGMC also has a role in the enforcement of the conditions of Mining Licences, Mining Permits, Mining Concessions, Prospecting Licences (for Large Scale Operations), Prospecting Permits (for Medium and Small Scale operations) and Quarry Licences. It is responsible for the collection of rentals, fees, charges, and levies payable under the Mining Act.

The GIS section at GGMC routinely collects information using field GPS units. The spatial layer developed holds information on the location of dredge sites and if available the person licensed to operate the dredge. The intention is to update this dataset quarterly.

GGMC also holds a spatial layer that defines the location of large and medium scale mining concessions. Recently GGMC also provided the reconnaissance areas in spatial form. The spatial layer that locates small-scale mining is not available at this stage. Spatial layers that show the extent of mining areas has been used to update the 2011 Intact Forest Landscape Map and qualifies as an exclusion area as defined by the Intact Forest Landscape Definition.

4.5 Guyana Lands & Surveys Commission

The Guyana Lands and Surveys Commission (GL&SC) remit includes the provision of land policy recommendations and draft land use plans to ensure orderly and efficient utilization of public land resources; advise on land surveying matters, and effective and efficient land administration.

- GL&SC also has a GIS unit that creates and provides geographic information. Several base datasets held by GL&SC have been identified as particularly useful. These include;
  - The extent of larger settlements in particular, Georgetown.
  - The location of registered agricultural leases.
  - Historical aerial photography not held by GFC
- Datasets from GGMC and GL&SC were consolidated into the GIS and used to assist with identification of areas undergoing change.

The following section provides details of image and GIS datasets considered relevant for the continued monitoring and mapping of temporal forest change in Guyana.

4.6 Monitoring Datasets- Satellite Imagery

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

Presently, reporting satisfies interim measures outlined in Section10. This requires that changes in forest land to other land uses be reported relative to the benchmark map. Currently changes occurring between lands defined as non-forest are not reported. Changes from non-forest to forest however, are being reported. The basic premise is that eventually changes in the six IPCC categories will be reporting for the LULUCF sector once the MRVS is fully operational.

For the period post 30 September 2009, additional measures include reporting forest change and degradation relative to the benchmark map. For the Year 2 assessment a remote sensing method has been adopted, rather than applying a generic 500 m buffer around newly detected infrastructure sites.. The shift to using a method based on remote sensing adheres to the guidelines outlined in the JCN.

To ensure consistency, all imagery was geo-referenced to a base mosaic image which was generated from data provided in MrSid format by the Global Land Cover Facility (GLCF). The GLCF holds a global set of regional images which are divided into tiles and overlap each other seamlessly at their edges. This ensures consistency between images of a similar type, and also between different image types and resolutions.

The following table provides a summary of the image datasets used for the Year 2 for both the monitoring and accuracy assessment. A detailed scene listing is provided in Appendix 2.

Table 4-2: Year 2 Imagery Datasets

Application	Satellite/ Source	Spectral Bands[15]	Pixel Resolution (m)	Image Extent (km)	No. Scenes	Temporal Coverage	Image Cover
Land use & Forest Change Mapping	RapidEye	VNIR	5	25 x 25	385	Aug-Dec 2011	56%
	Landsat 5 & 7	VNIR & SWIR	30	185 x 185	35	Aug-Dec 2011	Full
	DMC	VNIR	22 & 32	660 x 4100	10	Aug - Dec 2010	Partial
	IRS	VNIR & SWIR	23.5	142 x142	5	Nov-Dec 2011	Partial
	MODIS	VNIR	250	~2000	2	Dec 2011	Full
	ASAR RADAR	HH & HV	5 to 15	~70 x70	113	Jan- Nov 2011	Full
Verification & Accuracy Assessment	QuickBird-2	MS	2.7		1	09 Aug 11	0.02%
	WorldView-1	Pan	0.6		2	Aug-Oct 11	0.05%
	WorldView-2	MS	1.9		5	Aug-Sep 11	0.1%
	RapidEye	MS	6.5			Aug-Dec 11	56.%
	Over flights (1km_buffered flight lines)	Colour	Variable			2-3 Apr 12 and 3 Dec11	2.7%

4.7 Summary of Year 2 Image Datasets

For the second year of the MRVS, RapidEye and Landsat are the core datasets used to monitor land use change.

RapidEye

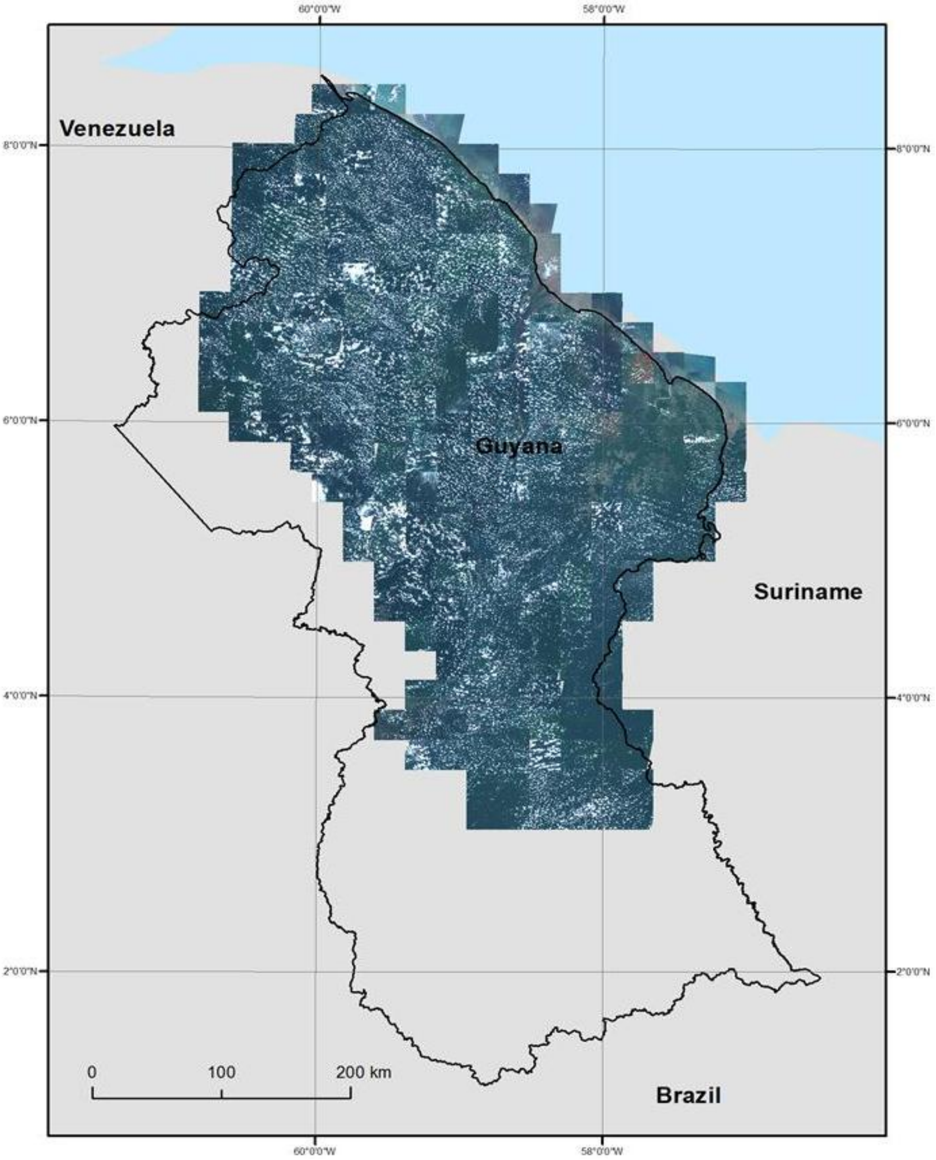
The RapidEye constellation consists of five satellites and began commercial operations in February 2009. RapidEye holds imagery in an online image archive, and is also available to be tasked to cover specific areas for custom acquisition. RapidEye provides both '1B' and '3A' 5 metre resolution products. The 3A product is terrain corrected and was used for this analysis. Experience has shown that this product requires a degree of post-processing to correct for geometric offsets.

The product is provided as 25 km x 25 km tiles, which can be downloaded via FTP. Imagery at 5 m resolution provides the possibility of detecting forest gaps and degradation, much more accurately than Landsat imagery.

[15] Bands used for the analysis

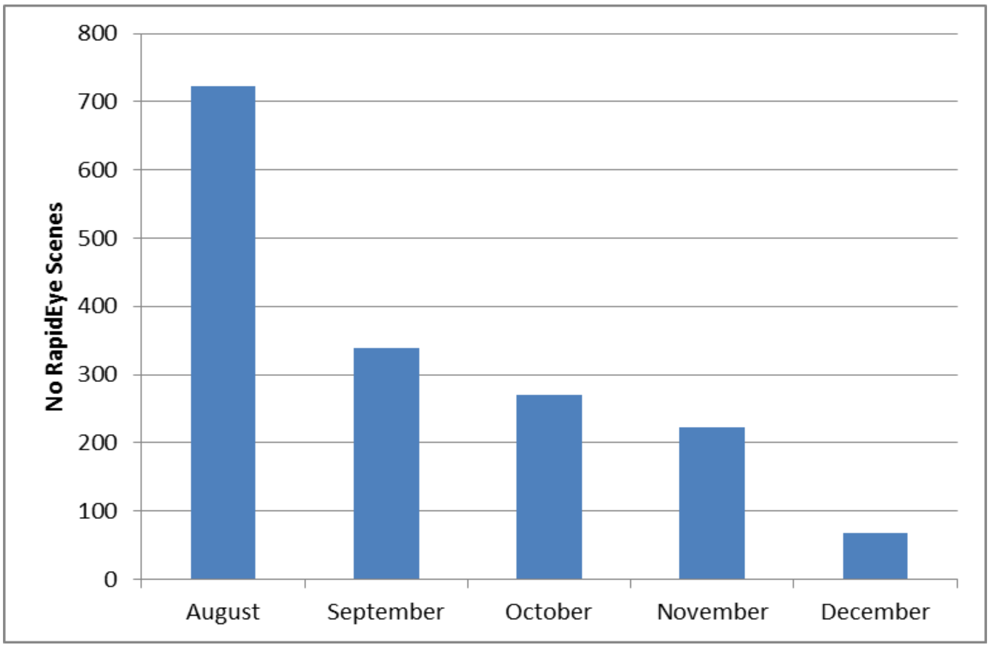
GFC tasked the RapidEye satellite constellation to acquire imagery over the most active change areas. These areas were change areas identified in the previous Year 1 assessment. Prior knowledge of these areas assisted in focusing the area for the Year 2 image acquisition (Figure 1). The tasking order included provision to collect multiple scenes over the same location. The ability to interpret multiple scenes increases the useable area of the imagery.

Figure 4: RapidEye Acquisition Summary August- December 2011



The tasking period spanned a five month period from August 2011 to 31st December 2011 which in Guyana is identified as the period with lower cloud cover. Figure 5 shows the RapidEye (56% of the country) image acquisition results. Most images were acquired from August to October for the Year 2 period. Landsat imagery was acquired over the entire country.

Figure 5: RapidEye Image Acquisition August to December



Higher priority was placed on analysing images acquired at the end Year 2 reporting period to ensure that changes that occur at the end of the Year 2 period are reported. Due to the cloudy nature of satellite imagery over Guyana multiple scenes from different dates over the same location have been analysed.

Landsat Imagery

To supplement the RapidEye acquisition, 30 metre Landsat 5 and Landsat 7 data was also acquired.

Landsat 5 and Landsat 7 imagery at 30 m resolution offers the most comprehensive temporal coverage over Guyana. This imagery is archived and is freely available and can be sourced from either the United States Geological Survey (USGS) or National Institute for Space Research (INPE) Brazil. The largest archive of Landsat 5 is held by INPE while USGS tends to have a larger inventory of Landsat 7[16] images. Imagery sourced through USGS comes processed as “L1T” or terrain corrected (using SRTM 90 m DTM), whereas INPE imagery typically does not. All Landsat imagery used in the Year 2 assessment was obtained from USGS.

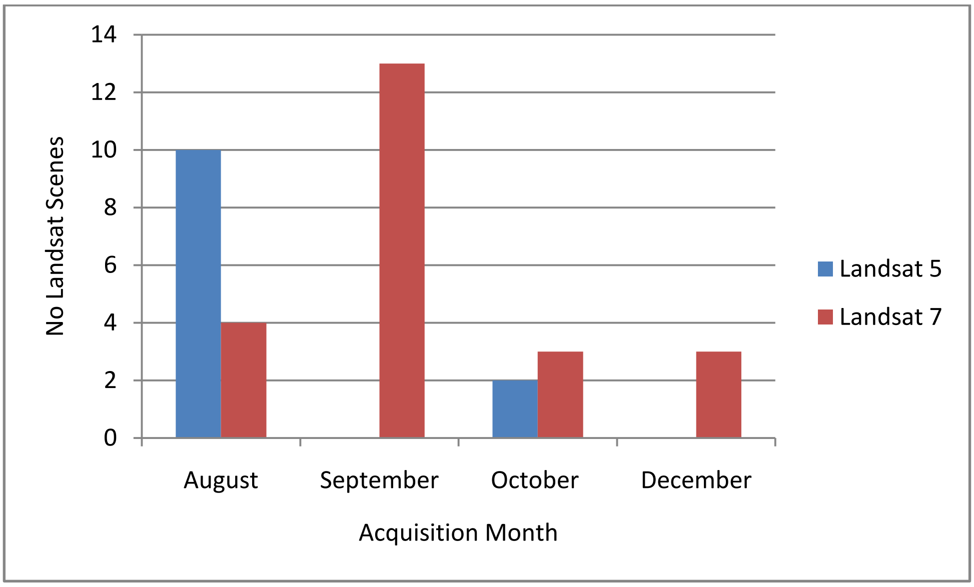
In May 2003, Landsat 7 encountered a scan line correction fault that caused a striping effect on the images. This fault has reduced the utility of Landsat 7 images for mapping, although it is still practical to use it visually for monitoring temporal change.

As of 18 November 2011, Landsat 5 imagery has become unavailable due to failure of an electronic component, which prevented the transmission of images to ground stations. This is a significant loss in image provision.

Figure 6 shows the temporal distribution of the Landsat scenes used for the year two analysis. A majority of the scenes (85%) were obtained between August and September.

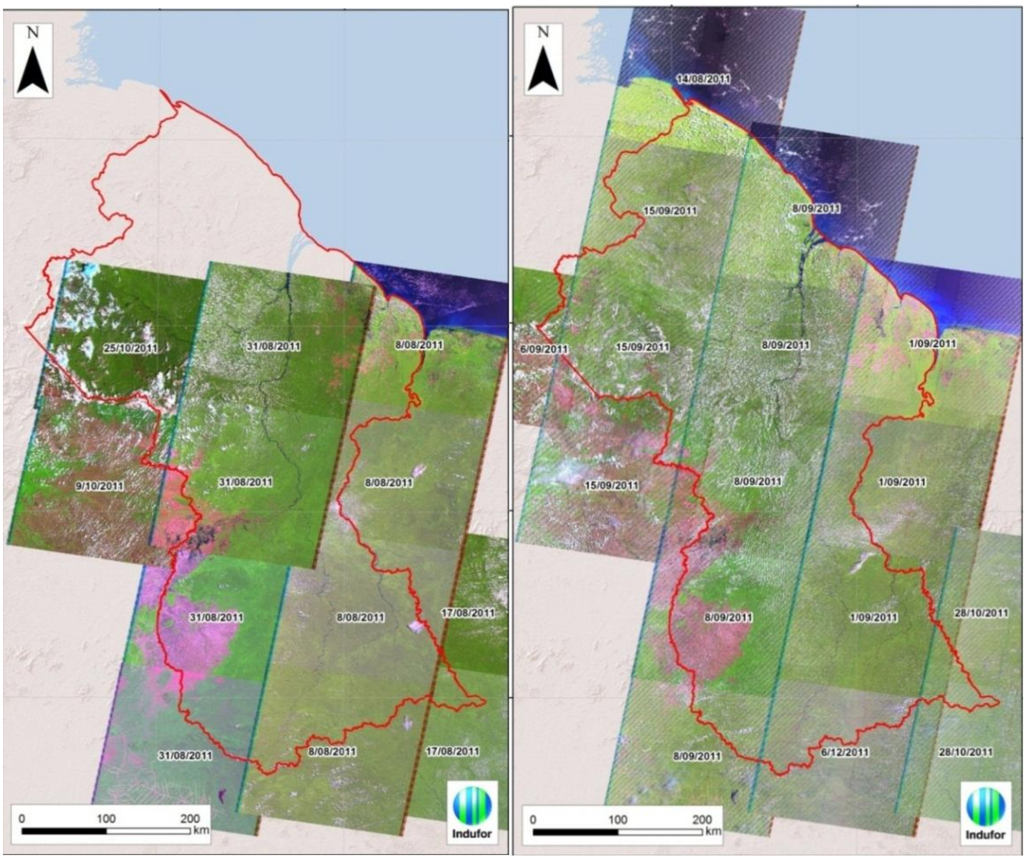
[16] On May 31, 2003 the Scan Line Corrector (SLC) in the ETM+ instrument failed. The SLC consists of a pair of small mirrors that rotate about an axis in tandem with the motion of the main ETM+ scan mirror. The purpose of the SLC is to compensate for the forward motion (along-track) of the spacecraft so that the resulting scans are aligned parallel to each other. Without the effects of the SLC, the instrument images the Earth in a "zig-zag" fashion, resulting in some areas that are imaged twice and others that are not imaged at all. The net effect is that approximately one-fourth of the data in a Landsat 7 scene is missing when acquired without a functional SLC.

Figure 6: 2011 Landsat Scenes Acquired



An overview of the spatial distribution used for the Year 2 analysis shows that full coverage is obtained by using a combination of Landsat 5 and 7 (Figure 7). The south of the country which is remote and difficult to access is predominately cloud-free.

Figure 7: Year 2 (2011) Landsat 5& 7 Coverage by Date



4.8 Additional Ancillary Satellite Images & Fire Datasets

Additional imagery to support the analysis was also used. The inclusion of DMC, IRS (LISS 3), MODIS and Radar datasets enabled areas of cloud persistent cloud over the RapidEye and Landsat areas to be assessed. It also provided a useful reference to confirm the timing of change events. A spatial representation of fire locations was also used to assist with attributing anthropogenic fire-driven change events

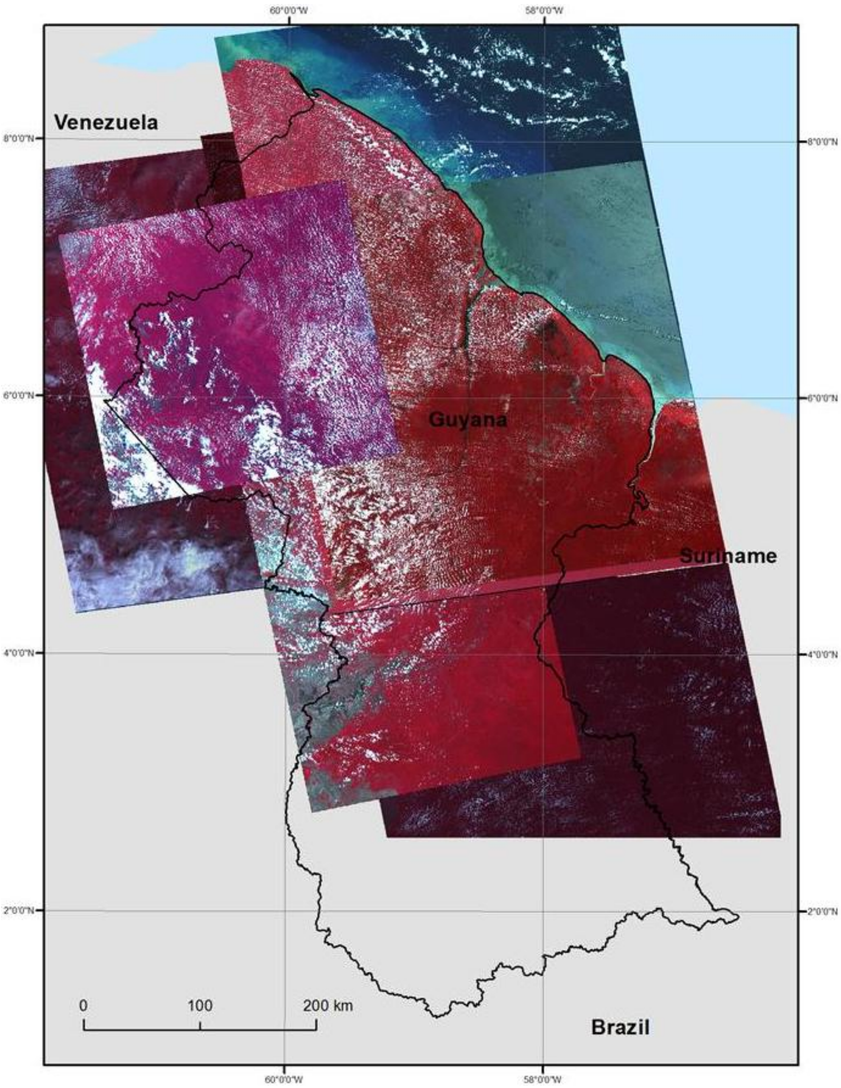
A summary of each dataset is as follows:

DMC

In 2010 (Sept 2010 to January 2011) GFC tasked DMC satellites (22 m and 32 m resolution) to provide cloud-free coverage for the Year 1 analysis. The Disaster Monitoring Constellation managed by DMC International Imaging targeted the most active areas. Several large ortho-rectified images were provided to GFC between September and December 2010.

Many of these images were provided to GFC after the Year 1 reporting period. As a result these scenes were not utilised in the Year 1 analysis. The images were included in this analysis. These images were used to assist with the detection and the timing of land cover change events.

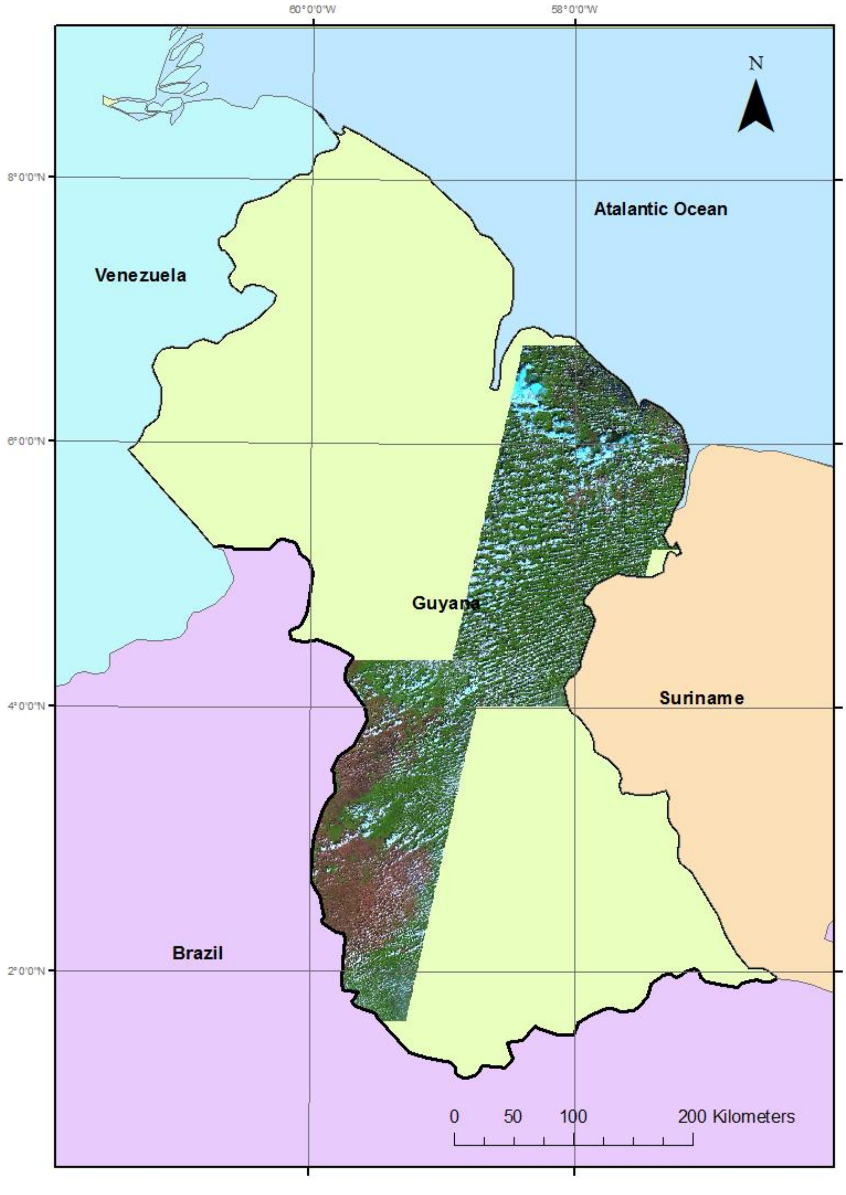
Map 4-1: DMC Coverage 2010 (Year 2)



4.9 IRS ResourceSat-1

Since 22 February 2010, images from the Indian Remote Sensing (IRS) ResourceSat-1 (IRS-P6) satellite have been made freely available via INPE's receiving station in Cuiaba, Brasil. This agreement includes distribution of Linear Imaging Self-Scanning Sensor (LISS-3) and the Advanced Wide Field Sensor (AWiFS). The IRS revisit period is 24 days which limits the number of images that are able to be acquired. For the Year 2 analysis five scenes obtained between November and December were assessed.

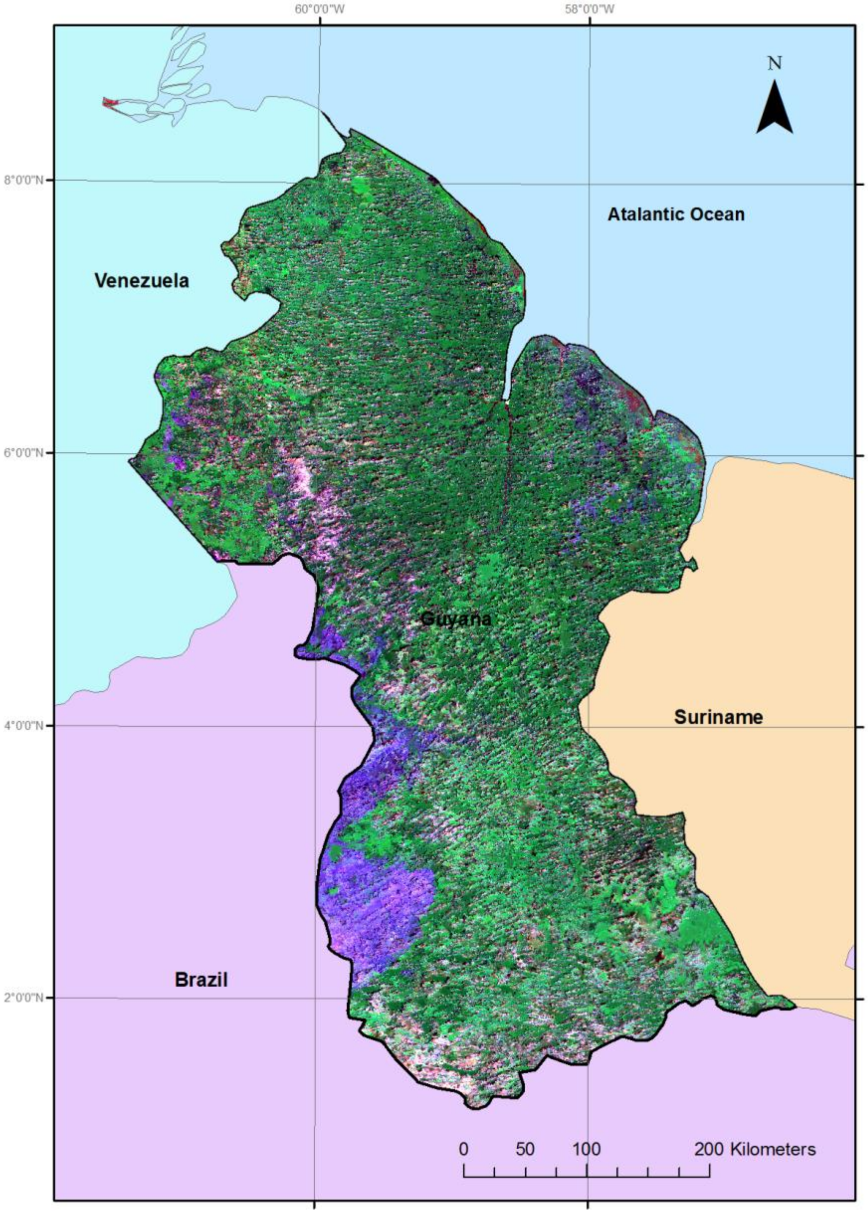
Map 4-2: IRS Coverage 2011



4.10 Monitoring Broad-scale Forest Change

MODIS data has also been evaluated to provide broad scale coverage of forest change. MODIS is a low resolution sensor so it is not suitable for mapping areas but does provide the location of potential change for areas >20 ha. Currently, two identical sensors on board two separate satellites: Terra and Aqua, provide daily images in the morning and afternoon at 250 m resolution imaging in the visible and near infrared range. To cover Guyana two images are required. Although the application of MODIS to detect small-scale is quite limited, the daily revisit period does offer an attractive option to monitor persistently cloudy areas for change. MODIS is used for this purpose in Brasil for the DETER program. Two scenes were obtained for December and used to analysis the areas of persistent cloud for change.

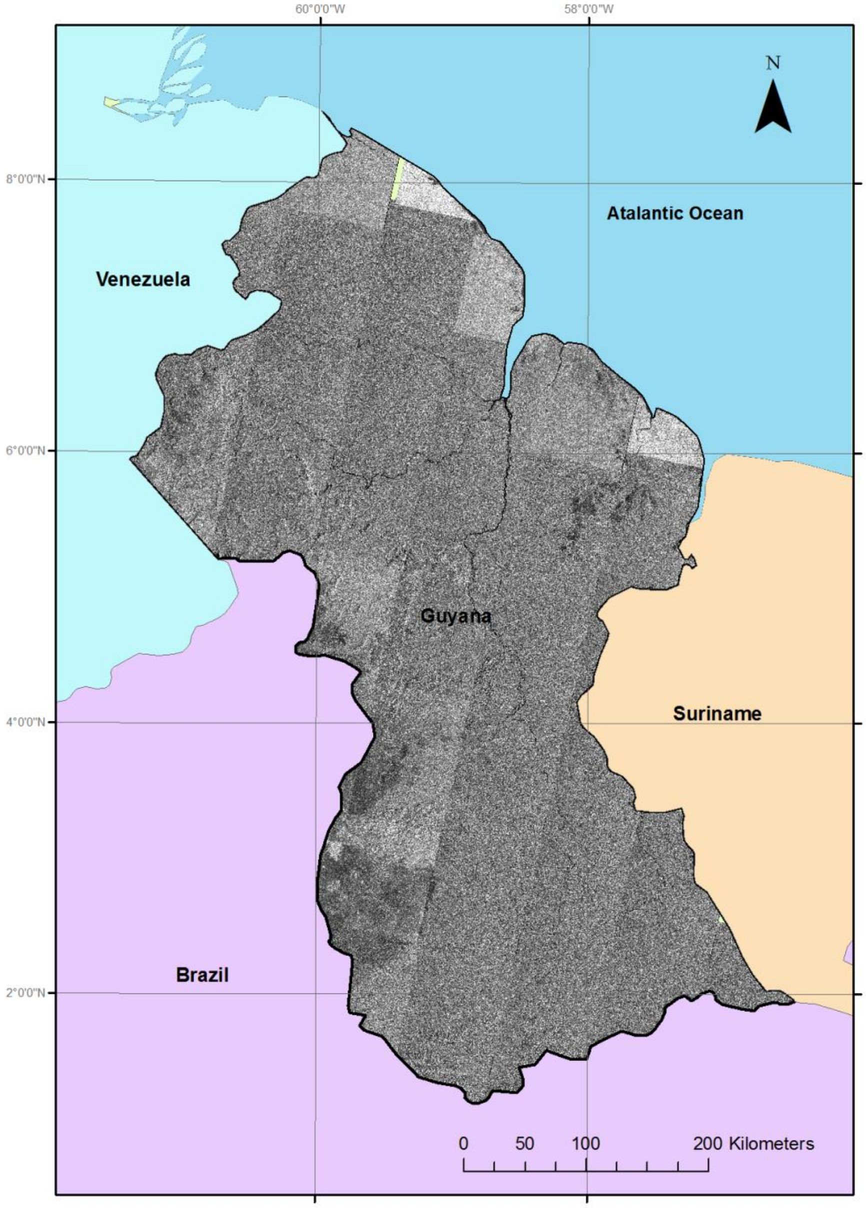
Map 4-3: MODIS Cloud-free Mosaic December 2011



Radar

RADAR data over Guyana can be obtained through the Forest Carbon Tracking Task (http://www.geo-fct.org/). This data portal has been established to assist with facilitating access to long-term satellite, airborne and in-situ data and follows the guidelines set out by the UNFCCC. The major advantage of incorporating RADAR into the analysis is that RADAR can penetrate through cloud, which assists in determining change over any areas of persistent cloud. A total of 113 ASAR dual polarised scenes were assessed. The spatial resolution ranged from 5 to 15 m. A majority of the scenes (70%) were acquired between January and May 2011.

Figure 8: ASAR 2010-2011 Coverage



4.11 Fire Monitoring - FIRMS Data

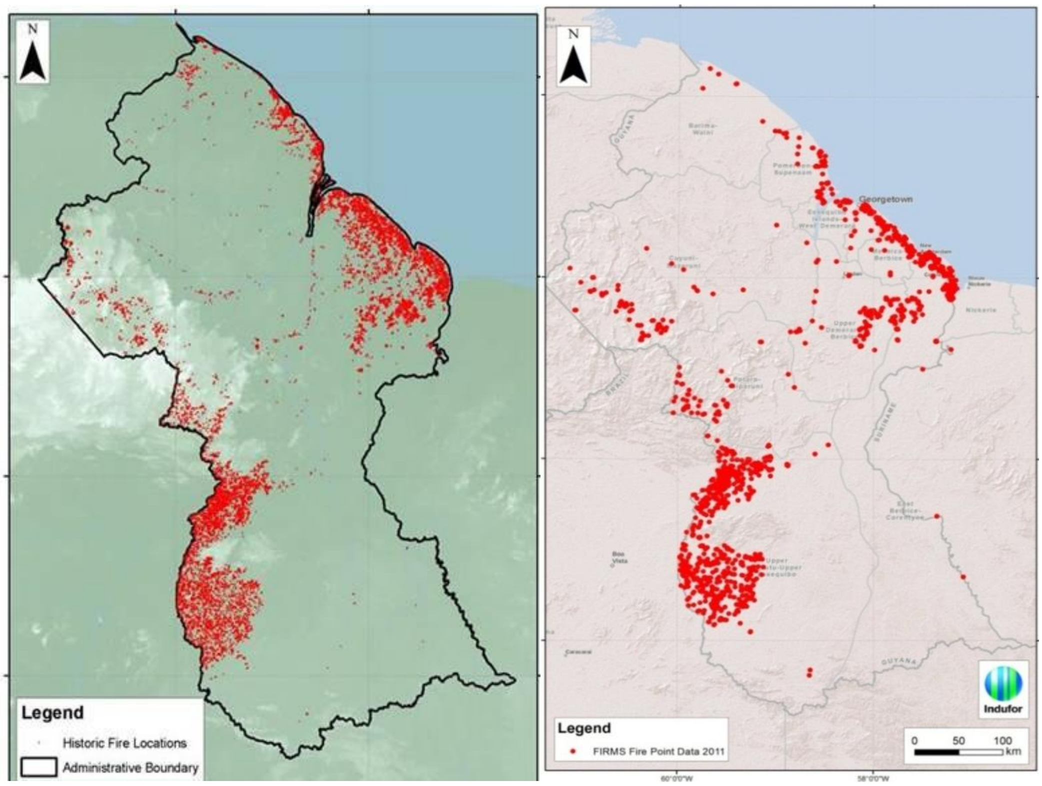
The Fire Information Resource Management Service (FIRMS) active fire dataset derived from thermal bands carried on the MODIS satellite has also been acquired. This data is freely available and is distributed via FIRMS. This dataset will assist with attributing anthropogenic fire-driven change events.

The Year 1 analysis utilised FIRMS to assist with detecting fire locations. This information was acquired using the Moderate Resolution Imaging Spectroradiometer (MODIS) as recommended in the GOFC-GOLD Sourcebook.

The MODIS dataset is onlyused to identify risk areas as the resolution is low and subsequent detection accuracy quite variable. The presence of fire was confirmed using RapidEye and Landsat images.

Figure 9 shows the fire locations for the Year 1 (left) and Year 2 (right) periods. It confirms that there is a distinctive spatial pattern associated with fire events. A majority of the fires detected by MODIS sensor are located in non-forest areas or along the coastal fringe.

Figure 9: FIRMS Data Year One & Two Period



INPE in Brazil also routinely downloaded and produces monthly fire maps from geostationary satellites such as GOES. These maps are freely available http://sigma.cptec.inpe.br/queimadas/index) and were also evaluated to see if they assist with the process of locating fire events.

4.12 Accuracy Assessment Datasets

The following additional high resolution datasets were acquired for the accuracy assessment.

4.13 WORLDVIEW-1

WorldView-1 was launched in September 2007, and the product acquired for the assessment exercise was 0.5 m nominal nadir-looking spatial resolution at one panchromatic band (400-900 nm). It was rectified with the use of rational polynomial coefficients that were provided with the product that would nominally offer accuracy of 5 m CE90 excluding terrain effects. In practice, it proved geometrically accurate enough for the validation purposes.

4.14 WORLDVIEW-2

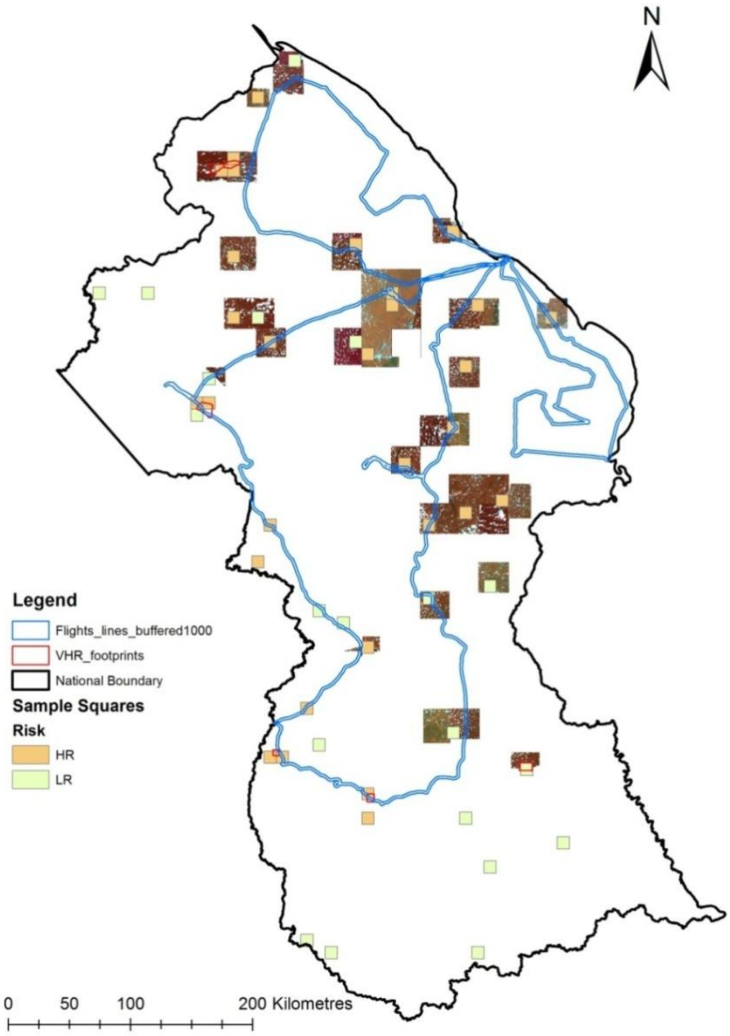
WorldView-2 was launched in October 2009, and the product acquired for the assessment exercise was 2.0 m nominal nadir-looking spatial resolution at four bands (red, green, blue, and near-infrared). It was rectified with the use of rational polynomial coefficients that were provided with the product that would nominally offer accuracy of 5 m CE90 excluding terrain effects. In practice, it proved geometrically accurate enough for the validation purposes.

4.15 QUICKBIRD-2

QuickBird-2 was launched in April 2011.The product acquired for the assessment was 2.62 m nominal nadir-looking spatial resolution with four spectral bands (red, green, blue, and near-infrared). It was rectified with the use of rational polynomial coefficients that were provided with the product. Typically this providesan accuracy of 23 m CE90 excluding terrain effects. In practice, it proved geometrically accurate enough for the validation purposes.

The following map provides an overview of the image data used for the accuracy assessment.

Figure 10: High Resolution Data Available for Validation



4.16 RADAR

Several radar datasets exist over Guyana available via the Forest Carbon Tracking Portal (www.geo-fct.org) and include single and dual polarised (30 m resolution) ASAR scenes that provide partial coverage of Guyana. The spatial resolution, as well as the nature of the backscatter product, is not of sufficient quality to allow detailed interpretation of forest change and forest change drivers and so these RADAR data were not used in the verification process. However, in future it may be possible to use fine beam-mode RADAR products to assist with change detection analysis.

4.17 Additional Verification Datasets

Two over-flights were undertaken using a Cessna 206 high wing light aircraft to provide high resolution photography of the ground from at altitude of 1,000-1,500 feet (Figure 3). GPS tagged oblique photographs were taken from both sides of the aircraft using 5 megapixel digital cameras. We estimate that each photograph captured an image of a 100 ha area every 1.5 km providing near total coverage of an area of 225,000 ha in total from two flights (see Figure).

Figure 11: The Cessna 172 and Observation Team

Figure 12: Example of over Flight Photography

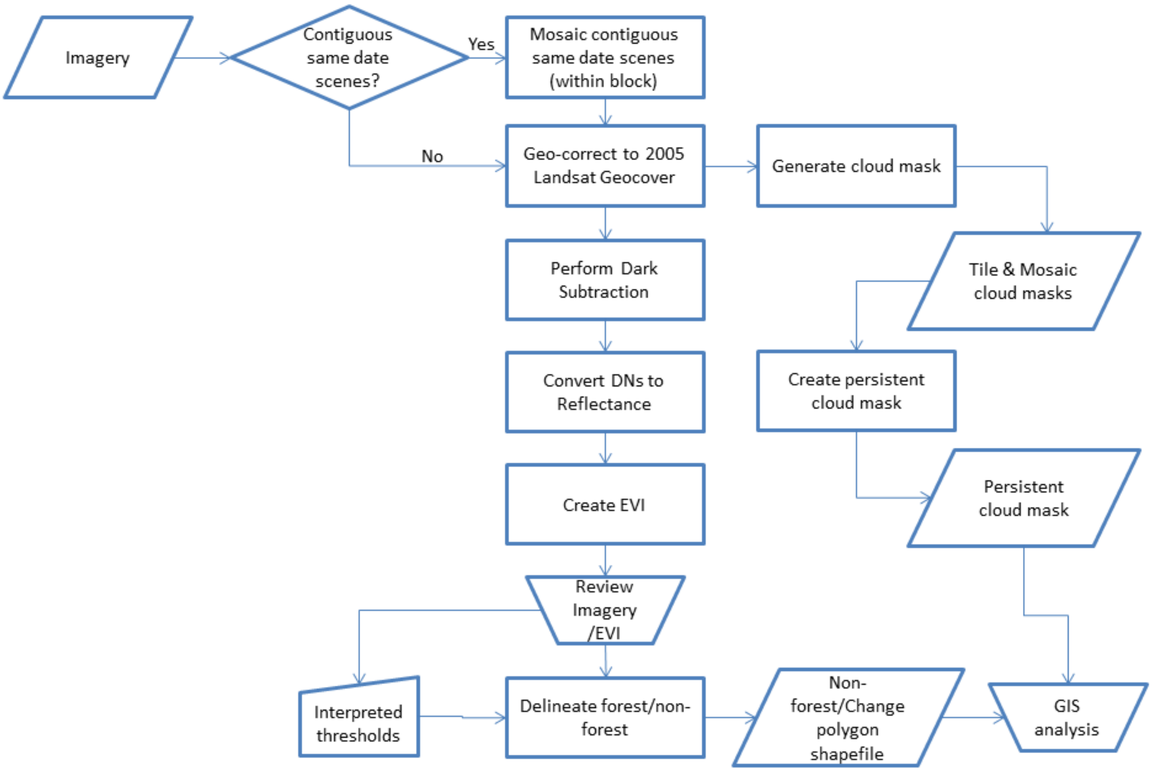
Top left shows clearance for shifting agriculture and fire; the top right photo shows a secondary road almost invisible and the bottom left, forest types easily confused with non-forest. Lastly, bottom right: a Year 2 mining camp/dredge.

5. IMAGE PROCESSING

The image processing focused principally on processing the RapidEye satellite images. The only processing applied to the Landsat was geo-correction and generation of the persistent cloud mask. All other image data (DMC, IRS, MODIS and ASAR) were only used for reference purposes in order to verify or attribute the drivers of forest change.

The degree of image processing applied to the RapidEye depended on the cloud cover of each scene. The level of processing applied to each scene was documented.

Figure 13: Image Processing



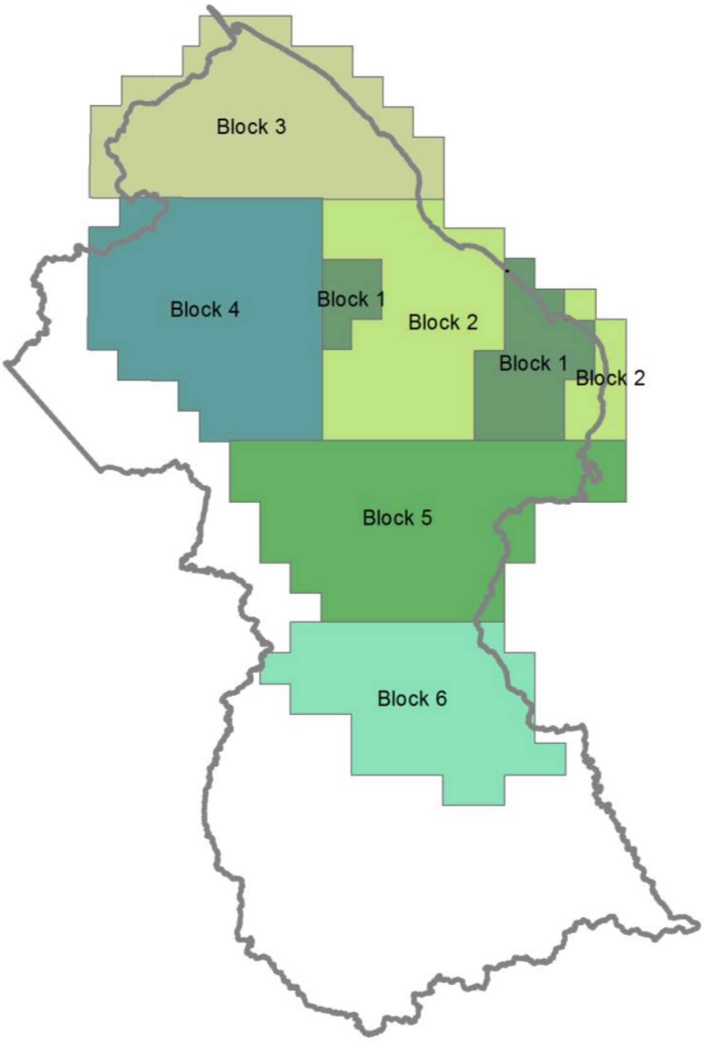
Automated methods are generally preferable where possible because the interpretation is repeatable and efficient (Herold, 2009). For the Year 2 analysis, automated image analysis methods were limited to normalisation routines and the extraction of the potential forest change polygons using the EVI ratio. From this point, direct interpretation and manual editing of the change area was performed. This is an acceptable approach that is recognised in the GOFC-GOLD sourcebook.

While automated change detection using multi-temporal image differencing was not feasible for this assessment it is anticipated that once repeat acquisition has been acquired for year 3 that methodology will be adapted to allow further automation.

5.1 Image Mosaic

The RapidEye data was ordered and delivered over time in six blocks as shown in Figure 14. To simplify the data management and processing of the large number of RapidEye scenes, contiguous image tiles acquired at the same date and time within a block were generally mosaicked into a single multi-band file. Scenes without contiguous image tiles acquired at the same date and time were always processed as a single tile.

Figure 14: RapidEye Processing Blocks



5.2 Image Geo-correction

All satellite images were geo-referenced to the 2005 Landsat Geocoverbase map. Accurate geo-referencing is important to ensure that changes detected in future time periods are valid and not simply artefacts caused by inaccurate co-registration.

In areas where duplicate RapidEye scenes were acquired, the most cloud-free scene was referenced to the base map ensuring mis-matches were less than one Geocover pixel. Subsequent overlapping scenes were referenced to the previously co-registered RapidEye.

5.3 Radiometric Normalisation

Radiometric normalisation is a recommended image processing practise to ensure the radiometric values within images obtained over different time periods and by different sensors are calibrated to common reference values. There are many methods applied for the normalisation of images that perform either a relative correction to a single scene or an absolute correction to standard reflectance units.

For practical purposes based on the project timeline, the number of RapidEye images to process, the generally high level of clouds per image and the availability of atmospheric correction data, the dark subtraction radiometric normalisation method implemented in ENVI was chosen.

Each scene was evaluated and the band minimum Digital Number (DN) values were automatically selected from each scene and subtracted from all pixels within the scene with the assumption the band minimum values are dark targets that are only influenced by atmospheric scattering.

The method adopted uses a combination of automated (calculation of vegetation indices) and manual interpretation and editing. The objective of the approach was to use a vegetation index to delineate areas of forest and non-forest.

Identified areas of non-forest within the forest mask represent potential areas of forest change (i.e. deforestation or degradation). The delineated non-forest areas were input into a GIS and used as an ancillary layer in the Year 2 change analysis mapping.

The key to differentiating forest from non-forest is to link the reflectance properties of the vegetation to its structure. Several vegetation indices exist that enhance non-forest detection as described by *Asner (1998).*

For this work the Enhanced Vegetation Index (EVI) as described in *Huete et al.* (1997) was favoured over other vegetation indices as it includes the blue reflectance. The strength of the EVI is in its ratio concept which provides a correction for soil background signals and reduces atmospheric influences, including aerosol scattering. This is particularly relevant given the lack of any aerosols, water vapour, and ozone concentrations to correct atmospheric conditions.

The EVI is calculated using the following equation as presented and described in *Huete et al 200*2,

$$\mathrm{EVI} = G\frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{red}}}{\rho_{\mathrm{NIR}} + C_1 \times \rho_{\mathrm{red}} - C_2 \times \rho_{\mathrm{blue}} + L} \qquad (1)$$

where G is the gain factor, ρ are atmospherically corrected or partially atmosphere corrected (Rayleigh and ozone absorption) surface reflectance's, L is the canopy background adjustment that addresses nonlinear, differential NIR and red radiant transfer through a canopy, and C_1, C_2 are the coefficients of the aerosol resistance term, which uses the blue band to correct for aerosol influences in the red band. The coefficients adopted in the EVI algorithm are, L=1, C_1=6, C_2 = 7.5 and G = 2.5.

The EVI values range from 0 to 1 with low values indicating non-vegetative surfaces and those closer to 1 representing closed canopy forest. The same approach was successfully applied to separate forest and non-forest components for the 1990-2010 period[17].

The method has also been widely discussed in the scientific literature. *Deng et.al. (2007)* found that EVIwas effective in vegetation monitoring, change detection, and in assessing seasonal variations of evergreen forests.

Additionally, the EVI has been found to perform well in the heavy aerosol, biomass burning conditions in Brazil *(Miura, Huete, van Leeuwen, & Didan, 1998).Miura, Huete, Yoshioka, and Holben (2001)* also showed EVI ratio can successfully minimize residual aerosol effects resulting from the dark target-based atmospheric correction. The same approach was applied in this assessment

An indication of the variation across the EVI values across the blocks is provided in Table 5-1.

[17] The independent accuracy assessment conducted in 2010 reported that the accuracy of the forest and non-forest mapping to be 97.1%.

Table 5-1: Non-forest EVI Values by Block

Block No.	Area (km^2)	No. Scenes	Min	Max	Mean EVI	s.d.
1	33,629	9	0.30	0.45	0.39	0.05
2		25	0.30	0.45	0.37	0.04
3	21,309	40	0.31	0.38	0.34	0.02
4	26,505	38	0.25	0.36	0.30	0.02
5	26,799	27	0.25	0.37	0.31	0.02
6	15,680	15	0.30	0.35	0.32	0.02
	122,932	154	0.28	0.39	0.33	0.03

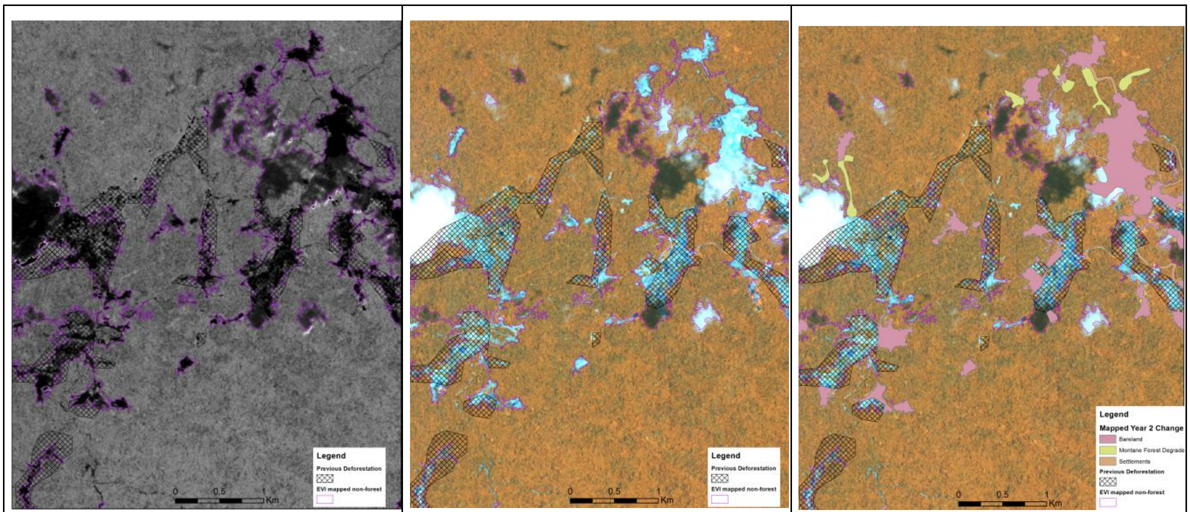
Overall 79% of EVI values over the 154 RapidEye scenes sampled fell between 0.25 and 0.35. The standard deviation for each block is very similar and small which provides an indication that the EVI is quite stable between individual scenes and across blocks. Fluctuations in the EVIrange (0.25 to 0.31) across the landscape are expected due to differences in vegetation composition, soil moisture content and shadow introduced by topography or cloud contamination.

The automated change detection process produces a vector layer delineating the potential areas of non-forest. The vector layer is subsequently input into the GIS for review, editing and attribution.

As part of continual improvements to the MRVS, additional aerial inspections were undertaken over further areas in 2011. These flights were planned so as to capture geo-located photos over new areas. This information was used to further refine the initial EVI thresholds applied to separate forest and non-forest cover.

The areas detected from the EVI were then systematically visually evaluated by placing a 10 x 10 km grid over the country. Each grid is visited by an operator and the EVI area assessed and edited as necessary to ensure areas of cloud, previously detected non-forest or change (pre-Year 1) were separated. The following sequence shows the EVI image (A) the detected areas (magenta) overlaid on the RapidEye with associated Year 1 change identified. The final image (C) shows the classified result which splits out the change from cloud, cloud shadow and previously mapped non-forest and change from the benchmark period (hatch area).

Figure 15: EVI Delineation and Resulting Change Analysis Mapping



EVI (A) | RapidEye (B) | Mapped Change (C)

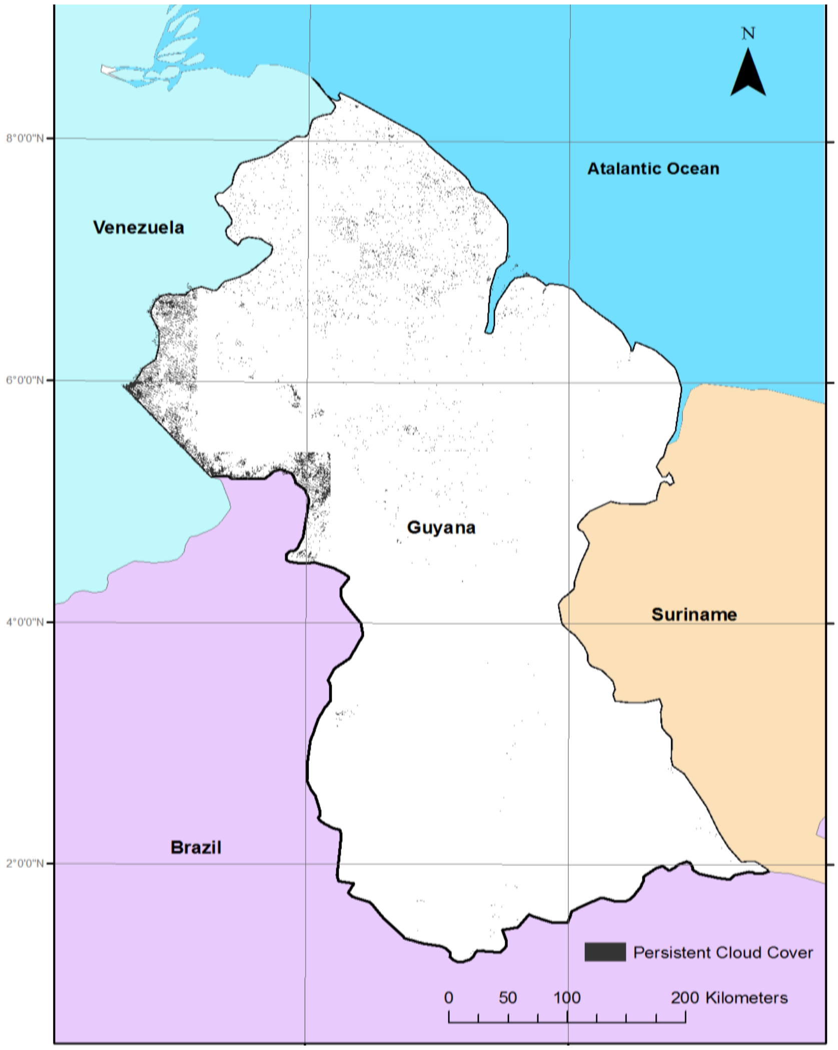
5.4 Persistent Cloud

One potential issue is detection of change in areas of sporadic and persistent cloud. In areas of sporadic cloud (i.e. where at least one period is clear) the change was attributed to the first period it was observed in. If areas are under persistent cloud cover then it is not possible to evaluate the area for change.

The impact of cloud was assessed by generating cloud masks for each RapidEye and Landsat image to identify those areas of persistent cloud. An additional gap mask was also created for the Landsat to mask out areas of no data caused by the failure of the on-board scan line corrector. The masks were generated by a simple band threshold approach and edited to remove areas of non-forest. The cloud mask does not identify cloud shadow so it provides only a broad estimate of cloud coverage.

The analysis showed that for Year two, 2.9% of the land area was persistently covered in cloud. In the most active areas of change (i.e. area tasked by RapidEye), the analysis showed that 1.3% of the land area was persistently covered in cloud. The distribution of the cloud is quite scattered and located over the northern half of Guyana as shown on Figure 16. The largest area of persistent cloud is observed over the western part of Guyana on the border with Venezuela. This is attributed to the Landsat no data values. This area falls outside of the main area of change which is concentrated in the centre of Guyana.

Figure 16: Cloud Cover Oct 2010 – Dec 2011



There are three verification options available over areas of persistent cloud;

- Ground inspections in accessible areas
- Aerial inspection
- Evaluation of alternative image datasets

Due to time limitations interpretation of alternative imagery was considered the most efficient option. This involved evaluatingMODIS and ASAR radar images for additional change. The resolution of MODIS restricts the minimum mapping unit (MMU) to about 20 ha[18] (Morton *et al*, 2002) and is only used as a guide to assist in the detection of change areas.

MODIS has been used in the region for a number of deforestation studies (i.e. Morton *et al* 2002 & 2005, DeFries *et al* 2005) and is used operationally by INPE in Brasil for near real time detection of monitoring of hotspot areas (DETER[19])

The main application of MODIS is the detection of large deforestation events (>20 ha) and identification of regions of increased forest clearing activities (Morton *et al* 2002 & 2005, DeFries *et al* 2005, Watt & Haywood 2007).

Daily MODIS 250 m images obtained for December 2011 were obtained from USGS. The MODIS 250 m product is provided processed to surface reflectance as a two-band product computed from the MODIS Level 1B bands 1 and 2 (centered at 648 nm and 858 nm respectively). The product is an estimate of the surface spectral reflectance for each band as it would be measured at ground level if there was no atmospheric scattering or absorption.

These images were combined to create a mosaic. The persistent cloud mask was then overlaid on the mosaic and systematically reviewed

In addition, dual polarised ASAR radar (nominal resolution of 5 to 15 m) images were also evaluated. Radar images offer another source of verification.

It is acknowledged that the utility of the MODIS and radar images for detections of smaller scale fragmented change is limited. This is due to the low resolution of the MODIS and inherent variation in the backscatter of radar. Without additional reference layers such as GIS boundaries, new change areas outside of the hotspot area are difficult to identify.

A more pragmatic approach and one that fits with the temporal monitoring system adopted is, to update the annual change layer for any missed areas in the next assessment period. At this point these missed areas are then accounted for and entered into the MRVS.

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[18] A single MODIS 250 m pixel is approximately equivalent to 6.25 ha
[19] http://www.obt.inpe.br/deter

6. DEGRADATION METHODOLOGY

An important aspect of the Year 2 assessment was the quantification of the extent of degradation caused by new infrastructure developments such as road construction and mining through remote sensing and field observations.

While there is still some debate internationally over the definition of 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* ".

During the year one analysis, a default distance of 500 m was applied surrounding all areas of new infrastructure to define degraded forest areas.

The rationale of this approach is expressed in the Joint Concept Note (JCN) as follows: "The establishment of new infrastructure in forest areas often contributes to forest carbon loss outside the areas directly affected by construction."

The JCN also states that "unless a larger or smaller area or greenhouse gas emission impact can be documented through **remote sensing or field observations**, the area within a distance extending 500 metres from the new infrastructure (including mining sites, roads, pipelines, and reservoirs) shall be accounted with a 50% annual carbon loss through forest degradation."

The approach taken in Year 2 was to estimate the area of degradation surrounding new infrastructure with the 5 m RapidEye satellite imagery. In the Year 1 analysis the default position of buffering areas by 500 m was adopted.

In this context it is important to:

- Understand the characteristics of degradation specific to Guyana.
- Review operational methods and research that have used optical datasets to characterise degradation.
- Implement a solution that is repeatable and easily adopted.

6.1 Characteristics of Degradation

The two main contributors to degradation in Guyana are roads associated with new infrastructure and degradation surrounding deforestation events such as mining.

Roads

Analysis of historical satellite imagery indicates that road construction has declined over the past 10 years and since year 2000 the annual area developed is similar. The exception to this is the recent construction of the access road to the Amaila Falls hydropower site.

Any secondary roads constructed are only accessible via the existing road network. It is these secondary access routes that are constructed around new infrastructure.

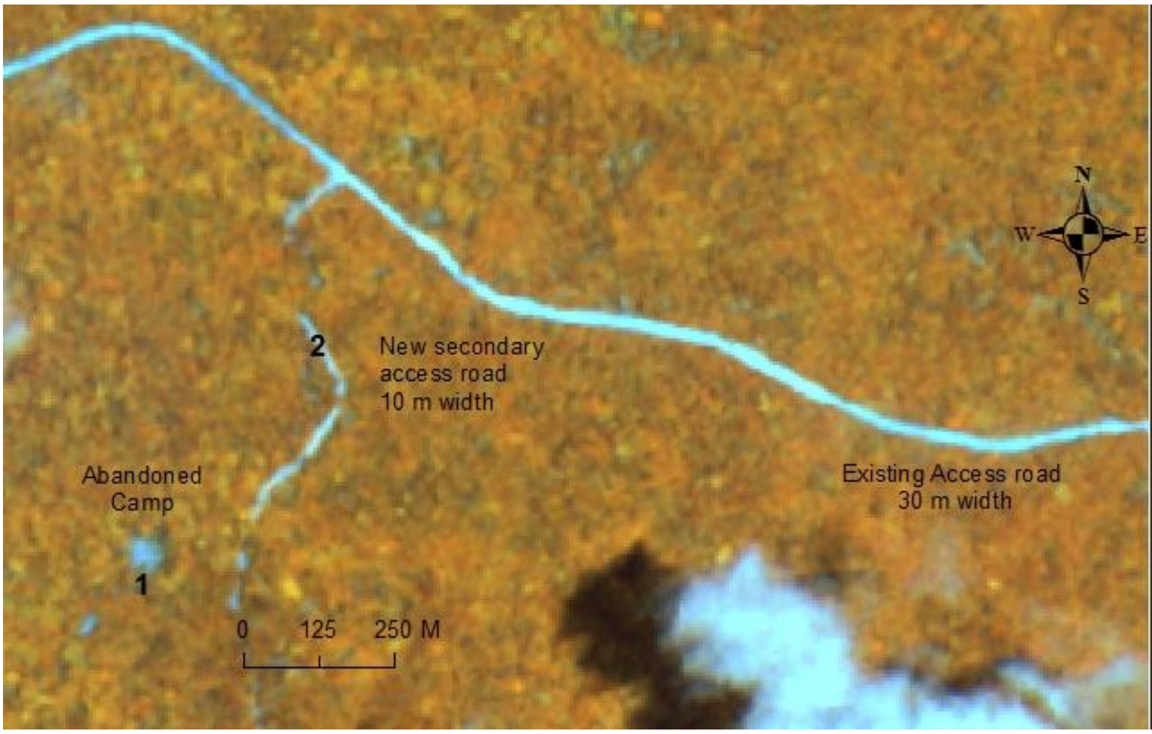
Based on field inspections and local experience, the characteristics of these roads can be described as follows:

- Used as transportation routes between existing roads and deforestation sites
- Lowly populated
- Infrequently ungraded and maintained
- Narrow in width(~10 m) and unsealed.
- Often sections are poorly drainedwhichrestricts accessibility to 4WD vehicles and all-terrain vehicles (ATVs)

- Nearby trees sometimes used to build temporary bridges and to stabilise the road
- Road sections are widened in persistently wet areas
- The road network is often abandoned once mining has been completed and temporary settlements (camps) dismantled(see Photo 1)

The following field photographs are matched to the satellite image using GPS. Photo 1 shows an abandoned camp site (0.5 ha) and Photo 2 the typical condition of a secondary road. These roads are accessed by either four wheel drive vehicles(fitted with a winch)orall-wheel drive trucks. The final photo shows an example of a primary road (~30 m in width).

Figure 17: RapidEye Image & Corresponding Field Photographs



Visual Interpretation of the satellite image over these sites shows areas of disturbance as distinct blue tones. Different forest typesarevarying shades of orange that transition to darker tones in wetter low lying areas.

On the image, roads are clearly identified by their shape and size. They appear as linear features and depending on their width, are either continuous or disconnected.

New Infrastructure Developments

The characteristics of degradation around new infrastructuresuch asmining sites follow a trend. The following sequence of photos, documents the main degradation activities.

For mining sites degradation is observed during the reconnaissance phase of mining. This involves establishing sample pits to determine the gold concentration (photo 1). These are usually established at regular intervals along a basic access track. This activity is potentially the precursor to commercial mineral extraction.

If area is mined then the forest cover is removed and the debris pushed to the edge of the site (photo 2).

Because the mining process requires access toa water source, mining sites characteristically follow streams and are located in depressions to allow the formation of ponds. The water is pumped from the ponds and pressurised into a jet that is focused on excavated mounds of soil. This process leaves depressions which fill with water (photo 3).

Often, scattered groups of trees are left across the site (photo 3). Once the site is abandoned, vegetation would sometimes begin to regenerate and cover the site (photo 4).

Figure 18: Infrastructure Field Photographs

Photo 1 Reconnaissance hole

Photo 2: forest cleared and pushed to site edge

Photo 3: Abandoned mine (<1 year after)

Photo 4: Regeneration (~ year after)

A common pattern is that once mining commences, it expands. This means that areas interconnect and forest areas can move from a degraded to deforested state. The approach adopted allows for the monitoring of these types of changes.

6.2 Review of Degradation Methods

Forest degradation is a dynamic process that varies in space and time. It is less well studied compared to deforestation, particularly in the context of measuring and monitoring for REDD+. As a consequence, the scientific and forest policy literature contains a range methodological approaches that have been used to help identify and in some cases, quantify the amount or level of degradation (Lambin, 1999; Ringrose *et al,*1990; Hellden, 1991; Tucker *et al.,* 1991; Prins and Kikula, 1996).

The studies of most relevance to REDD+ are summarised in Table 6-1(degradation table) and are drawn from a wide range of mostly tropical forests from around the world. It is noticeable that almost all of the peer review published papers focus on degradation due to selective logging, fire, unplanned harvesting, collection of fuel wood and non-timber forest products, production of charcoal, grazing and shifting cultivation (GOFC-GOLD, 2008).

The geographical focus of studies is mainly but, not exclusively, in South America (especially the Amazon basin) and south Asia (Indonesia, India, Nepal, Papua New Guinea). Many of these studies have attempted to use multispectral imagery from medium resolution satellite data such as Landsat to identify degraded forest and several studies compare and contrast methodological approaches and image processing algorithms for this task (Griscom *et al.,* 2009;Herold *et al.,* 2011; Lambin, 1999;Murdiyarso *et al.,* 2008; Potapov *et al.,*2009);Roy *et al.,* 2005).

The purpose of this review is to ensure that the procedures used to identify and verify forest degradation in Guyana follow, and in some respects advance on, best practice as evidenced from the international peer review scientific literature.

Methods

Forest degradation is caused by a variety of factors which in turn affects the choice of the most appropriate and reliable monitoring techniques. Remote sensing-based methods are particularly appropriate when degradation leads to detectable gaps in the forest canopy such as is typically the case for selective logging and fire (Wertz-Kanounniko, 2008). However, ground measurements are needed when the degradation occurs under the canopy and affects the soil (Broadbent *et al.*, 2008). For example, overexploitation of fuel wood, some selective logging and mining may be difficult to observe from space when the forest canopy appears largely intact (Becker *et al.,* 1995; Darmawan *et al.*, 2001; Tang *et al.,*2010; Roy *et al.,* 2005).

Therefore, many studies suggested a combination of remote sensing and ground-based survey for forest degradation monitoring e.g. Asner *et al.* (2005), Broadbent *et al.* (2008),Brown and Braatz (2008),Gibbs *et al.* (2007), GOFC-GOLD (2010), Lambin (1999), Hansen *et al.* (2008), Harold*et al.* (2011), Saatchi (2007),and Wertz-Kanounniko (2008).

In Guyana forest degradation is unique and caused mainly by mining althoughloss through selective logging and forest fire are also evident. Moreover, degradation from mining is very rapid and dynamic. Itis difficult to identify from Landsat imagery and therefore this makes it challenging to detect if compared to previous studies, for example, Asner *et al* (2009) andMonteiro *et al*. (2003) that have used Landsat.

6.3 Remote Sensing Techniques for Monitoring Degradation

Mapping forest degradation using remote sensing methods is more difficult than mapping deforestation because degraded forests are often a complex mix of different land cover types (vegetation, dead trees, soil and shade) that result from different human interventions. In optical imagery, the reflectivity and the spectral signature of degradation can change very quickly making identification very dependent on the timing and season of image acquisition (GOFC-GOLD 2008).

Methods using optical imagery for mapping forest degradation cluster into two broad categories: i) **direct** - simple visual interpretation using aerial photography or very high spatial resolution satellite imagery and ii) **indirect** - automated algorithms that search for spectral or texture differences by pixel or neighbourhood of pixels in medium resolution satellite imagery (Achard *et al.*, 2008).

Herold (2008) suggests that if degradation intensity is low and the study area is large, automated methods may be preferred because the costs of acquiring fine-resolution images may be prohibitive. To minimize costs, he recommends first assessing the causes of degradation in a given area and then to adapt the monitoring techniques accordingly.

Direct interpretation studies by Souza Jr. *et al.* (2009) using SPOT imagery and by Souza & Roberts (2005) using IKONOS imagery, reported on the potential of high spatial resolution imagery for identifying forest degradation. Although costly, very high spatial resolution optical imagery allows gaps in forest canopies to be interpreted directly, thereby offering the potential to distinguish among a range of potential degradation drivers (DeFries *et al.*, 2007). It is notable that, as yet, there are no papers available that evaluate the potential of RapidEye with its sensitive red-edge band for degradation mapping.

Although direct visual interpretation of high resolution imagery by experienced analysts is a robust approach, Wertz-Kanounniko (2008) highlights a number of limiting factors that need to be considered in forest degradation monitoring. First, because degradation signatures of logging and forest fires change quickly in high resolution images, frequent or at least annual mapping is required. Second, forest degradation by humans can be often be confused with natural forest changes and finally, cloud cover can limit the availability of data from optical sensors.

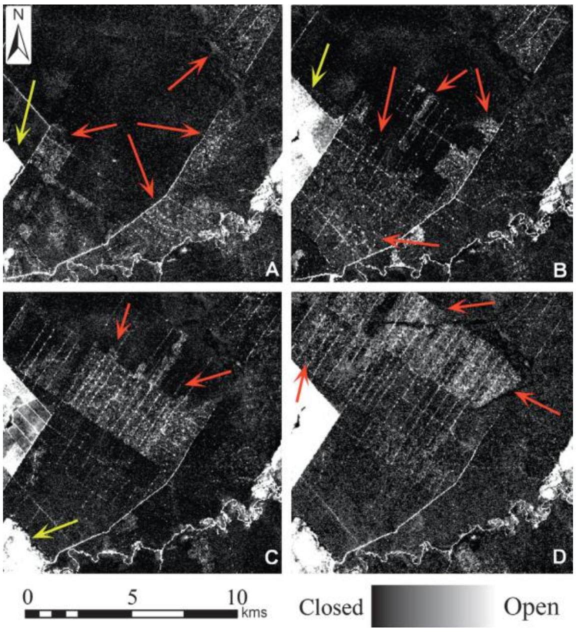
Asner *et al.* (2005) and Broadbent *et al.* (2008) have pioneered indirect methods to help map forest degradation using Landsat imagery for large-scale selective logging assessment using an approach they term the CLAS method (Carnegie Landsat Analysis System, see Figure).

CLAS data processing steps include: i) atmospheric correction; ii) deconvolution of spectral signatures into sub-pixel fractional cover; iii) cloud, water, and deforestation masking; iv) pattern recognition algorithms for forest disturbance mapping. The major limitations of CLAS include the difficulties of atmospherically correcting Landsat imagery in the tropics and correcting for shade caused by partial cloud cover (Asner *et al.,* 2005).

In Amazonia, shade fractions average approximately 25% of land covers for typical Landsat coverage. A study by Asner & Warner (2003) using 44 IKONOS scenes showed that it was difficult to separate cloud shadow from canopy shadow caused by openings due to selective logging. This problem impacts negatively on the linear mixture model used in CLAS. Moreover, it is difficult detect change in a 30 m by 30 m pixel where degradation from selective logging contains various land-uses.

Certain limitations of the CLAS method could be addressed using high resolution imagery since Landsat TM, ETM+ and SPOT XS data cannot identify to any precision, forest gaps smaller than 6 ha (Broadbent *et al.*, 2008). Furthermore, apart from visual identification, smaller gaps could be identified in high resolution imagery using 'forest canopy gap fraction' method used by Broadbent *et al.* (2008). Forest canopy gap fraction uses canopy texture, which is defined as the mean absolute difference in forest gap fraction between adjacent pixels, within a moving *N x N* pixel window. For Landsat imagery, Broadbent *et al.* (2008) used a *6 x 6* pixel window which is about 3.24 ha.

Figure 19: An example of spatio-temporal dynamics of deforestation and selective logging from 1999-2002 (A-D, respectively) in central Mato Grosso.



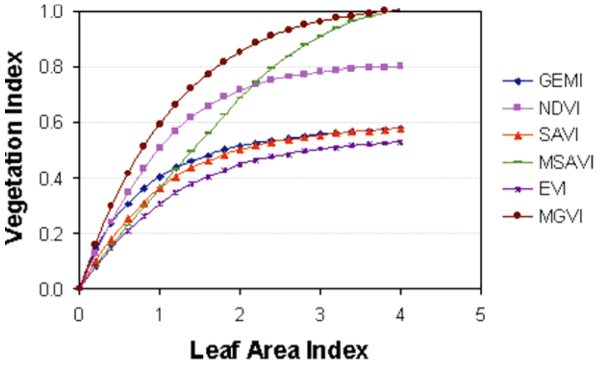
Areas of deforestation and new logging are indicated by yellow and red arrows, respectively (Broadbent *et al.,* 2008). Subdivided forest fragments are visible within logged areas.

In this method degraded forest 'pixels' are identified as mixtures of different land cover types/materials such as vegetation, dead trees, bark, branches, soil and shadow (Souza and Roberts, 2005). Therefore, spectral mixture analysis (SMA) has been used to estimate the area of canopy versus non-canopy within a pixel of Landsat imagery (Cochrane and Souza, 1998). Fraction images derived from SMA seem to help enhance the detection of logging infrastructure and canopy damage. For example, soil fractions enhance log landings and logging roads (Souza and Barreto, 2000), while non-photosynthetic vegetation (NPV) fractions enhance the identification of forest damage (Cochrane and Souza, 1998; Souza *et al.*, 2003) and the green vegetation (GV) fraction is sensitive to canopy gaps (Asner *et al.,* 2004).

These studies demonstrate the value of spectral indexes in enhancing subtle differences in tropical forest canopies. Canopy damage detection caused by forest degradation driven by factors such as logging and forest fires, can be detected with Landsat imagery within a year of the degradation event with 90.4% overall accuracy using spectral indexes (Souza Jr *et al.,* 2005).

In a study of forest canopy cover in the Amazonian state of Mato Grosso Brazil, Wang *et al.* (2005) used reflectance data simulated from the scattering by Arbitrarily Inclined Leaves (SAIL) model to estimate a leaf area index (LAI) from six different vegetation indexes: soil adjusted vegetation index (SAVI), modified soil adjusted vegetation index (MSAVI), enhanced vegetation index (EVI), global environmental monitoring index (GEMI), Medium Resolution Imaging Spectrometer (MERIS) global vegetation index (MGVI) and normalized difference vegetation index (NDVI). They found that, although all the vegetation indexes display a similar trend with leaf area, EVI, SAVI and GEMI converge more rapidly (Figure 20). In this study the resultant fractional cover map derived from Landsat data was validated using IKONOS data and the authors claimed a regression coefficient (R^2) of 0.80.

Figure 20: Relationship between Leaf Area Index and Vegetation Index



2.2 Ground-based Methods for Monitoring Forest Degradation

Ground-based methods for degradation monitoring are time-consuming and necessarily limited by the area that can be mapped. As a pilot-scale degradation study in Uganda, Becker *et al.* (1995) used biodiversity indexes such as the Simpson's dominance index, Shannon diversity index, relative frequency, and importance value index (IVI). From 30 randomly selected points, Becker and his team (1995) sampled using concentric circles at radial distances of one (for measuring herbs and woody seedlings), three (for saplings, and shrubs) and ten (trees) metres respectively. The results were useful in characterizing changes in tropical forest plant communities and also captured many details of the ecological impacts of deforestation from logging and other associated activities.

Griscom *et al.* (2009) catalogued eight different ground-based degradation case studies that are related to the implementation of REDD principles. For example, in the Garcia River Project from California, USA, they assessed mangrove degradation by taking a random sample of 1,051 permanent inventory plots and measured carbon pools to provide baseline information for a future REDD+ monitoring scheme. Similarly in Bolivia (another case study site of the Griscom *et al.,* 2009 paper), forest degradation was measured based on carbon stock that was calculated using 625 sample plots and wall-to-wall mapping of Landsat imagery from 1986 to 1996. A baseline scenario of avoided degradation was created based on expected emission from logging. The effects of logging were quantified using 102 permanent paired plots established within the same forest types in an adjacent forest concession and monitored growth over time.

In summary, the literature reports on degradation methods suited to assessing ecological impact of human disturbance and a second set of methods for measuring forest (and carbon) stocks from precise mensuration and sampling. Inventory-based approaches (field surveys) and forest statistics such as logging or mining concessions and harvest estimates do exist, but there is little evidence from literature that these are well adapted to assess the level and impact of degradation. This is usually because large-scale monitoring using ground measurements is costly and impractical at a national scale.

6.4 Integration of Remote Sensing and Ground-based Degradation Monitoring

Ground measurements are often used to help validate or corroborate results obtained from remote sensing and have the advantage that they can collect additional data relevant to carbon stock or other measurements. Skutsch (2007) for example, describes how local stakeholders (communities) can be involved in conducting ground-level surveys. Thus although ground-based monitoring of degradation is hardly feasible for large-scale assessments, they can be particularly useful at a project-level. There are generally three commonly used parameters and/or proxy indicators when identifying degraded forests or forest degradation.

1. Reduction in biomass or volume often measured by canopy cover and/or stocking or basal area per ha.
2. Reduction in biological diversity – numbers of a specific species
3. Reduction in soil quantity and / or quality as indicated by soil cover, depth or fertility

Souza Jr. *et al.* (2009) combined ground and satellite-based observations to perform a regression analysis of 28 field-derived forest carbon stock plots against NDFI values derived from satellite imagery. This is one of the first studies of its kind to attempt to assess the precision of degradation in mixed tropical forest using satellite-based vegetation indexes.

The study highlighted many of the difficulties associated with such correlation such as locating ground plots on imagery using GPS, geo-rectification of satellite data, understanding the precise meaning of “pixel values”, problems with locating random samples in the field, as well as the practical difficulties with collecting robust field data in humid tropical forests. Souza Jr. *et al.* note the practical advantages of transect methods of the study and their papers document survey techniques that use measurements of diameters at breast height (dbh) > 10 cm mapped along 10 m by 500 m transects (i.e. 0.5 ha).

In addition, they selected sub-parcels (10 m x 10 m; 0.1 ha) every 50 metres along each transect and all trees < 10 cm dbh were mapped with total ground cover and canopy gaps estimated using a hemispherical lens and densitometer. Aboveground live biomass (AGLB), for each transect (trees > 10 cm dbh), was estimated using published allometric equations (e.g. Gerwing 2002). They also collected land use and disturbance history data where possible.

6.5 Conclusions from Literature

Reflecting on the applicability of published studies of forest degradation mapping and their applicability to the MRV for Guyana, a number of important conclusions emerge.

1. It is necessary to assess on the ground, the nature and spatial extent of degradation that results from agriculture, shifting cultivation, infrastructure (settlement and roads), mining, and burning) before deciding on the applicability of a direct or indirect approach to mapping.
2. Direct (manual interpretation) and indirect (automatic enhancement using an appropriate vegetation index) methods have intrinsic value and an approach that combines the best of both may have value.
3. A full scientific study is beyond the scope of this project, but a transect study that seeks to validate any satellite-based interpretation on the ground would assist in assessing any bias in interpretation from different satellite imagery data sources.
4. Given the results of the year 1 deforestation monitoring, which showed that dredge mining and associated infrastructure were the main drivers, it would be prudent to better understand the level and extent of degradation that is typically associated with mining activities and to compare ground and satellite data for sample areas.

Comment from Norwegian Ministry of the Environment

It seems a lot of the methodology is revised based on reports made by Winrock and Applied GeoSolutions. One related to collateral damage and wood products, and the other concerning the new method for estimation of degradation. Have these reports gone through a peer review process or similar to validate the methods used?

Response to Comment

The following reports are available for verification by DNV:

- *Brown S, Collateral Damage and Wood Products from Logging Practices in Guyana, December 2011*
- *Salas, W. Hagen, S, et al. Winrock International and Applied GeoSolutions.A Pilot Study to Assess Forest Degradation Surrounding New Infrastructure. Guyana Forestry Commission. February, 2012.*

These reports were peer reviewed. Indufor and GFC both have reviewed these reports and provided feedback, which were used to update the reports. Also, field validation was carried out by Indufor on the Report on Forest Degradation. Additionally, this report used or evaluated peer-reviewed methods as published and tested by remote sensing experts including Carlos Sousa.

Winrock International is part of the GFC/Indufor team for this year 2 of verification.

Further, the aspects of collateral damage and wood products were included in the Sample design document which was peer-reviewed.

Table 6-1: Relevant Approaches to Characterising Degradation

Country	Area	Remote sensing and GIS	Field survey	Details on methodology	Source
Brazil	Deforestation and logging (forest fragmentation). Over large geographic region (about 10,000km^2) in Amazon	Radiometrically and atmospherically corrected Landsat 7 ETM+ and MODIS VCF. The study used special model named CLASlite. Target pixels were studied in field	Using field spectrometer measuring surface reflectance (400-2500nm)	Modified AutoMCU sub-model uses spectral endmember libraries, derived from extensive field measurements and hyperspectral satellite imagery, to decompose each image pixels using linear equation and derived outputs: photosynthetic vegetation (PV), non- photosynthetic vegetation (NPV) and bare substrate. Therefore this method needs high technical expertise.	Asner *et al.* (2009)
Brazil	Mapping forest degradation: burning, logging in eastern Amazon	Mixture models using SPOT 4 and IKONOS imagery	GPS coordinates based data base (mainly secondary)	Classified SPOT 4 imagery using Isodata and Pixel Purity Index (PPI) to derive forest fraction image through linear mixing model. Finally forest degradation map was derived from forest fraction images by decision tree classification of IKONOS using field data.	Souza Jr. *et al.* (2003)
General	Methodological aspect of forest degradation			Essential considerations to design and develop forest degradation have been discussed.	Herold *et al.* (2011)
Brazil	900km^2 area of Amazon.	Geometrically and Atmospheric correction followed by ISODATA classification and soil fraction image by application of a mixture model	GPS survey of 20 GCPs	Forest map was derived from Landsat TM5 by grouping the spectral classes (n=15) generated by ISODATA into thematic classes (forest, non-forest (i.e. pastures, agriculture, secondary growth, urban areas), and water). Then isolated pixels and small forest gaps were removed with a 'clump' filter. Log landings were identified from soil fraction images derived from a mixture model. Soil abundance greater than 20% and >100m from river site, selecting small area (1-4 pixels) as log landings. Area affected by logging was derived from mean of harvesting area radius of randomly selected 100 harvesting sites. Temporal logging (i.e. new, old and repeated) was analyzed by through identification of areas in 1992 and 1996. This method is suitable especially using high resolution imagery	Monteiro *et al.* (2003)
Brazil	Selective logging. Study area was 32,520ha in Amazon.	Linear mixture model using PPI, Kauth-Thomas Brightness Index	Forest canopy cover data	Linear mixture model was used to estimate soil, vegetation and shade fractions within each pixel of 1984, 1991, and 1996 Landsat TM images. Finally forest soil fraction image was prepared to identify logging areas. Soil fractions above 20% that contained from 1 to 3 contiguous pixels were considered log landings. This method is suitable especially using high resolution imagery	Souza Jr. and Barreto (2000)

Brazil	Selective logging and degraded forest measures in Amazon	Landsat and SPOT imagery were used to prepare Spectral Mixture Analysis (SMA) and Normalized Difference Fraction Index (NDFI) after necessary radiometric and atmospheric correction. GPS coordinates were used to locate transects in imagery and draw polygons of 30m*30m to select 30 random pixels within the transect area pixels.	49 transect inventories were conducted in five different degraded forest classes and 12 for undisturbed sites. Transect size: for dbh >10cm - 10m by 500m and for dbh <10cm – 10m by 10m at every 50m of main transect.	SMA and NDFI values of 30 randomly selected pixels from transect areas to perform a regression analysis of carbon stock against NDFI. Needs high technical expertise.	Souza Jr. *et al.* (2009)
Democratic Republic of Congo			Using permanent sample plots (PSP)	Field measuring of forest degradation using PSP	Kamungandu (2009)
Global	Forest alternation with special focus on global/regional scale (minimum 50,000ha)	Potentially useful by using Landsat TM/ETM+, MODIS VCF. GIS database		Intact Forested Landscape (IFL) approach of forest alternation map using satellite imagery and publicly available maps. Expert based visual interpretation, GIS overlays, topographic maps used to differentiate human induced alternations and fragmentation from intact forest. Applicable at global/regional scale with moderate expertise	Potapov *et al.* (2009)
Nepal	Forest degradation measure and monitoring in national/local scale	Scope and potentials of remote sensing and GIS	Role of ground survey	Scope and potentials of different remote sensing,, GIS, and ground survey options has discussed with limitations as well based on specific degradation types. Suitable at national/local scale.	Acharya and Dangi (2009)
Mexico		NDVI map were calculated from MODIS	10% of 25,000 plots developed for the National Inventory of Forests and Lands were revisited through systematic sampling process	Analyzed monthly behaviour of NDVI for different vegetation types. Dry season (15 February – 15 April) imagery from 2005 to 2008 (each year); estimated average NDVI has selected from regression analysis (R^2=0.8334) with biomass (dbh >7.5cm) derived from estimation of 16942 number of sample plots measured under the National Inventory of Forests and Lands program. Suitable for replication in global/regional/national scale.	Tovar (2009)
General	Forest degradation methodology	Role and contribution of remote sensing data		Generic approach of forest degradation measure. Spectral, spatial and temporal aspect of remote sensing data in assessing forest degradation has been discussed in detailed	Lambin (1999)

General	Forest degradation methodology and reduction strategies		Assessed mangrove degradation with random sampling of 1,051 permanent inventory plots since 2004 and measured carbon pools in Garcia River Project, California, USA.	This study is site specific. Focused on some distinct aspects of GOFC-GOLD. Also reported some project findings on degradation measures: Bolivia: Measured forest degradation based on carbon stock that was calculated using 625 sample plots and wall-to-wall mapping of Landsat imagery from 1986 to 1996. Baseline scenario of avoided degradation was created based on expected emission from logging. Effects of logging were quantified using 102 permanent pair plots established within the same forest types in an adjacent forest concession and monitored growth over time. Finally field activities have been monitored using Landsat imagery between 1997 and 2005. Using MODIS, 115 fire sites has detected between 2001 and 2004. In west Arnhem, Australia; both field survey and remote sensing methods have been adopted to monitor carbon change especially forest fire.	Griscom *et al.* (2009)
Brazil	Forest degradation: fire and logging. Study area was 30,000km^2	Multi-annual land use and land cover GIS layer for 1992 through 2004. GPS coordinate of each forest transect corners were recorded	12 transect plots (500m*10m) were surveyed. 423 hemispherical photos were recorded to estimate canopy openness beneath undisturbed and disturbed forest canopies.	47 canopy fractional points were estimated, both field data and different vegetation indexes. Integration of field data with remote sensing were conducted through detailed image analysis by vegetation index, modified vegetation index, SMA, endmember selection. Finally burned areas were derived through filtering of NPV fraction imagery. Needs high technical expertise.	Matricardi *et al.* (2010)
Brazil	Forest degradation in Amazon	Landsat Tm 1984, 1988, 1991 and 1996; SPOT 4 1999 and IKONOS 2000. Historical geo-referenced field data was also used.		Virtual identification of log landings from IKONOS and compared with Landsat TM, SPOT imagery. It focused on potential of spatial resolution in forest degradation mapping. So, simple in replication for other sites.	Souza Jr. and Roberts (2005)
USA	Degradation type: Forest fire in Flathead National Park and Glacier National Park	Landsat imagery: August 28, 1988; September 20, 1989, September 3, 1990 and Aerial Photographs		Radiometric and atmospheric correction applied that are preceded by radiometric normalization. Fire incidence occurred on September 6, 1988 was studied by spectral analysis from pre-fire incidence imagery and NDVI analysis of all selected imagery. Finally results were verified using aerial photographs taken after fire incidence.	White *et al.* (1996)

Global	Forest fire at global scale	MODIS surface reflectance time series data		To map fire-affected areas at a global scale Bi-Directional Reflectance Model-Based Expectation change detection approach was modified for systematic global implementation and maps at 500 m the location and approximate day of burning. The algorithm does not use training data but rather applies a wavelength independent threshold and spectral constraints defined by the noise characteristics of the reflectance data and knowledge of the spectral behaviour of burned vegetation and spectrally confusing changes that are not associated with burning.	Roy *et al.* (2005)
Madagascar	Deforestation and forest degradation in the Analanjirofo region	SPOT 4 panchromatic: 12 August 1991; SPOT 5 multispectral: 9 June 2004 and 1 February 2009		Image processing, biomass inventory, development of site and forest type specific allometric equations, and combination and analysis of relation between ground-based and satellite-based measurements.	Eckert *et al.* (2011)
Brazil	Selective logging in Amazon	Landsat ETM+		Used Carnegie Landsat Analysis System (CLAS) that are based on atmospheric correction, sub-pixel classification, masking (cloud, water, and deforestation), and pattern recognition for disturbance mapping: 1999-2000, 2000-2001, 2001-2002.	Asner *et al.* (2005)
Brazil	Studied selective logging in Amazonian state of Mato Grosso, Brazil (Landsat ETM+ scene: path 226, row 68)	Landsat ETM+ : 18 June 2000 Pan sharpened multispectral IKONOS: 13 June 2000.	The IKONOSimage was used as ground truth to validate fractional cover maps derived with the Landsat ETM+ image when no field measurements are available.	From six different vegetation index, optimal vegetation index, modified soil adjusted vegetation index (MSAVI) was selected by using scattering by arbitrarily inclined leaves (SAIL) model as a function of leaf area index (LAI). From the MSAVI values, fractional cover (fc) map was derived to identify degraded forests (0.3-1.0), clear cut areas (0-0.4) using ETM+. Finally, the fc map was validated using 1m pan sharpened IKONOS imagery. Validation using 1:1 line shows significant correlation in mapping degradation (R^2 = 0.8).	Wang *et al.* (2005)
General	Forest degradation measures and monitoring. Generic guidelines for at country level. This could be used a potentially useful guidelines for forest degradation measures.	Potentials and possibilities of remote sensing and GIS has discussed	Field based assessment and monitoring especially stock difference and gain and loss approach has discussed in details	Based on IPCC guidelines, different approach and strategies of forest degradation measuring and monitoring at country level with special reference to Tire 1, 2 and 3.	Murdiyarso *et al.* (2008)

East Asia	Biosphere reserves across the border of China and North Korea. Potential applicability in other areas for degradation study.	Landsat TM Imagery in 1985, 1993, 1999, and 2007. Google earth has used to validation and further sampling		ISODATA classifications were performed using 40, 50, 60 and 70 spectral classes form each year of Landsat imagery. A single forest cover map was derived for each year from these classes based on majority cover under each pixel under primary (undamaged and restored forest) and non-forest (secondary and damaged forest) types. Non-forest areas were further studied based on stratified random grid sampling with 30 samples (1*1 km^2).	Tang *et al.* (2010)
	East Kalimantan, Indonesia. Studied forest degradation based on soil erosion hazard associated with forest fire.	Landsat TM: 14 October 1996 and DEM derived from topographic map 1:50,000 scale		Tested six candidate model based on fuel type, dried vegetation index, elevation, gradient, aspect and buffer road respectively. A simplified end member technique and tasselled cap were carried out to drive maximum approximation of based soil pixels. Then bare soil pixels were categorized based on assumed susceptibility index.	Darmawan *et al.* (2001)
Papua New Guinea	Deforestation and forest degradation at national level.	1972 land cover map using GIS and for 2002 land cover map, Landsat ETM+ and SPOT 4 & 5.		1972 land cover map were digitized from 1:100,000 scale vegetation map. While 2002 land cover map was derived from Landsat ETM+ and SPOT imagery. Tasselled cap and Brovery transformation was applied using object recognition package "eCognition" software. Finally each classified polygons were defined using expert visual interpretation and decision rule system. Low elevation aerial photography (0.1-1m resolution) of 431 locations in West New Britain and Madang provinces during 2004 and 2008 were used for validation of results.	Shearman *et al.* (2009)

Uganda	Forest degradation was studied in Namungo Forest and Lwamunda Forest Reserve. Detail information on vegetation structure and composition but limited with remote sensing and GIS applications.		30 randomly-selected plots were mapped in each forest. After random selection of plot centre, three concentric circles were established around it at radial distances of one, three, and ten, meters. Species of herbs and woody seedlings were identified in the smallest circle, and the percentage of ground covered by each species was recorded. In the circle with a three-meter radius, tree saplings and shrubs were identified, and details of each individual's maximum stem-diameter (cm) and height (m), were recorded on IFRI coding-sheets.	Degradation was measured in terms of disturbance level from soil condition, logging intensity, Simpson dominance index, Shannon Index, DBH distribution level, species richness, stocking (trees/ha), basal area, importance value index (IVI), etc.	Becker *et al.* (1995)
India	Forest degradation measure in the upper catchment of the river Tons in the Uttarakhand state of India, including Govind Wildlife Sanctuary and the National Park. Suitable for hilly areas.	IRS 1D-III (Spatial resolution 23.5m*23.5m and PAN (spatial resolution 5.8m*5.8m) imagery of 15 December 2005 were merged using wavelength fusion technique to generate 5.8m spatial resolution false colour imagery. SRTM DEM also used to relate degradation with slope.	GPS based field study of all representative forest types to collect information on cover types, general land degradation status, slope, aspect and elevation.	Forest degradation was studied using canopy over classes: undegraded (>70%), moderately degraded (40-70%), degraded (10-40%) and severely degraded (<10%). 124 locations were filed verified to assess classification accuracy. A slope map was derived from 6 slope categories which then correlated with degradation map to derive slope-wise forest degradation information.	Nandy *et al.* (2011)

6.6 Review of Degradation Monitoring Methods Appropriate to Guyana

As part of the on-going improvement process, the default distance of 500 m established as part of the interim measures was reviewed firstly by Applied GeoSolutions LLC who undertook a pilot study (2012) to determine the extent of forest degradation surrounding new infrastructure. The full study is provided in Appendix 7 of this report.

This work drew several relevant conclusions that showed that degradation was contained to a distance of 100 m:

- Three remote sensing based indicators were evaluated using Landsat 30 m imagery. Of the three indicators used, a 'loss of EVI' was found to describe forest degradation caused by logging most accurately.
- An analysis undertaken using 30 m Landsat found that nearly all of the degradation as a result of new infrastructure was found within a 100 m buffer. This is significantly less than the 500 m default distance, previously applied. The ratios tested provided similar results.
- High resolution data (<1 m) outperforms Landsat in identifying degraded forest areas, and could be reliably used for a number of years following the activity.

Building on these results and those presented in the peer-review literature (Section 6.2),GFC and Induforexpanded the study to cover a range of sites to assess the impact of degradation using higher resolution RapidEye images. A combination of previous studies and the findings of this work were then used as a basis for developing a GIS-based method to identify and monitor forest degradation. This method was then expanded and applied across the RapidEye coverage.

6.7 Method Development

The method evaluated was divided into two parts. The first part evaluated the change in EVI values calculated at set buffer distances from new 2011 infrastructure (roads or mining infrastructure). The intention of this analysis is to quantify the distance that degradation impacts extend from new infrastructure.

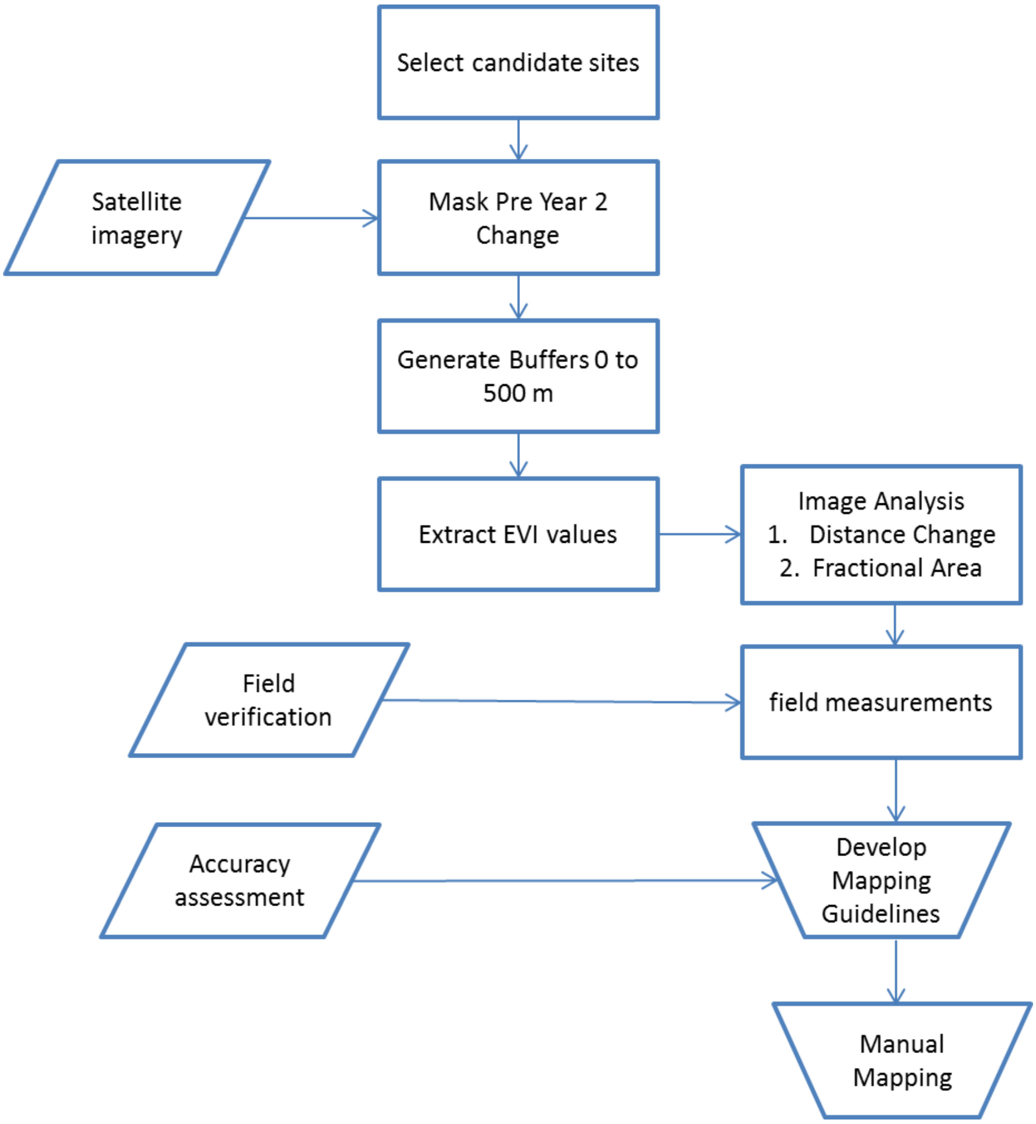
In this context the EVI-derived measures are used as a proxy for degradation. The first methodology evaluated the change in pixel values as the distance from the deforestation site increases and second uses the fractional area as adopted by Applied GeoSolutions LLC. A brief overview of each method is outlined as follows:

- The distance change method plots the change in EVI values as the distance from the deforestation site increase.
- The fractional area method calculates the percentage of pixels from the deforested area that meet a pre-defined threshold. The selected EVI threshold is based on the value associate with undisturbed forest area (Salas et al 2012).

The second part involved a field inspection of seven sites in order to measure the impact of degradation.

The outcome of this analysis resulted in the development of a set of GIS-based rules that replaced the automated buffering approach used in the Year 1 assessment.

Figure 21: Degradation Mapping Process



6.8 Site Selection

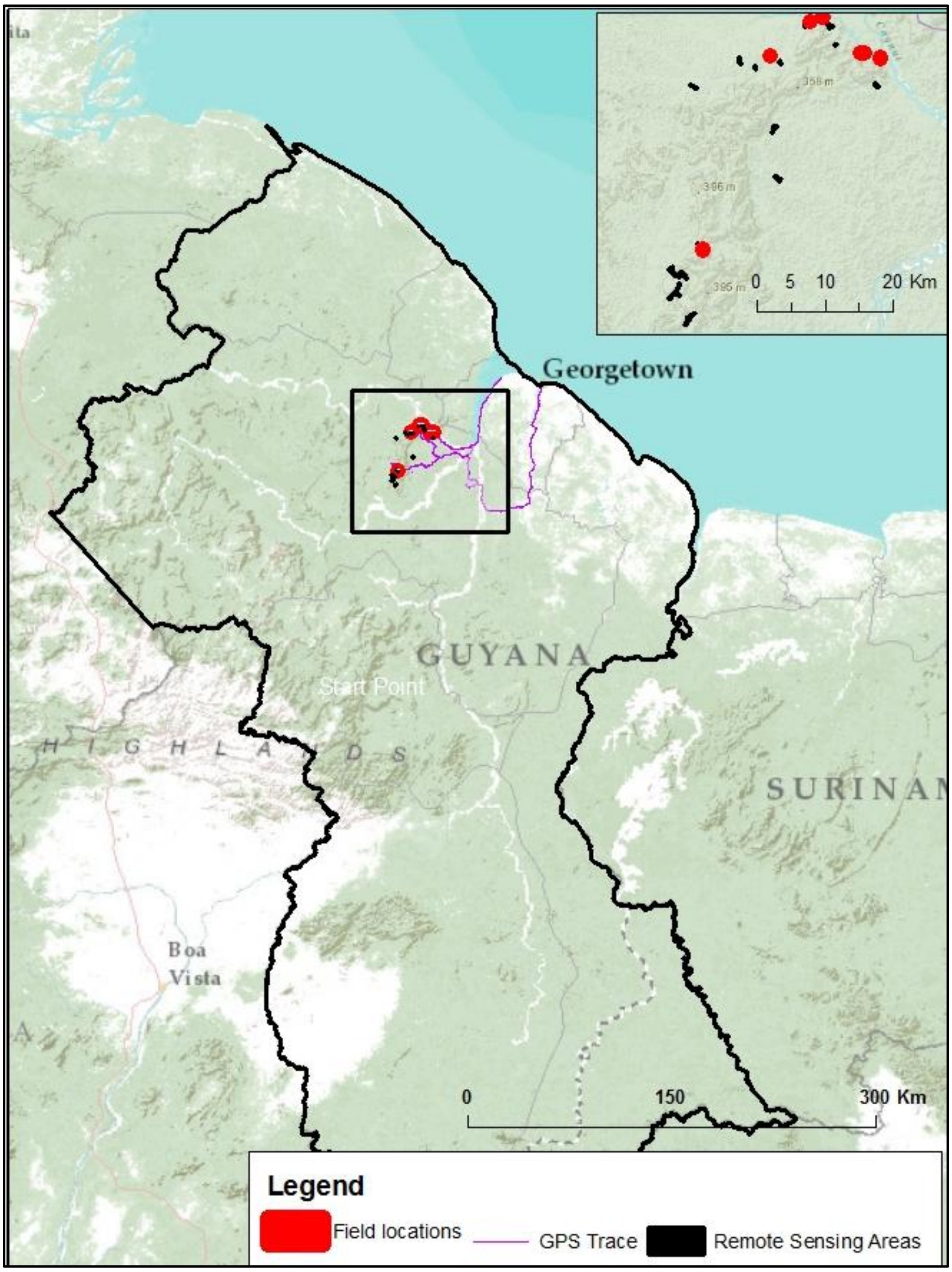
Twenty four Year 2 deforestation sites, distributed over an area of 1850 km^2 were selected around Itaballi landing. Itaballi is approximately 20 km west of Bartica (as shown on Figure 22) and is reached via vehicle ferry that crosses the Mazaruni River. This area is one of the most actively mined areas in Guyana.

The selection included 15 mining sites and 9 road sections. The selection included a range of sites in terms of size, accessibility and intensity. The combined area of all sites was calculated at 348 ha.

The historical 2009-11 Landsat and 2010 DMC scenes were consulted to ensure the selected change areas were associated with Year 2 change events. The most recent 2011 coverage over the same area was provided by five adjacent RapidEye scenes.

Field verification over seven sites was undertaken to gain an impression of the field conditions, the size and scale and spatial distribution of forest degradation.

Figure 22: Location of Degradation Assessment Sites



6.9 Buffer Generation & Extraction of EVI Values

Once the boundary was established, a 500 m buffer was generated in the GIS and applied to each site. Each area was assessed with some areas excluded. These exclusions were applied to ensure that any additional non-forest areas[20] surrounding the deforested site are not included in the analysis. This process involved delineation and masking of all areas that met the following criteria:

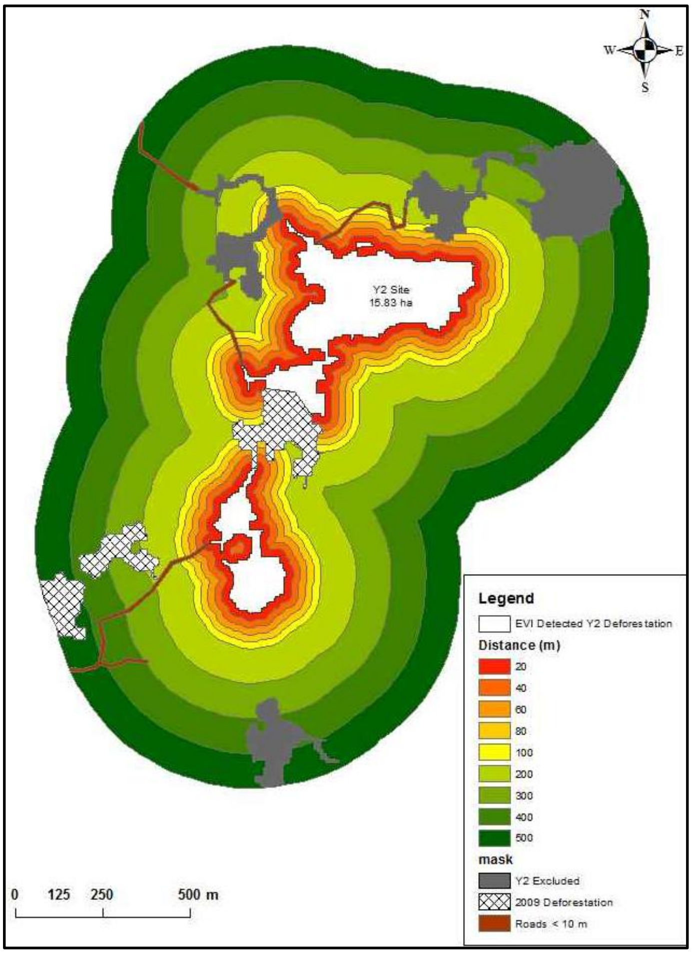
[20] The rules outlined in the JCN require that the reporting of degradation surrounding Year 2 infrastructure sites such as roads, mining sites and pipelines.

1. Land use change that occurred prior to Year 2
2. Any additional 2011 (Year 2) deforestation areas not selected for analysis but that fell inside the 500 m buffer
3. Roads that are equal to or exceed 10 m width as these are mapped as deforestation events.
4. Naturally occurring features – i.e. water bodies
5. Cloud and cloud shadow

In accordance with the Year 2 change detection mapping rules (Appendix 9), areas <1 ha were included (seeFigure 23).

Set buffering distances were then applied to each site. Concentric buffers were established at 20 m intervals for a distance of 100 m from the feature. Thereafter the buffer increments increased by 100 m intervals to a distance of 500 m. Figure 23 illustrates the buffers and exclusion mask applied around a Year 2 site.

Figure 23: Establishment of Site Buffers & Exclusion Mask



The individual buffers were exported into the image processing software (ENVI) and the corresponding EVI values extracted and summarised by buffer width.

6.10 Relationship between EVI and Infrastructure Distance

Prior to the field assessment the relationship between EVI and increasing infrastructure distance was assessed. The assessment measured value changes from the edge of the new infrastructure site to a 500 m distance. If extent of degradation cannot be determined from remote sensing methods then the default value of 500 m to Year 2 infrastructure sites as per the JCN is applicable.

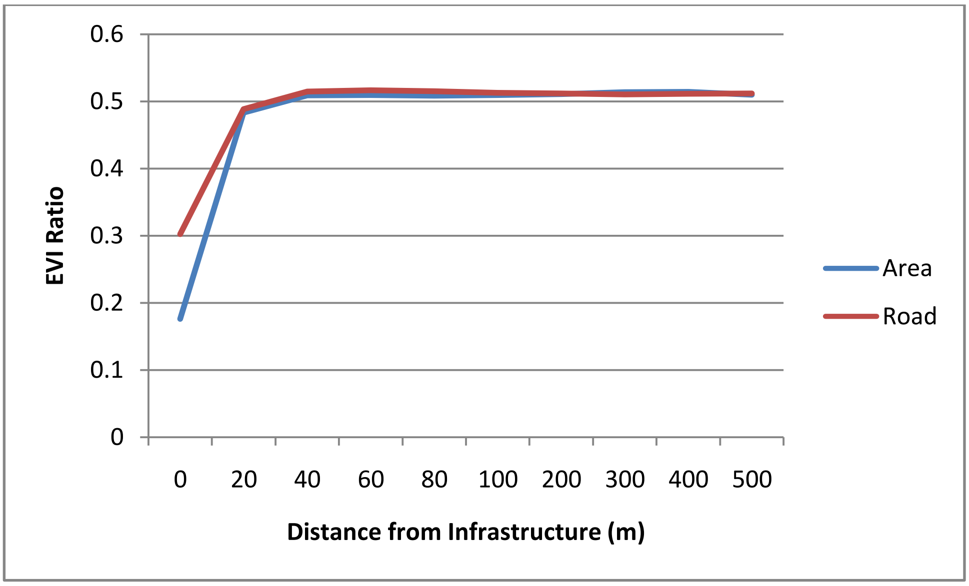
The two image analysis methods evaluated produced similar trends with values showing reduced degradation as a function of distance. The results presented are generated from the average EVI values over all sites.

Distance Change Method

The mean EVI values suggest that the EVI changes as the distance from the deforestation site increases. Initially a rapid increase in EVI value is observed from the site for a distance of 20 m as the transition from non-forest (low EVI values) to forest occurs (high EVI values).

A second step is seen from 20 to 40 m but remains constant thereafter. The same trend is observed between deforested area and clearance associated with roads construction; however the initial EVI starting value recorded for roads is twice as high.

Figure 24: EVI Ratio Change Relative to Infrastructure Distance



This difference is most likely due to the scale and intensity of the clearance activity. Road construction activities are smaller in scale and linear which means that surrounding forest areas will also contribute to the EVI response. The mixing of non-forest and forested pixels has the impact of increasing the EVI values.

If the change in EVI is used as a proxy for degradation then it can be assumed that the level of degradation diminishes rapidly, and that beyond 40 m no disturbance in the forest cover is detectable. The analysis also indicates that the level of degradation surrounding roading infrastructure is lower than for larger deforested sites.

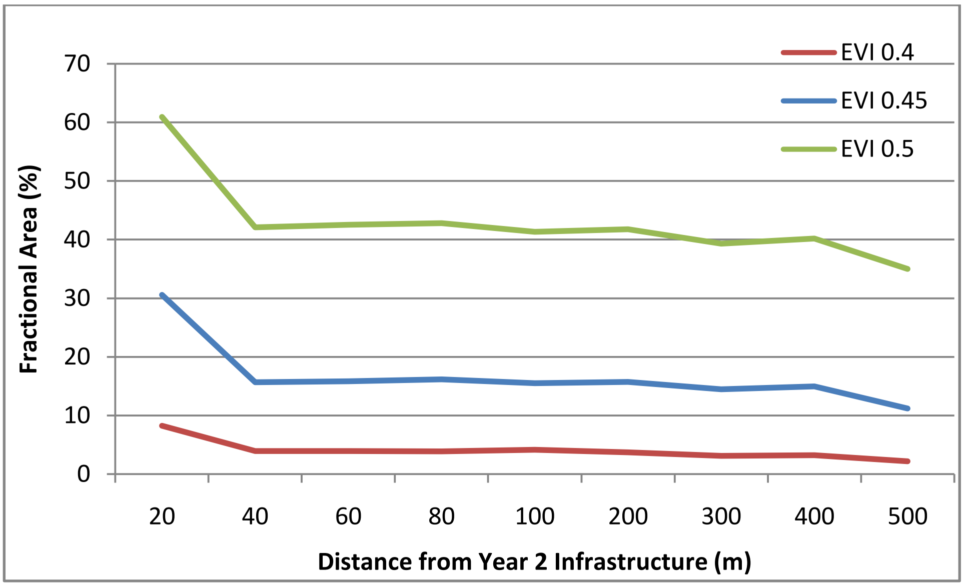
Fractional Area Method

To implement the fractional area method an EVI threshold for forest needs to be established. This needs to be set higher than the non-forest threshold of 0.34 as partially forested or degraded forest cover also needs to be considered. Insight is provided by the distance change method as this effectively tracks the change in EVI as it transitions from non-forest to forest.

To establish this threshold the impact of three values were evaluated. The EVI values selected included 0.40, 0.45 and 0.50. Lower EVI values are thought to be indicative of sparse forest cover. The trend shows that for any threshold, as the distance from the deforestation event increases, the area impacted decreases quickly over the first 40 m. Thereafter it stabilises with little variation in EVI observed. For example if an EVI value of 0.4 is reviewed at a distance of 40 m, then approximately 5% of the values fall below this value.

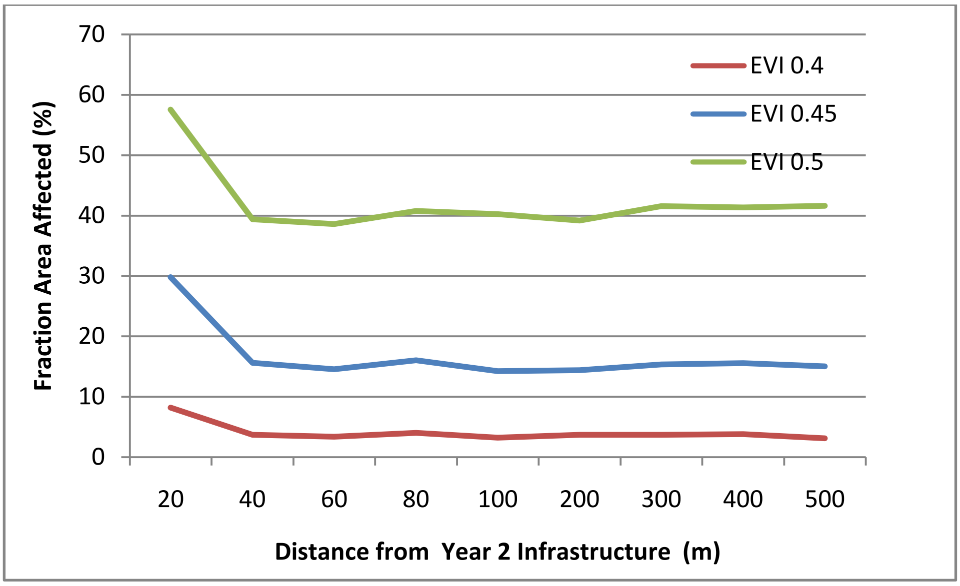
A similar trend was also observed in the Landsat 30 m data surrounding new infrastructure by Salas et al (2012). In Salaset al 2012, EVI values stabilised at a distance of 100 m (~3 Landsat pixels). The main difference in the results presented here is the increase in resolution from 30 to 5 m. The higher resolution allows for greater discrimination of vegetation disturbance.

Figure 25: Fractional Area Relative to Distance from Infrastructure



Similar trends in the fractional area are observedbetween infrastructure and roads. In both cases the fractional area quickly declines beyond 40 m. The trend is consistent regardless of the threshold value used. This indicates that most of change is occurring in this zone. Beyond this point the response is relatively stablewhich indicates that variations in EVI caused by canopy disturbances decline.

Figure 26: Fractional Area Relative to Distance from Roads



Both methods evaluated support the assumption that forest disturbance around infrastructure and roads is more localised than previously thought. The initial findings were then evaluated in the field to establish if the trends observed around deforestation sites could be corroborated.

6.11 Field Measurements

The fieldwork focused on characterising forest change over two areas - small-scale and large-scale mining areas. Small-scale mining areas were identified as those areas where deforestation events were newly established and scattered with alow density road network. Large scale areas were identified as those areas where mining areas had continued to expand.

The field assessment involved the establishment of field transects 20 m in width from the edge of the Year 2 deforestation event. The start of each transect was located using a Garmin Map 62 GPS unit. The approximate accuracy of these units under forest canopy is +/- 20 m.

For each transect the diameter at breast height (dbh) of each tree> 10 cm was recorded. The location relative to the start of the transect was also measured by plotting the approximate tree position. Transect lengths varied depending on orientation of the disturbance and proximity to other features such as streams and roads.

The following table provides a summary of measurements for each transect classified by mining intensity.

Table 6-2: Summary of Field Measurements

Transect Ref:	Site Classification	Plot Size (ha)	Length (m)	Stocking Trees/ha	Basal Area (m^2/ha)	Biomass (ton/ha)	Disturbance Score
2	Small-scale	0.2	99	315	24	348	No
18	Small-scale	0.2	99	190	13	167	No
3	Large-scale	1.3	645[21]	285	21	283	Yes
4	Large-scale	0.2	95	325	20	258	Yes
2_1	Large-scale	0.3	145	287	21	294	No
1_1	Large-scale	0.2	100	205	20	291	No
1_2	Large-scale	0.1	74	640	37	461	No

For two of the seven plots, the degree of the disturbance on the forest floor and canopy was also recorded. These plots were located in the larger-scale mining areas. Disturbance scores were recorded at ten metre intervals and ranged from 1 to 5. A score of one, represented intact forest with no sign of disturbance, and a score of 5: very disturbed forest.

The above-ground biomass at ten metre intervals was calculated using the same equation used to calculate carbon stocks in Guyana's national biomass plot network (Winrock, 2012). This equation is documented in Chave et al (2005) and calculates biomass (expressed in kg) using tree diameter and a species-specific or a generic wood density factor.

The table suggests that scale of the mining does not directly correlate with either the basal area or biomass for each transect. The lowest values are observed for transect 18 which was established close to an isolated mining site. This is a reflection of a low density forest type rather than an indication of the degree of degradation.

The EVI was extracted for each transect and plotted against the biomass and, if measured, the canopy and forest floor disturbance scores.

6.12 Analysis

The field results indicate that variations in both biomass andEVI values are observed across different sites. Three profiles are presented that cover both small and large-scale mining events. The transects presented, provide an overview of the trends observed.

Small-Scale Mining

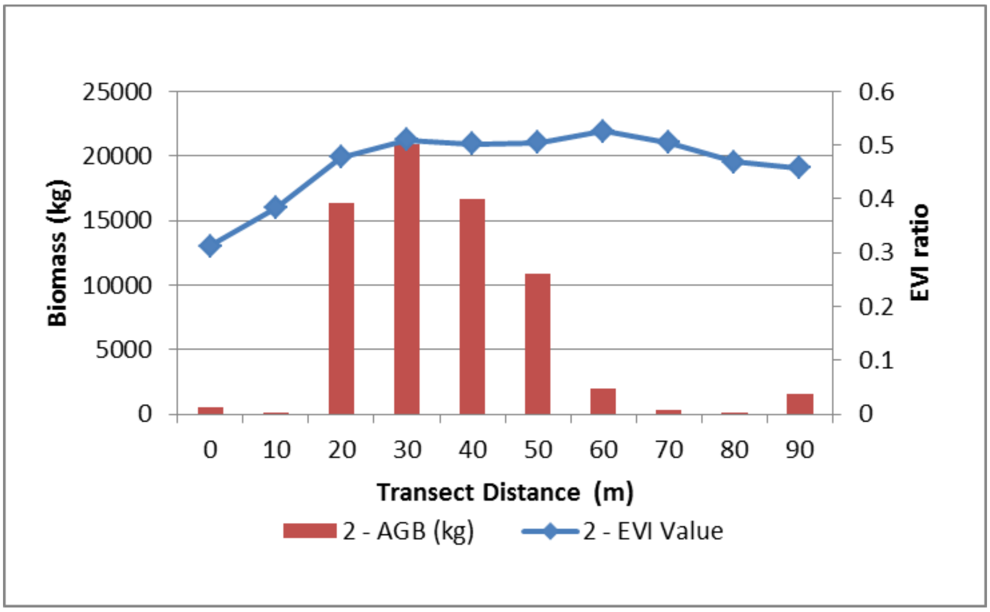
Transect 2 was located in an area dominated by small-scale and fragmented mining activity. The general trend shows that initially low EVI values appear to correlate with lower levels of biomass. It also apparent that the EVI values saturate at around 0.5 about 20 m from the start of the transect. Thereafter the EVI stabilises as the biomass increases.

When no disturbance beyond 60 m is recorded, the forest biomass decreases and the EVI shows a slight decline. Field photos taken 56 m along the transect confirm that even at low biomass

[21] For this transect tree measurements were recorded at 100 m intervals along the transect.

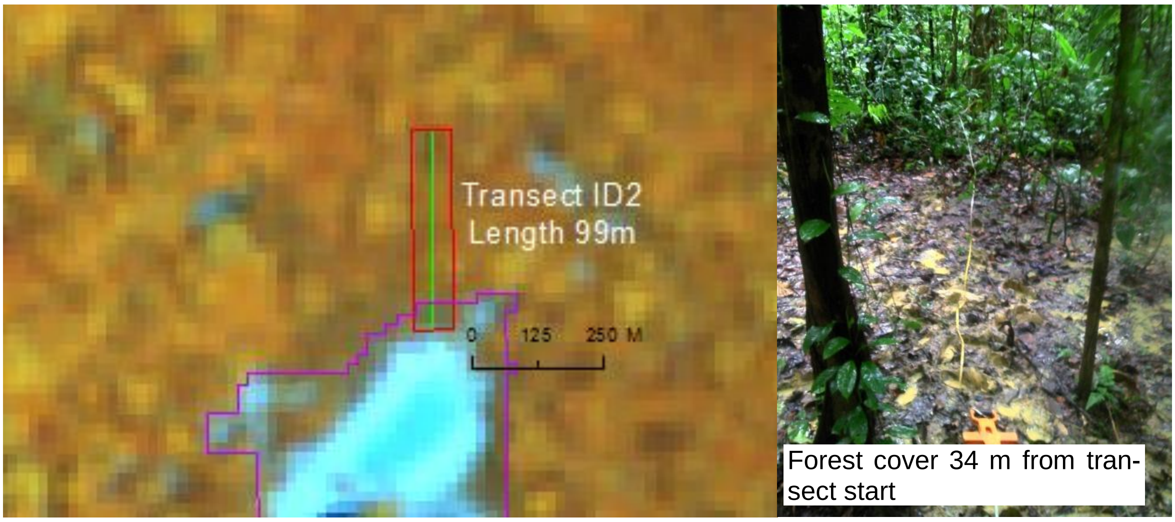
levels, the presence understory and taller trees mean there are no apparent gaps in the canopy. For this site, the change in biomass is attributed to an increase in shrubs and smaller trees. This is due to increased wetness of the area.

Figure 27: Transect 2 Biomass and EVI Profile



An assessment of the RapidEye image confirms that the transect is forested with no apparent gaps of any significance. The field photo taken at 34 m along the transect shows the presence of a dense understory and wetness of the forest floor.

Figure 28:RapidEye overlaid with the Forest Transect



Transect 18 is also located in a low impact mining area. The forest composition is a combination of dense shrubs and small diameter trees. The EVI shows a similar trend to transect 2 and increases from the start of the transect and remains relatively static thereafter.

No disturbance is observed after 20 m. In this case the biomass starts at a higher level due to the presence of a number of large remnant trees located on the fringe of the mining site. Thereafter the biomass fluctuates across the transect.

Figure 29: Transect 18 Biomass and EVI Profile

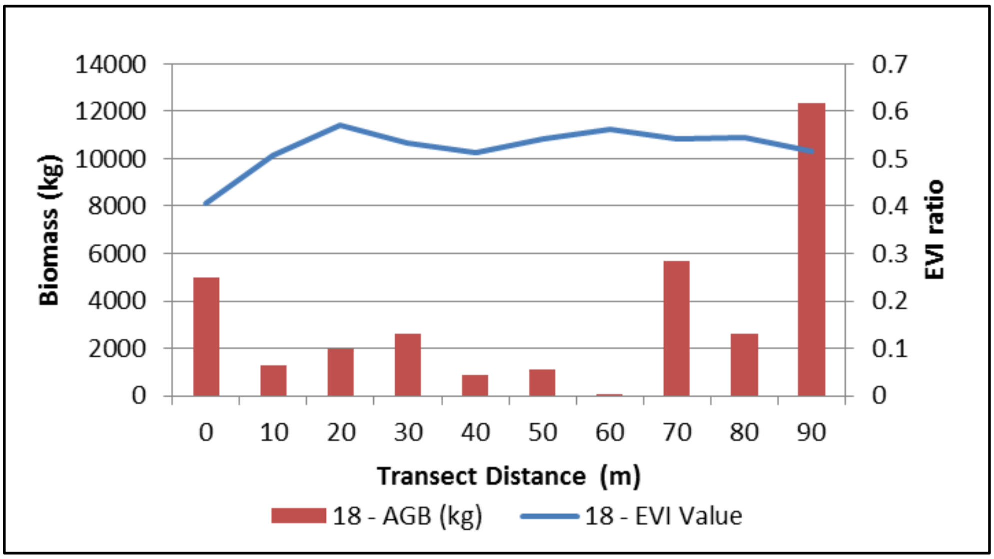
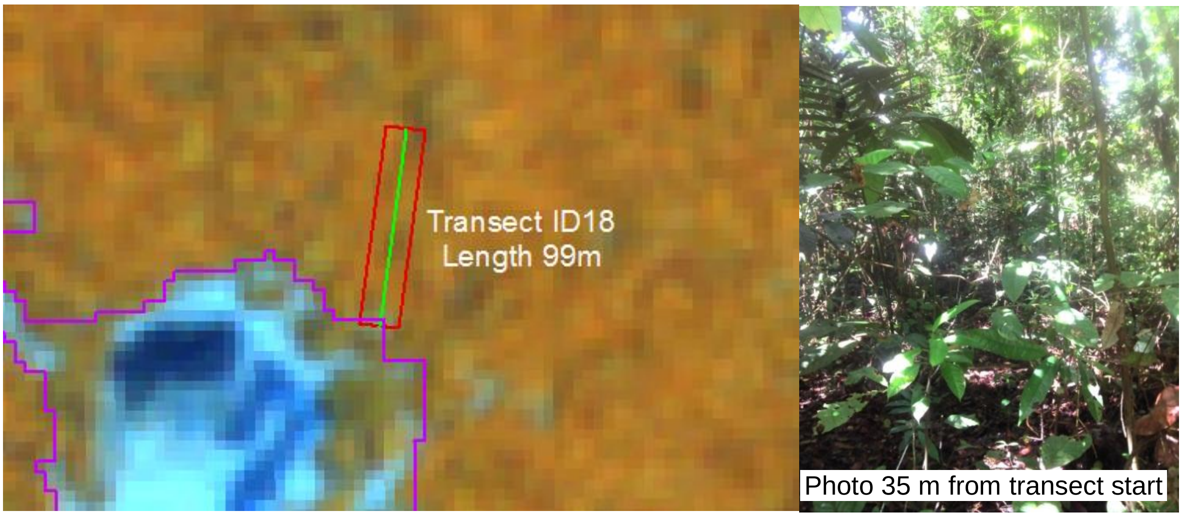


Figure 30: Transect Overlaid on the RapidEye Image



High Impact Area

The second area inspected targeted historical mining areas that had continued to expand. The five transects were placed around Year 2 infrastructure sites. Transect 3, the longest, covered a distance of 645 m, started from a Year 1 mining area (abandoned) and connected with a Year 2 road. Based on the experience of earlier measurements the methodology was adapted to include scoring the degree of the disturbance on the forest floor and canopy. This was then plotted against the EVI. The overall trend shows that the disturbance can be detected if it is large enough.

Figure 31:Transect 3 Disturbance Score and EVI Profile

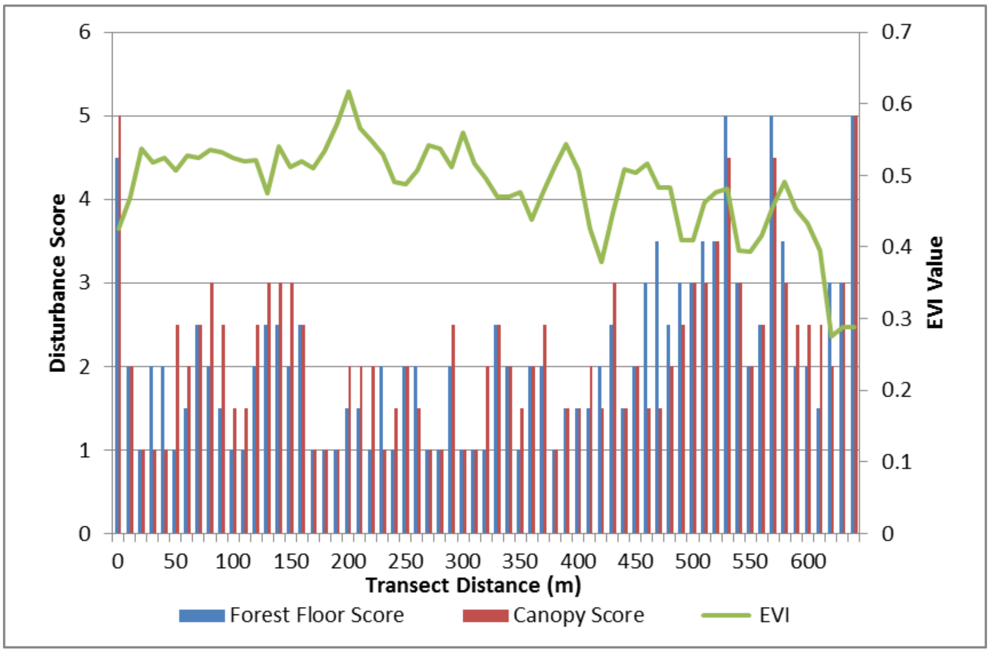
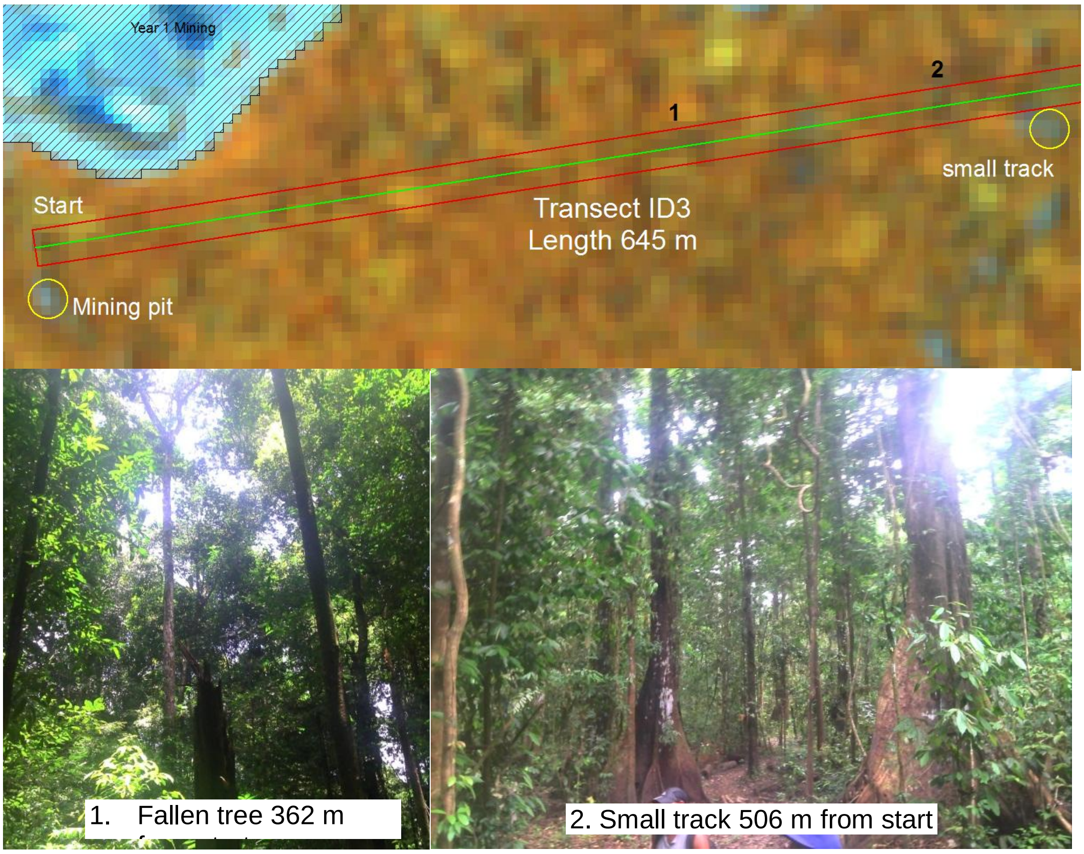


Figure 32: Transect Overlaid on the RapidEye Image

The following sequence of photographs shows how particular disturbances along the transect appear on the RapidEye image.



The first photo shows a natural disturbance where a tree has fallen and caused an opening in the canopy. The scale of this disturbance is not detected on the 5 m RapidEye image. The second disturbance is a small track that leads to an abandoned camp. Small exploration pits dug by an excavator have also been established along the roadside. This disturbance is detected and shows the spectral and shape characteristics associated with mining operations.

6.13 Conclusions

The following conclusions are relevant for identifying and mapping degradation in Guyana.

The intention of the study was to determine the extent of degradation surrounding deforestation sites and also to match losses in biomass with changes in EVI values. This information provides the basis for applying a remote sensing solution to mapping degradation in Year 2.

The results provide a useful insight into the characteristics of the forest composition and also into the trends associated with mining operations. A summary of the main findings are as follows:

Field transect results:

- Field transects suggest that infrastructure-related degradation is restricted to the immediate area around the deforestation site.
- Low biomass or basal area values surrounding deforestation sites can be due to differences in forest types (i.e. swamp forest) rather than being indicative of degradation.
- The inclusion of field-based measure of disturbance assists with identifying canopy openings. These openings may not be reflected in the biomass measurements
- Field observations suggest that in active areas, any future expansion of deforestation is likely to include degraded areas.
- Naturally occurring small-scale disturbances (<100 m^2) such as localised wind damage or mortality are at a scale that is difficult to detect from 5 m RapidEye images.

Relationship between field measurements and EVI:

- Analysis of EVI values around new deforestation sites shows that degradation typically does not extend more than 40 m from deforestation sites. The two methods evaluated 'distance change' and 'fractional area' provide very similar results.
- Vegetation indices such as EVI are useful for identifying forest disturbance provided the disturbance is large enough (>100 m^2)and that the vegetation is disturbed to the point where the soil is exposed.
- Natural variation is seen across the transects. Areas with low biomass or basal area do not always correspond with low EVI values. In this context no decrease in EVI values are observed if a dense understory of shrubs is present.
- Patterns associated with prospecting or small-scale tracks can be detected due to spatial patterns and proximity relative to existing operations.

The results indicate that the most pragmatic approach is to use the EVI or RapidEye images as a guide to assist with the identification of degradation. The evidence collected in the field indicates that degradation is quite sporadic and is associated with the mining process. This process includes prospecting, establishment of trails to connect to larger roads and expansion of mining sites. Any expansion of an existing mining site, will likely result in further degradation of the surrounding forest. The acquisition of RapidEye images in Year 3 will assist with monitoring degraded areas.

Degradation Approach

The approach taken was to directly interpret the satellite image in the GIS. In the GIS a 100 m buffer around each Year 2 deforestation site was established. This buffer is quite conservative since the degree of degradation is low and fragmented and in the field plots visual observation confirmed it did not extend further than 40 Mathis was supported with a series of mapping rules that provide guidelines to assist with the identification of spatial patterns associated with degradation (See Appendix 9).

Comment from Norwegian Ministry of the Environment

While the method should give a good estimation of degradation where clear breaches in the canopy can be observed from RapidEye imagery, we are concerned that significant biomass loss can take place without there being an observable breach in canopy. Supplementing information on how this is treated should be added.

Response to Comment

Based on the MRVS Roadmap, for the full MRVS, both forest area assessment and forest carbon stock assessment (and associated monitoring system), will be used, taking account of both deforestation and forest degradation drivers. This is not a requirement under the interim measures but under the full MRVS. As such the Forest Carbon Monitoring System being designed integrates this using the gain / loss method.

Forest harvest, which is the main driver that will lead to biomass loss, is being addressed under the forest carbon monitoring system with an emission factor already established for this (further calculations are provided below).

In the same way, degradation from mining, fire, infrastructure, and shifting agriculture (which are more likely to be detected from satellite imagery) are also being explored from field studies, and will have also emission factors established.

Further, in conducting the accuracy assessment, field checks of the degradation methods was completed. This is proposed to be a standard part of all annual reporting since it allow for a validation of the completeness of the degradation reporting.

This is covered in: Forest Carbon Monitoring System Design Document (Goslee, K., Brown, S., et al. Sampling Design and Implementation Plan for Guyana's REDD+ Forest Carbon Monitoring System (FCMS). Guyana Forestry Commission, September 2011.

What is considered significant biomass loss---the estimated total carbon stock of the forests based on the FCMS sampling design is 321 t C/ha (average of more and less accessible, excluding soil). One might argue a loss of 10% or more might be considered significant loss if that loss was sustained. Thus do degrading activities reduce the biomass by more than about 32 t C/ha? Which pools could be affected by agents of degradation in the buffer zone (these will include the people working in the mines and to a lesser degree by people associated with logging when satellite logging camps are established) that do not cause a breach in the canopy. First litter could be one of these pools (currently estimated to be about 5-6 t C/ha) and it is possible that this pool could be affected—however in its natural state in Guyana's forest this pool likely turns over about once a year , that is the litter decomposes, emitting CO2, but then replaced by litter fall during the year. So even if this pool was disturbed there are not net emissions.

Understory herbaceous biomass is another potential pool to be affected. Based on field data from preliminary plots this was estimated to be <0.5 t C/ha and was considered insignificant and not included in final sampling plan—so we assume this pool can be ignored.

Sapling could be trampled and killed—the estimate of sapling biomass obtained from the field plots is 1.2 t C/ha—even though these could be killed, they will likely recover quickly given the growing conditions in the forest and the existing seed source. There is no use for dead wood by degrading agents so this pool would not be affected.

The only pool likely to be reduced and not show up as a breach in the canopy is the use of small diameter trees (5-15 cm range) by the degradation agents—trees in this size class are often cut to provide poles etc. for the people working in the mining and logging areas. We estimated the size of this pool from the field plots to be 22 t C/ha—however it is unlikely that the degrading agents would cut all these smaller size trees so that the actual impact is significantly lower than the 22 t C/ha.

So overall we argue that the biomass loss from degrading activities in the buffer zones that does not cause a breach in the canopy is insignificant.

Further evidence is also provided by analysis conducted by Winrock International which is based on the empirical data collected from;

- *biomass plots*
- *logging plots on collateral damage, gap area, volume per gap extracted*
- *the GFC Code of Practice timber extraction rates*
- *estimates of total emissions from logging for the period 2001 to 2010.*

These data are used to estimate the likely reduction in biomass (and thus C stocks) of Guyana's forests under different levels of extraction. Since logging is an operation of some scale it represents the upper limit of degradation. Logically degradation around mining and road infra-structure is not practiced at the same intensity.

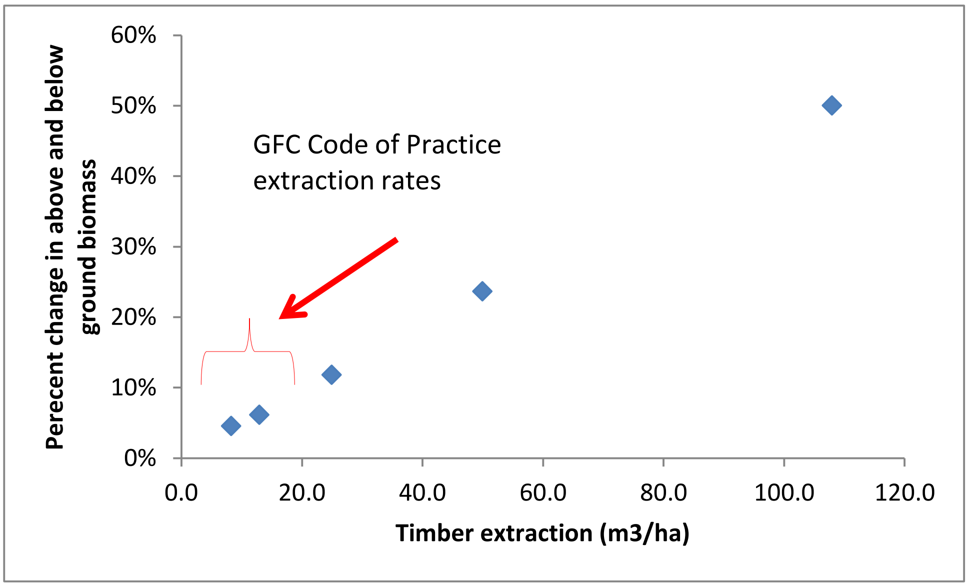
We then estimated the reduction in biomass for extraction rates higher than the code of practice levels and also estimated how much timber would need to be extracted to reduce the biomass of the forests by 50%. The results are given in the following table and figure.

It is clear that to get a reduction of 50% as proposed in the JCN would involve a huge rate of timber extraction, and that such a level would be readily identifiable in the remote sensing imagery. As it is, identification of degradation in remote sensing imagery indicates relatively small changes compared to deforestation, thus the evidence presented here cannot support the 50% reduction indicator and instead is more like <8% or so.

Table: Percent reduction in biomass and canopy as a function of different timber extraction rates.

Volume extracted m3/ha	% biomass reduction	% canopy loss
8.3	5%	3%
13.0	6.1%	4.3%
25.0	11.8%	8.3%
50.0	23.6%	16.7%
108.0	50.0%	36.0%

Figure: Relation between timber extraction rate and percent change in above and below ground biomass. The GFC Code of Practice extraction rates are less than 20 m^3/ha.



Source S. Brown - Winrock International 2012

Comment from Norwegian Ministry of the Environment

Observable degradation is mapped around a 100 meter buffer around year 2 infrastructure. But what about degradation that happens in the vicinity of infrastructure from previous years? We believe that areas surrounding infrastructure should be mapped for degradation every year, as degradation is likely to not always take place in the same year the infrastructure is developed.

Response to Comment

Back dating of degradation for previous change periods (i.e. year 1) is more challenging given the scale, intensity and fragmented nature of forest degradation. Additionally these areas rapidly recover biomass and appear very similar on 30 m resolution images to surrounding intact forest. For these reasons the default 500 m buffer was applied to year 1 change to account for degradation in that period.

We agree that degradation for subsequent periods should be mapped and as such the plan is to build on the second year by acquiring 5 m resolution imagery for the year 3 assessment. This temporal coverage will allow degradation to be spatially tracked by identification of new areas associated with year 3 change. GFC is currently considering expanding the coverage of RapidEye to all forest areas (~18 million ha).

Comment from Norwegian Ministry of the Environment

As a general comment; we think the approach to use RapidEye imagery to estimate degradation is very interesting. However, the studies conducted seem to be too few and conducted in too small of an area to justify application of the method to the national level. We would encourage to do more studies and to ensure sufficient samples to better validate the methods.

Response to Comment

It should be noted that Winrock International and Applied Geosolutions study conducted developed a method that was proven to be sound, consistent and applicable to the practical circumstances relating to the drivers of forest degradation. The findings of this were based on matching empirically derived data to a range of satellite sensors and image processing techniques across degradation sites. The report concludes the following;

The fact that the radius of observable degradation seen in this analysis is limited to 100 metres is not surprising given that significant losses of trees in principle should only be associated with direct effects of installing new infrastructure. Indirect effects will be limited to subtle changes in forest structure and biogeochemistry that are likely caused by: (1) drying due to increased exposure; (2) altered turbulence and wind patterns; (3) invasion of gap species, out-competing low light species; and (4) temperature changes. All of these factors occur at close proximity to the gap edge and require actual penetration of altered light and moisture regimes into the canopy at distance. Indeed, many of these mechanisms could actually result in enhanced carbon storage (e.g. introduction of faster growing species in the buffer region). Therefore, viable mechanisms for removing carbon in the 10-50% range require large scale extraction of stems and crowns that we have demonstrated are visible in the remote sensing imagery. Furthermore, the signal of tree removal and associated gap formation is directly observable in satellite imagery due to the fundamentally different reflectance spectra associated with NPV and soil, versus green vegetation. While there are always uncertainties in image analysis associated with geo-location and atmospheric effects, the underlying principles of this analysis are straightforward, and similar to many other analyses that have performed in other regions. There is nothing strictly location-specific about the methodology we used because it relies almost entirely on the simple notion that vegetation appears differently in the visible and near infrared regions than non-vegetation, and as we have also shown, this applies to imagery with resolutions ranging from 0.5 to 30-metres. While additional field work will assist in improving the precision of our results, especially the actual carbon impacts, we feel the general conclusions in this section should have broad applicability across similar vegetation types.

These methods were tested by Applied Geo Solutions which concluded that 40 m is the extent of forest degradation. These were then further tested by Indufor over 24 sites using remote sensing techniques. The results were verified over seven field sites to determine the applicability of the methodology developed and scrutinised further during the independent accuracy assessment.

The GFC/Indufor field measurements confirmed that degradation impact is localised to the immediate extent of the deforestation event (~40 m). Additionally the findings concur with Applied Geosolutions conclusions that there is nothing strictly location specific to the approach adopted.

A series of mapping rules were developed. These were designed to be conservative by evaluating 100 m buffer around each year 2 deforestation event. These rules were applied and evaluated during the accuracy assessment.

7. 2010-11 GIS-BASED FOREST CHANGE MAPPING

The Year 2 forest change layer was created by identifying new change relative to the existing Year 1 map. For Year 2, RapidEye coverage was ordered over all the previously identified Year 1 change areas (~12 million ha). In addition to the RapidEye area, allof Guyana was covered by a combination of Landsat 5, Landsat 7, IRS, ASAR and MODIS.

The shift from Landsat to the higher resolution RapidEye means that areas will be delineated with a higher degree of accuracy compared with previous assessments.

The increase in resolution has two implications for the current assessment:

- Year 1 change determined from Landsat may have also captured asYear 2 change areas
- Additional Year 1 change areas large than the MMU or, with unclear boundaries maybe identified.

The approach taken for the Year 2 mapping was to overlay the benchmark and Year 1 mapping datasets to determine if areas had already been mapped or, if areas had been omitted from the year 1 mapping.

If areas had already recorded in Year 1 then they were not considered as Year 2 change[22] as the change has effectively already been accounted for. Converselyif any areas of Year 1 change thatwereomitted, were discovered, then these areas were not mapped. It is planned that these areas will be revisited as part of the year 3 improvement process.

In keeping with the methodology applied in previous assessments, Guyana was divided into series of regularly spacedgrids to enable a systematic assessment. Over the major change areas (RapidEye coverage) the imagery was processed to produce an EVI image.

The EVI was vectorised and used as a guide to assist operators with the change boundaries edited as required. Often, multiple RapidEye images or combi-tiles were available over the same location. This coupled with the Landsat data enabled a near-cloud free coverage over each area.

The generation of a persistent cloud mark from the RapidEye and Landsat enabled the targeting of persistently cloudy areas. The analysis showed that for Year two 2.9% of the land area was persistently covered in cloud. Within the previously identified most active areas for change (i.e. area tasked by RapidEye), the analysis showed that 1.3% of the land area was persistently covered in cloud. As with previous years these areas were reviewed using ASAR 5- to 15 m and MODIS 250 m images and updated as necessary.

Direct interpretation of satellite images is a recognized approach that is outlined in GOFC-GOLD, (2010). The reporting objective for the national monitoring system is Approach 3, which for Guyana requires land use changes to be monitored spatially at a 1 ha scale.

The main drivers of deforestation and degradation in Guyana are well known and several projects supported by WWF (detection of mining) and ITTO (temporal forest change) have mapped various drivers and their spatial distribution over different time periods (Watt & von Veh, 2009 & von Veh & Watt 2010 and Poyry & GFC 2010).

For each temporal period, the area converted to non-forest and the main drivers of the change were documented. Formally, the general 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 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 SFM that adhere to the forest code of practice are not considered deforested as they have the ability to regain the elected crown cover threshold.

[22]The Interim measures only require that Year 2 change is accounted for. Any preceding change has already been reported.

The five anthropogenic change drivers that lead to deforestation, identified in previous assessment included:

- Forestry (clearance activities such as log landings)
- Mining (ground excavation associated with small and large-scale mining)
- Infrastructure such as roads
- Agricultural conversion
- Fire (all considered anthropogenic and depending on intensity and frequency can lead to deforestation)

There is still some debate internationally over the definition of 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 relevant to this reporting period include

- Degradation surrounding new infrastructure around mining and roads
- Fire

For the Year 2 reporting period, and the interim phase of the MRVS, certain changes such as or shifting cultivation and changes associated with forests under SFM are not required to be reported

However, for completeness it is important that all cover changes are monitored to ensure that the drivers of change and transition of the change through time (i.e. regeneration or continued degradation) are recorded[23]. All naturally occurring disturbances, such as erosion and wind damage were also identified to ensure that these events are differentiated from anthropogenic changes.

To assist with interpretation of change events and drivers, examples were provided to the interpreters (See Appendix 9 for mapping guidelines). To assist with classification, an aerial over-flight over change areas during which GPS-located oblique photographs taken, was conducted in November 2011. These photos are linked to the GIS to assist with driver identification.

Comment from Norwegian Ministry of the Environment

On page 59 it is stated that “An important consideration is 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 SFM that adhere to the forest code of practice are not considered deforested as they have the ability to regain the elected crown cover threshold.” Are these areas monitored to ensure that the crown cover is indeed regenerating?

Response to Comment

The Interim Indicators do not require that a spatial representation of forest degradation over managed forest areas. This is required once the full MRVS becomes operational.

The Interim Measures require that forest degradation around new infrastructure be mapped. This has been done using 5 m resolution imagery for a large part of the forest area of Guyana (all of the allocated State Forest Estate) - as outlined in the report. It should be noted that if the area is in fact deforested then it is mapped in accordance with the mapping guidelines.

[23] Lands that have been converted to another land use should be tracked under the appropriate sections for as long as carbon dynamics are influenced by the conversion and follow up dynamics. 20 years is consistent with IPCC Guidelines, but Tier 3 methods may use longer periods where appropriate to national circumstances.

The Interim indictors instead speak to reporting on forest management and converting removed forest produce to carbon numbers. This was done.

As such, the Forest Carbon Monitoring System includes assessment of forest degradation with the Gain/ Loss Approach to be applied and uses empirical data (for collateral impacts, incidental damage and re growth). This is therefore accounted for under the MRVS.

We also point out that the typical timber extraction rate of about 8.3 m^3/ha (set by GFC) has a very small impact on the forest canopy. Based on the logging plots measured as part of the FCMS (184 logging plots) we found that the harvested trees yielded an average of 3.4 m^3 of extractable timber (3.4 m^3/logging plot). The average gap area created by these felled trees is 33.3 m^2/m^3 extracted. Thus the total number of trees harvested per ha is about 2.3 (2-3). The harvesting of these trees creates a total gap area of about 276 m^2 (0.028 ha). Thus the typical timber harvesting practices creates gaps representing about 3% of a hectare. Skid trails can also create gaps—based on data from the logging plots and from GFC on total timber harvesting and length of skid trails, we estimate that skid trails affect 280 m^2/ha or potentially another 3% of the canopy. However, it is unlikely that the skid trails actually breach the canopy as they do not cause large trees to be felled.

In conclusion the harvest of trees using the code of practice affects no more than about 5-6% of the canopy of 1 ha.

As for the issue of regeneration—we have also collected preliminary data for estimating regrowth and regeneration after logging. We established plots in 69 recently logged gaps and 28 in logging gaps created three years ago—we used the same plot design in both occasions. We compared the carbon stocks of the two age classes and found regeneration and regrowth rates of about 5 t C/ha per year—a very healthy rate of recovery.

The Interim Measures require for forest degradation new infrastructure to be mapped and this is done by remote sensing in year 2 for the reasons outlined in the report, one of which is the fact that in this year, 5m resolution imagery was acquired for a large part of the forest area of Guyana (all of the allocated Sate Forest Estate).

Additionally wall to wall mapping is done of all areas so the coverage is national and complete/comprehensive.

7.1 Year 2 Mapping Process

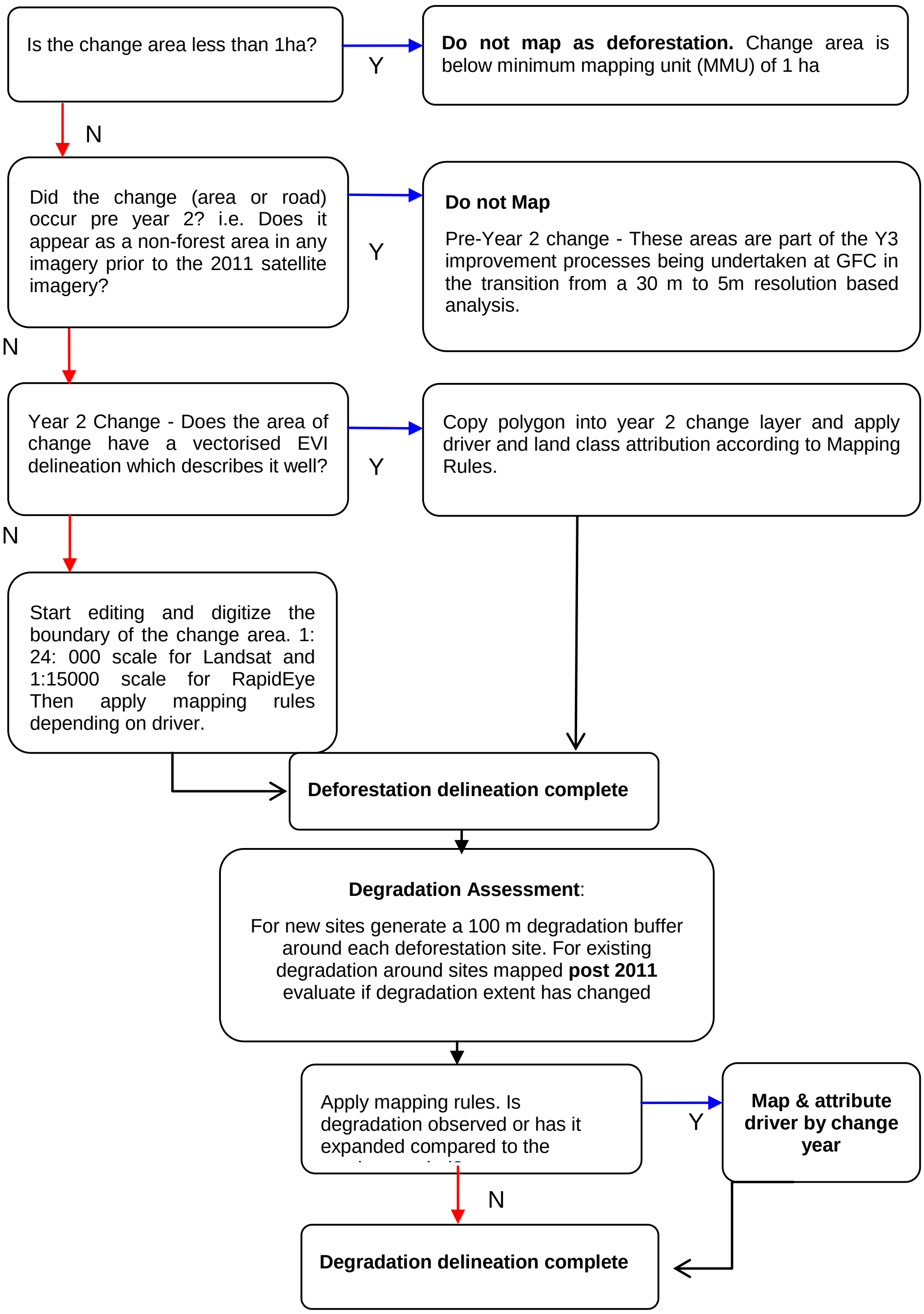
The mapping process involved a systematic review of 24 x 24 km grid tiles at a resolution of 1:15 000 over the RapidEye coverage region and a scale of 1:24 000 over the Landsat coverage region. If cloud is present on the RapidEye, then Landsat images over that location are also assessed.

The tile size was chosen to align with the footprint of a single RapidEye tile and the different mapping scales were used to best align with the differences in image resolution. The RapidEye tiles were then subset to a 1 km x 1 km grid. A two stage approach to mapping change was used.

Stage one involved delineating the change while stage two involved attributing the delineated change. The delineation was based on a vectorisation of the EVI threshold which was brought into the GIS and manipulated as required by operators.

The decision tree that shows the process followed when mapping deforestation and degradation delineation, is seen in Figure 7-1.

Figure 33: Deforestation & Degradation Process Diagram



Once the polygon has been delineated through the manual review of EVI vectors, the driver and resultant land use class are determined by visual inspection of the RapidEye imagery. The following rules outline how the mapping was undertaken for each driver.

The method used to delineate degradation is based on the results of the degradation study as described in Section 6.

7.2 Mapping Guide and Rules Applied to Year 2 Change

The following table provides an overview of drivers and associated deforestation or degradation activities that are reported spatially in the GIS as part of the MRVS. Some activities are not yet accounted for in the MRVS.

Table 7-1:Summary of Activities & Drivers Captured in the GIS

Activity	Driver	Criteria	Ancillary Info Available	Accounted in MRVs	End Land Use Class
Forestry	SFM	Fall inside state forest area and is a registered concession with GFC	Annual harvest plans, GIS extent of concession, previously mapped layers, Satellite imagery	No	Degraded forest by type
	Roads formed to access and extract timber from concessions including landings	Roads > 10m		Yes	Settlements
Mining	Roads	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	Assess area within 100 m buffer around deforestation event – road or new infrastructure	Existing Year 2 deforestation sites, Satellite imagery	Yes	Degraded forest by type
Agriculture	Deforestation	Deforestation sites > 1 ha	Registered agricultural leases, Satellite imagery	Yes	Bareland or crop land
Fire	Deforestation	Deforestation sites > 1 ha	FIRMs fire points, spatial tends from preceding periods, Satellite imagery	Yes	Bareland or crop land
	Degradation	Deforestation sites < 1 ha		Yes	Degraded forest by type
Roads	Deforestation	Roads >10 m	Existing road network . Satellite imagery	Yes	Settlements
	Degradation	Assess area within 100 m buffer around deforestation event – road or new infrastructure	Existing Year 2 deforestation sites, Satellite imagery	Yes	Degraded forest by type
Shifting Agriculture	Degradation	Assess historical patterns	Proximity to rural populations, water sources and Satellite imagery	No	Degraded forest by type
Afforestation	Afforestation	Monitor abandoned deforestation sites	Historical land use change Satellite images	No	Afforestation forest or land cover by type

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. Previous projects also show that the spatial distribution of change in Guyana follows a pattern and is clustered around existing access routes (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.

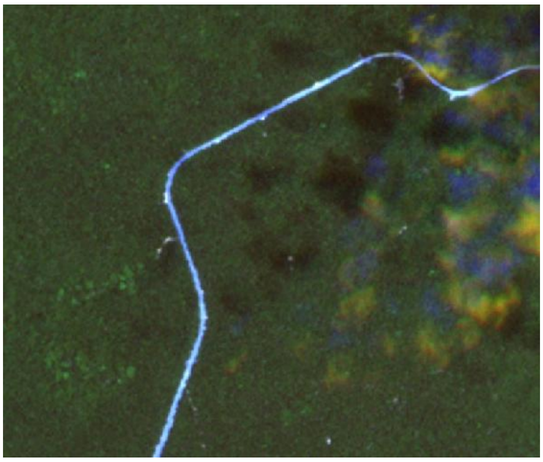
Supplementary GIS layers were also included in the decision making process to reduce this uncertainly. The following description and examples provide a summary of the main characteristics of each driver.

7.2.1 Roads

Characteristics

Roads are readily identifiable by their distinctive linearity. Linear features are deemed to be roads if the spectral response shows the presence of bare soil which is associated with the construction of unpaved roads. Soil is depicted in grey, beige or red colours in the imagery (Figure 34).

Figure 34:Example of Infrastructure Activity



Mapping Criteria

The roads (>10 m width) were traced from the imagery as linear features and converted to areas by applying a buffer on either side of the features and where appropriate the buffer was edited.

From the imagery three classes of road were attributed according to their width.

- 10 m (or up to 2 Rapideye pixels)
- 20 m (or up to 4 Rapideye pixels)
- 30 m (or up to 6 Rapideye pixels)

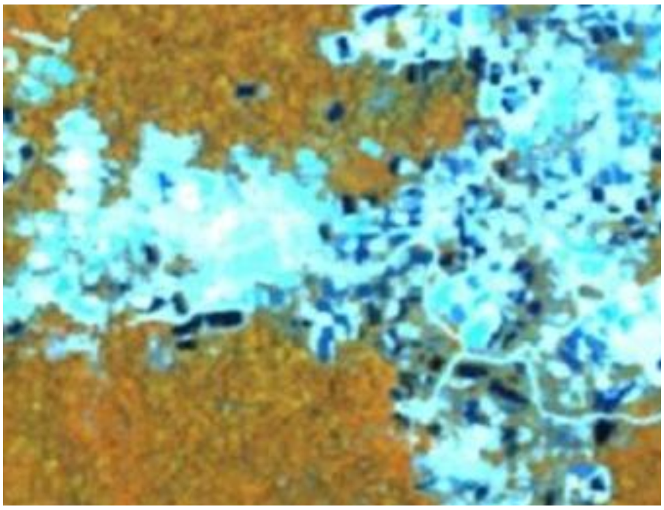
Deforestation associated with roads is recorded as ‘settlements’ in the GIS and attributed by the driver of the change.

7.2.2 Mining

Mining activity produces forest clearings with very variable shapes and sizes and with sharp boundaries The clearings often occur in clusters along streams or near water bodies and in remote areas with limited road infrastructure. Since 2009, GGMC has been locating and recording large and medium scale mining operations with accompanying dredge sites, with GPS, every six months. There is much utility in expanding this effort to small scale operations as well.

Areas cleared by mining activity have a distinctive spectral response from other change with sand, mud and rock depicted in highly reflective white, pink or grey colours and pools of water appearing blue in colour (Figure 35).

Figure 35: Example of Deforestation Associated with Mining Activity



Smaller scale mining also exists. Again the shape is often linear and tracks water bodies. It appears that some of these areas regain some vegetation cover over time rather than remaining in a bare land state. The extent of any regeneration still remains to be quantified in the field and it is an important part of determining the carbon potential of these areas. This aspect will be covered during the development of the carbon monitoring systems.

Mapping Criteria

Digitise or edit EVI delineation of mining area and attribute with a land use class of 'bareland'. For both mining areas and mining roads, the mapping of forest degradation is also required.

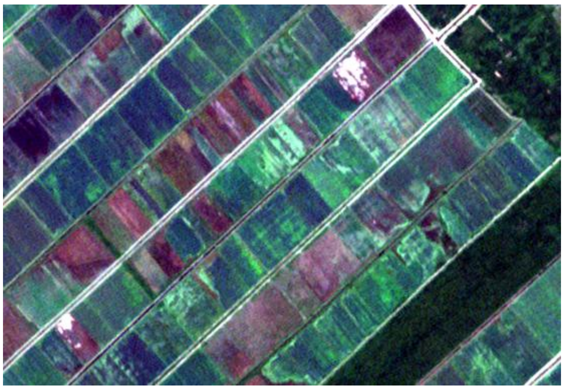
7.2.3 Agriculture

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.

Cropland is identified as permanent fields, mainly sugar cane fields, but also other crops or mixed agricultural land, as long as the agricultural component appears to be dominant. These areas are also located in close proximity to settlements and along the coastal fringe and appear in the form of larger >5 ha regular shaped blocks. The GL&SC also provided registered agricultural leases which provide an additional reference layer.

Intensive production agriculture is identified by the presence of large rectangular patches arranged in an ordered regular pattern. Each patch has its own distinctive spectral signature (Figure 36). The converted land generally lies adjacent to existing established farmland.

Figure 36: Example of Agricultural Fields



Mapping Criteria

Digitize a single polygon around the spatial extent of the change area. Agriculture is differentiated from shifting agriculture as it is a permanent land use change from a forest class to a non-forest class. Pay special attention that shifting agriculture areas (forest degradation) are not confused with agriculture (deforestation). Assign a land use class of 'Cropland'.

7.2.4 Fire - Biomass Burning

GOFC-GOLD (2010) states that fire is often associated with forest cover change (deforestation, forest degradation) either through deliberate human fire use or wildfire. This is also the case in Guyana where the cause of fires (biomass burning), which, based on local knowledge, are largely human induced or anthropogenic events, largely occurs in managed forest lands, and in the case of deforestation by fire (not including shifting agriculture which is separately listed under Forest Degradation), leads to a permanent change in land use: Forestry to Cropland or Bareland.

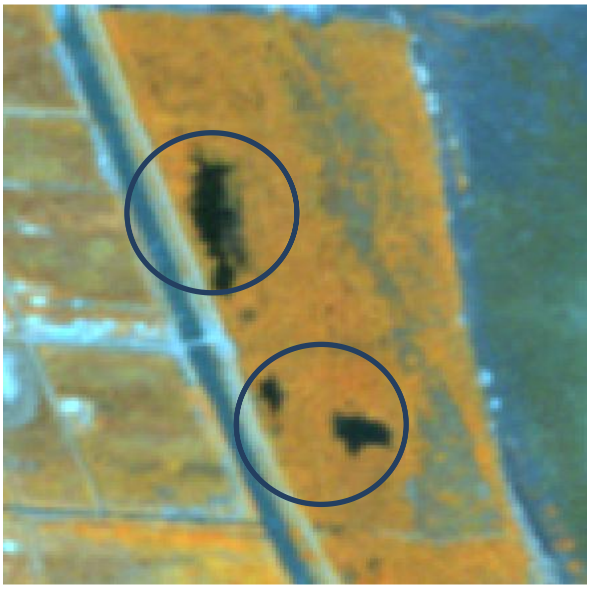
It is for these reasons that fire has been included as a deforestation driver. The Fire Information for Resource Management System (FIRMS) and the 500 m burnt area product provides information about historic and present day fire locations using the Moderate Resolution Imaging Spectroradiometer (MODIS). Since MODIS works on the basis of detecting thermal anomalies, it is only effective in cloud-free conditions.

Successful detection of burnt areas depends on the intensity and the scale of the fire[24]. If the event has occurred recently, the burnt areas will show a strong response in near infrared band due to a decrease in actively photosynthesising vegetation. In Guyana the areas most at risk include the coastal zone and savannah or white sands regions. Often burning is associated with land clearance and if not detected immediately may be classified as shifting agriculture.

Figure 7 5 shows a typical spectral signature observed after burning.

[24] MODIS routinely detects both flaming and smouldering fires 1000 m² (1 ha) in size. Under very good observing conditions (e.g. near nadir, little or no smoke, relatively homogeneous land surface) flaming fires one tenth this size can be detected. Under pristine (and extremely rare) observation conditions even smaller flaming fires 50 m² can be detected".

Figure 37:Burning Example



Mapping Criteria

Areas affected by fire are most reliably detected by spectral signature, and their generally non uniform shape. They tend to be near existing agricultural areas as fire is used to deforest new areas for agricultural development. The FIRMS fire point dataset for the Year 2 period also shows evidence of fire locations, however it cannot be relied upon as a guarantee of fire. The temporal difference between the fire occurring and the image date may mean land cover regeneration has occurred. For the biomass burning driver, attribute a land use class of either a degraded forest type or deforestation (bareland), depending on the shape and size of the feature.

7.3 Mapping Degradation

Degradation surrounding Year 2 sites, is mapped by selecting the polygon of deforestation and buffering the event by 100 m.This buffer is more conservative than the 40 m degradation zone identified in the study Salas *et al* 2012and the degradation assessment conducted for Year 2. .

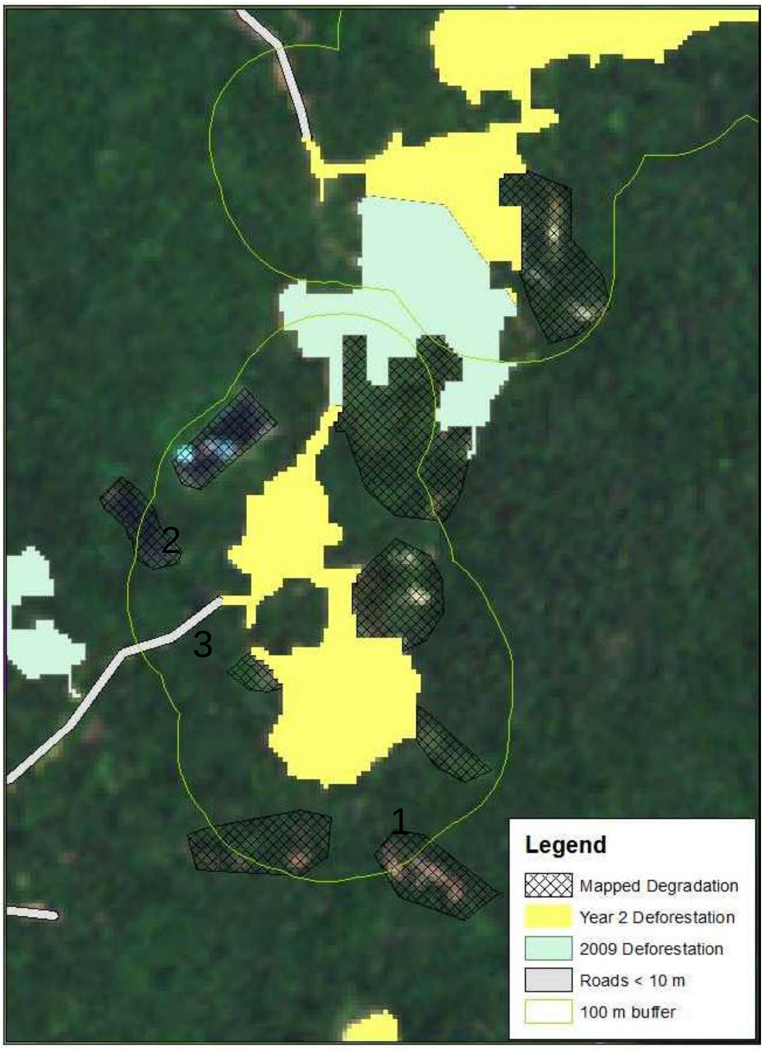
Any forest that shows visual evidence of forest degradation starting inside the 100 m buffer is mapped as degradation resulting from Year 2 infrastructure.

Mapping Expanding Degradation

Repeat coverage of RapidEye over the same locations allows for areas identified as Year 2 degradation to be revisited. This action considers the likelihood that prospecting may resume around recorded deforestation sites. This may result in an expansion of the degradation zone.

The following example shows an area with change from different periods. Mapping is only conducted on Year 2 areas. It is therefore important that these areas are separated from previous periods. This is achieved by evaluating satellite images used for the previous assessment and overlaying the Year 1 GIS change layer and non-forest layer.

Figure 38: Degradation Mapping



The yellow area is Year two deforestation event. Around the event is a 100 m buffer (green). Degraded areas (hatched) are mapped. These include canopy gaps where the ground is visible (blue). The degradation extent captures these areas by drawing around these pockets.

Site 1 Starts inside the 100 m buffer, so the entire extent is mapped even though it extends beyond the buffer. The buffer is automatically generated in the GIS from the outside of the deforestation event.

Site 2 Includes deforested areas that are < 1 ha these are included as degradation. Again if the area starts inside the buffer, the area outside the buffer is also included. If it occurs outside of the 100 m buffer, it is not mapped.

Site 3 No degradation is mapped around this road as it is < 10 m in width which is deemed below the MMU for roads. No degradation is mapped around sites from periods preceding Year 2.

The direct interpretation method adopted for mapping degradation is considered a pragmatic way to map degradation. The visual interpretation method has the advantage over a remote sensing method as it allows for context to be included in the decision-making process.

7.4 Land use Changes Not Recorded in the MRVS

There are several land cover changes that have not entered the MRVS at this interim stage. Under the JCN, changes in these areas are not currently reported. For completeness, the general extent of these areas is mapped to ensure that they are not accounted for as measured land use change.

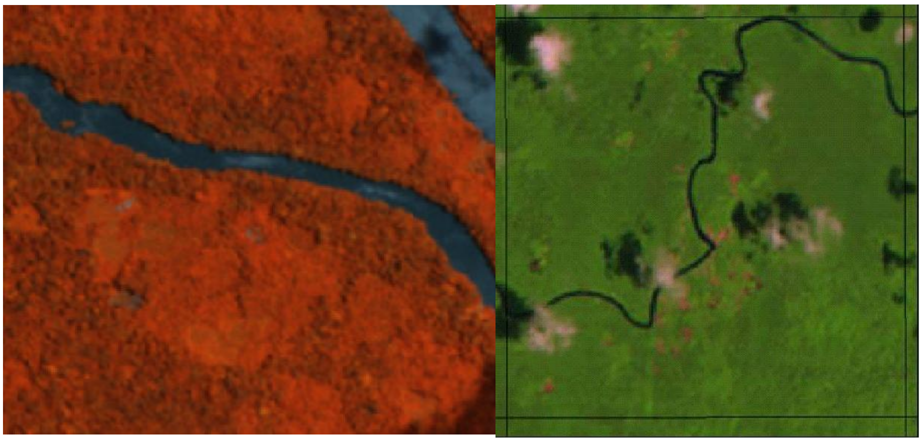
7.4.1 Shifting Agriculture

Areas of shifting cultivation are not considered in the interim MRVS, but do represent a change (albeit temporary) in carbon stock. They are often presented in the landscape as a mosaic of land cover that are often small and scattered, appearing in different states spanning from bare land to grassland to regenerating forest. Small forest blocks can be found within this class as well. These areas are located in close proximity to villages.

Generally there are two types of shifting cultivation: pioneer and rotational. Pioneer shifting cultivation involves the cutting of primary forest and subsequent cropping and then abandonment. Rotational shifting cultivation involves revisiting areas on a rotational cycle.

Subsistence agriculture is characterized by a disordered patchwork of forest clearings often near rivers and in proximity to settlements. Small patches of soil cover are interspersed with areas of cropland and grassland (Figure 39). The patches are amorphous to regular in shape. The spectral response from bare soil typically appears beige to red in colour and the cropland and grassland displays as pale green tones. The transition of these areas to forest if abandoned is usually gradual. The extent of these areas was mapped by delineating the extent of the activity. Over time the coverage of these areas may extend or contract. The extent of any regeneration still remains to be quantified in the field.

Figure 39: Example of Small-scale Shifting Agriculture



Mapping Criteria

A single polygon around the spatial extent of the visibly impacted area is created. The polygon includes a patchwork of degraded forest areas and land under temporary cropping.

Agriculture is differentiated from shifting agriculture as it is a permanent land use change for a forest class to a non-forest class. In contrast shifting agriculture areas (forest degradation) are not rotational and are irregular in shape. In the GIS mapping, a land use class of ‘Cropland’ is assigned.

7.4.2 Forest Harvest

Characteristics

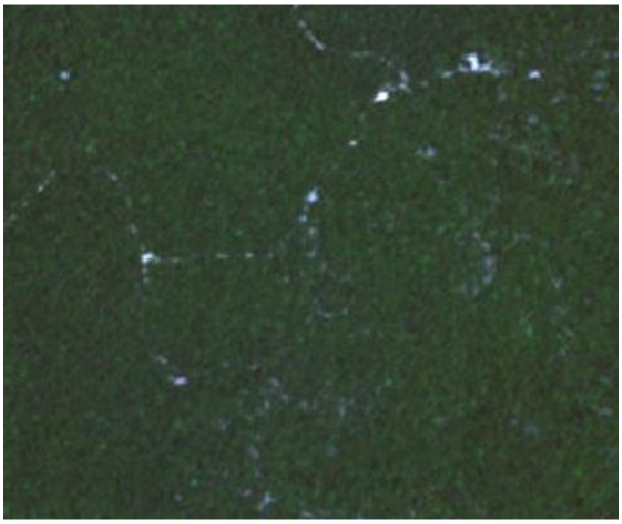
Forestry activity within the State Forest Area is recognized most noticeably by the appearance of roading and the degradation caused by surrounding selective harvest areas. As part of a large concessionaires’ annual plan they are required to submit maps (to GFC) that show intended harvesting roads. Additionally all blocks require approval before harvesting may commence. This information is recorded in the GIS by GFC. This is also one way in which forest roads are differentiated from mining roads.

On satellite images forestry roads typically define a dendritic pattern with short tracks radiating outwards into forest from a major road.

The extent of selective forest harvesting is difficult to estimate and has a higher level of uncertainty associated with it, as it relies on estimating the area by the level of degradation using the degree of canopy closure as a guide.

Small-scale harvesting and degradation of forest is identifiable from the RapidEye imagery, however some spectral confusion between natural forest variation and actual selective harvest areas can occur. In mapping forest harvest, the best method is an extent polygon of areas that appear to have been harvested due to canopy gaps and spectral differences within or nearby provided harvest polygon areas.

Figure 40: Example of Forestry Roads and Harvesting



Mapping Criteria

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

7.4.3 Natural Events

Natural events are considered non-anthropogenic change, are typically non-uniform in shape and have no evidence of anthropogenic activity nearby. These areas are attributed with a land class of degraded forest by forest type or bareland as required.

8. FOREST CHANGE

The results summarise the Year 2 period (01 October 2010 to 31 December 2011) forest change. This includes estimates of deforestation and degradation for all land eligible under Guyana's LCDS.

The measurement period for Year 2 is effectively 15 months or 1.25 years. For simplicity, deforestation has been reported as if measured over a 12 month period – this means that the annual rate of change is lower than the figure presented.

As agreed under the JCN, infrastructure associated with the construction of the Amaila Falls hydro power development has been included in the total deforestation figure for Year 2, but for clarity it has been itemised separately. For Year 2, the area associated with this development is 225 ha (see Table 8-2).

For referencing purposes, historical change relating to the benchmark period (1990 to 30 September 2009 and Year 1 (01 October 2009 to 30 September 2010) are also provided.

The change for each period is calculated by progressively subtracting the deforestation for each period from the forest cover as at 1990. Forest is defined in accordance with Guyana's national definition of forest which has remained consistent across the historic, benchmark period, and years 1 and 2. The forest cover estimated as at 1990 (18.47 million ha) was determined using manual interpretation of historical aerial photography and satellite images. This area was determined during the first national assessment (Pöyry 2010) and verified independently by the University of Durham (UoD, 2010).

This analysis provides a benchmark against which all future change is referenced. The results for each period are further divided by the five change drivers identified by the MRVS steering committee. This information can be used to provide indicative trends for the periods analysed.

For the Year 2 detection, four main improvements have been implemented:

- Unlike preceding periods, the Year 2 assessments has used repeat coverage of high resolution RapidEye images over previously detected change areas.
- This has allowed better delineation and detection of change. Notably roads > 10 m have been mapped in Year 2. In previous assessments only roads detected on Landsat 30 m data were mapped.
- A method for mapping degradation around new infrastructure has been established.
- The impactof cloud (which may obscure change) has been minimised by using a combination of radar scenes and lower resolution MODIS images.

Additional factors that should be considered when evaluating the forest change results include:

- The Year 2 period spans 15 months, but for simplicity, the change results in the annualised comparative tables have beenreported as if conducted over a 12 month period. It is envisaged that the Year 3 reporting period will cover January to December 2012.
- Forest change reported for the Year 2 period is based on interpretation of satellite images acquired for the last three months of 2011
- Although not required for the interim measures reporting, degradation (shifting cultivation and forest harvesting) were mapped as observed.
- Only roads visible on the images (>10 m in width for RapidEye) were included in the analysis. All roads were treated as deforestation events. This is a conservative approach as some vegetation cleared for roads appeared to regenerate. Further work is required to ascertain the regeneration potential of these areas. This is planned and will form part of the carbon monitoring program.

8.1 Changes in Guyana's Forested Area 1990-2011

Historical Analysis

The historical analysis indicates that the total area converted from forest to non-forest between 1990 and 2009 was 74 917 ha. This was calculated by subtracting the initial 1990 forest area as mapped in the GIS from the 2009 September forest area (~19.75 years).

This estimate included all forest to non-forest change i.e. detected mining, road infrastructure, agricultural conversion and fire events that result in deforestation. It does not include forest degradation caused by selective harvesting, fire or shifting agriculture.

The same approach and criteria was applied to calculate the area of deforestation from 2009 to 2010 (Year 1 period). The total area of deforestation for this period was calculated at 10 287 ha.

8.2 Year 2 Analysis

For Year 2 the total area of deforestation over the 15 month period is calculated at 9 889 ha. This is a decrease of about 400 ha when compared to Year 1 (0.056% and when rounded to two decimal points – 0.06%). This is equivalent to a change rate of 0.054% for the Year 2 period (and when rounded to two decimal points – 0.05%).

The total change and change expressed as a percentage of forest remaining is provided in Table 8-1.

Table 8-1: Area Deforested 1990 to 2011

Period	Years	Forest Area ('000 ha)	Change ('000 ha)	Change (%)
Initial forest area 1990		18 473.39		
Benchmark (Sept 2009)	19.75	18 398.48	74.92	0.41%
Year 1 (Sept 2010)	1	18 388.19	10.28	0.05%
Year 2 (Oct 2010 to Dec 2011)	1.25	18 378.30	9.88	0.05%

Based on the initial 1990 forest area, the forest cover change for the 1990-2009 period is estimated at 0.41% (i.e.<1%). As with Year 1, the FAO (1995) equation as cited in Puyravaud (2003) has been used to calculate the annual rate of change. Puyravaud (2003) suggests an alternative to this equation, but at low rates of deforestation the two are essentially the same.

Equation 8-1:
Rate of Forest Change

$$q = \left(\frac{A_2}{A_1}\right)^{1/(t_2-t_1)} - 1$$

Whereby the annual rate of change (%/yr or ha/yr) is calculated by determining the forest cover A_1 and A_2 at time periods t_1 and t_2.

If the 1990-2009 period is annualised this represents an average rate of change of about 3 800 ha/yr^{-1} which is equivalent to a deforestation rate of - 0.02%/ yr.

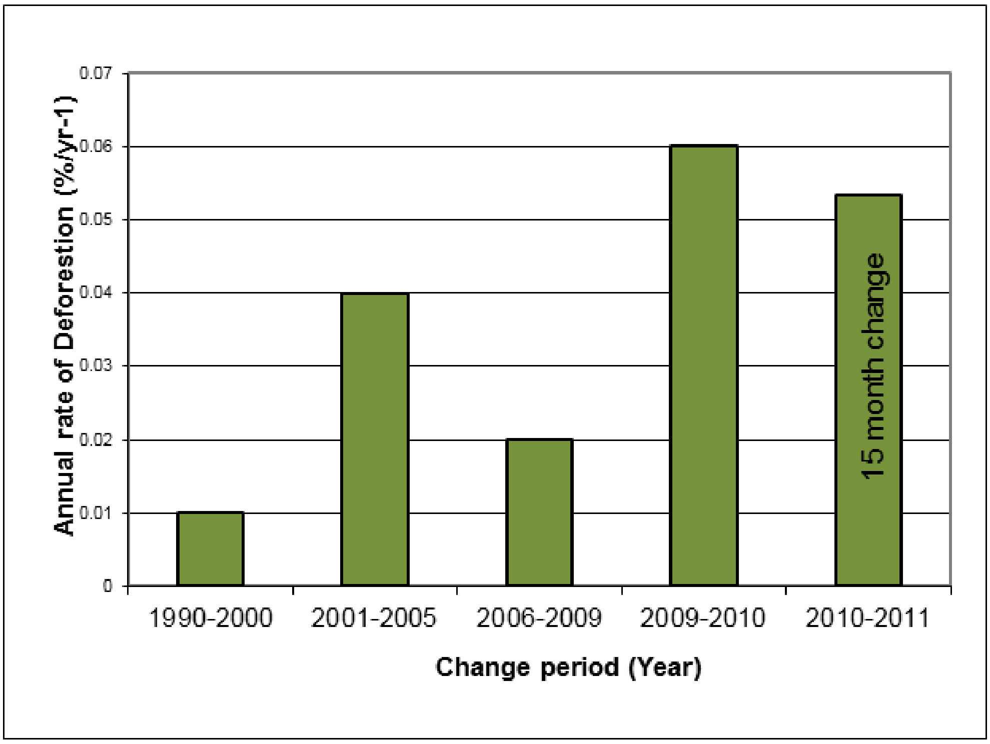
From this point the deforestation increased for the Year 1 period to 0.06% and has remained at a similar level for Year 2 (0.05%). The rate is in fact lower (0.043%) if the change is expressed as an annual rate rather than presented for the entire Year 2 period.

Overall, Guyana's Year 2 deforestation rate is very low when compared to the rest of South America, which according to the FAO 2010 forest resource assessment is tracking at an annual deforestation rate of -0.41%/yr.

The following figure shows the deforestation trend by period. The rate presented has been annualised for the benchmark and Year 1 period. The value for the full 15 month assessment period is shown for Year 2.

The trend suggests that deforestation rates have increased since 1990 but have remained reasonably constant over the last two assessment periods with a small decrease shown in Year 2.

Figure 41: Annual Rate of Deforestation by Period from 1990 to 2011



8.3 Forest Change by Driver

The forest change was divided as assessed by driver. In Year 2, degradation as measured from the 5 m RapidEye images was also included in the analysis. Details of this methodology are provided throughout Section6.

Table 8-2 provides a breakdown by forest change drivers for the benchmark, Year 1 and Year 2 period. Interpretation of the change areas during the benchmark period identifies mining (which includes mining infrastructure) as the leading contributor of deforestation (60% of the total), particularly between 2001 and 2005.

This trend continues with the area of deforestation attributed to mining (which includes mining infrastructure) showing a sharp increase in Year 1 with approximately 9 000 ha deforested in this year.

In year 2, this trend continues with a similar area deforested over the past 15 months. Mining is still the main driver of forest change and in Year 2, accounted for 94% of all recorded deforestation.

Table 8-2: Forest Change Area by Period & Driver from 1990 to 2011

Driver	Historical Period			Year 1 2009-10	Year 2 2010-11 (15 months)	
	1990 to 2000	2001 to 2005	2006 to 2009		Deforestation	Degradation
	Area (ha)					
Forestry (includes forestry infrastructure)	6 094	8 420	4 784	294	233	147
Agriculture	2 030	2 852	1 797	513	52	N/A
Mining (includes mining infrastructure)	10 843	21 438	12 624	9 384	9 175	5 287
Infrastructure	590	1 304	195	64	148	5
Fire (deforestation)	1 708	235		32	58	28
Amaila Falls development					225	
Area Change	**21 267**	**34 249**	**19 400**	**10 287**	**9 891**	**5 467**
Total Forest Area of Guyana	18 473 394	18 452 127	18 417 878	18 398 478	18 388 190	
Total Forest Area of Guyana Remaining	18 452 127	18 417 878	18 398 478	18 388 190	18 378 299	
Period Deforestation %	0.01%	0.04%	0.02%	0.06%	0.05%	

Comment from Norwegian Ministry of the Environment

We see that the deforestation rate presented do not include 225 has of deforestation related to the Amaila Falls project. While it is indeed important to clarify how much deforestation is a consequence of the Amaila Falls project, we do believe that the indicator for gross deforestation should be presented as a total of deforestation. One option could be to present the total deforestation number, and state in the same paragraph that "this includes 225 hectares of deforestation rate related to the Amaila Falls project", or similar. Should the deforestation rate in a year fall above the agreed maximum level of deforestation, we think presenting a total number first, and then subtracting the Amaila Falls related deforestation, would be the clearest way of reporting. We do feel that this would best reflect the wording in the JCN, and that it would indeed represent "Gross deforestation" in the most correct way possible.

Response to Comment

The Indicator on Gross Deforestation has been adjusted in this version of the Report (Version 3) to include the 225 ha associated with the Amaila Falls development. A notation is made to reflect this. This change increases the total area of deforestation from 0.053% to 0.054%

Comment from Norwegian Ministry of the Environment

The table on page 73 states no number for degradation in relation to agriculture. Have areas surrounding agricultural land been assessed for degradation?

Response to Comment

For the current interim measures degradation is only reported for areas surrounding new infrastructure. New infrastructure includes (mining sites, roads, pipelines and reservoirs). Degraded areas reported for other change drivers such as forestry are related to degradation surrounding roads.

Once operational the degradation methodology developed in Year 2 will be applied to map and monitor degradation surrounding forest change areas.

8.4 Degradation

Degradation associated with deforestation caused by new, Year 2 infrastructure is estimated at 5 460 ha. This figure is substantially lower than the previous Year 1 estimate of 92 413 ha.

The difference is due to implementation of a revised and more precise methodology for degradation assessment. In the Year 1 assessment it was not possible to reliably measure degradation from Landsat type imagery (30 m) due to the resolution of the imagery, and the scale of degradation events in Guyana. The fall back approach in this situation as outlined in the JCN was to account for degradation by applying a 500 m buffer around newly detected deforestation events but to do this, based on the evidence seen, will be to grossly overestimate this total. For Year 2 the approach was changed and the RapidEye used to identify forest degradation events – the JCN provides for remote sensing and field observations to be used as well.

The main cause of degradation is mining which accounts for 97% of all degradation mapped. This is expected as mining also accounts for the largest area of deforestation and it is evident that around deforestation events that forest degradation impacts are largely detected.

8.5 National Trends

The temporal analysis provides useful insight into trends in total deforestation relative to 1990. A more meaningful comparison is provided if the rates of change are annualised using Equation 8-1.

- Forestry related change has remained relatively stable between Years 1 and 2. All of the Year 2 deforestation detected in this category is associated with forest road construction activities. As in the case of Year 1, benchmark and historic mapping, these are attributed to the Forestry driver (not Infrastructure driver).
- Agricultural developments causing deforestation have declined in Year 2.
- Mining remains the largest contributor to deforestation. The area of deforestation also includes roads used to access mining sites. This includes roads that lead direct to mining sites. Mining deforestation has declined marginally in Year 2.
- Deforestation from fire events has increased relative to the post 2000 period. The area is still less than the large area of deforestation observed from1990 to 2000. Evidence suggests that this coincided with the dry conditions associated with the El Niño weather pattern.

Table 8-3: Annualised Rate of Forest Change by Period & Driver from 1990 to 2011

Change Period	Change Period (Years)	Annualised Rate of Change by Driver – Forestry	Agriculture	Mining	Infrastructure	Fire	Annual Rate of Change (ha)
		Annual area (ha)					
1990-2000	10	609	203	1 084	59	171	2 127
2001-2005	5	1 684	570	4 288	261	47	6 850
2006-2009	4.8	1 007	378	2 658	41		4 084
2009-10	1	294	513	9 384	64	32	10 287
2010-11	**1.25**	**186**	**41**	**7 340**	**298**	**46**	**7 912**

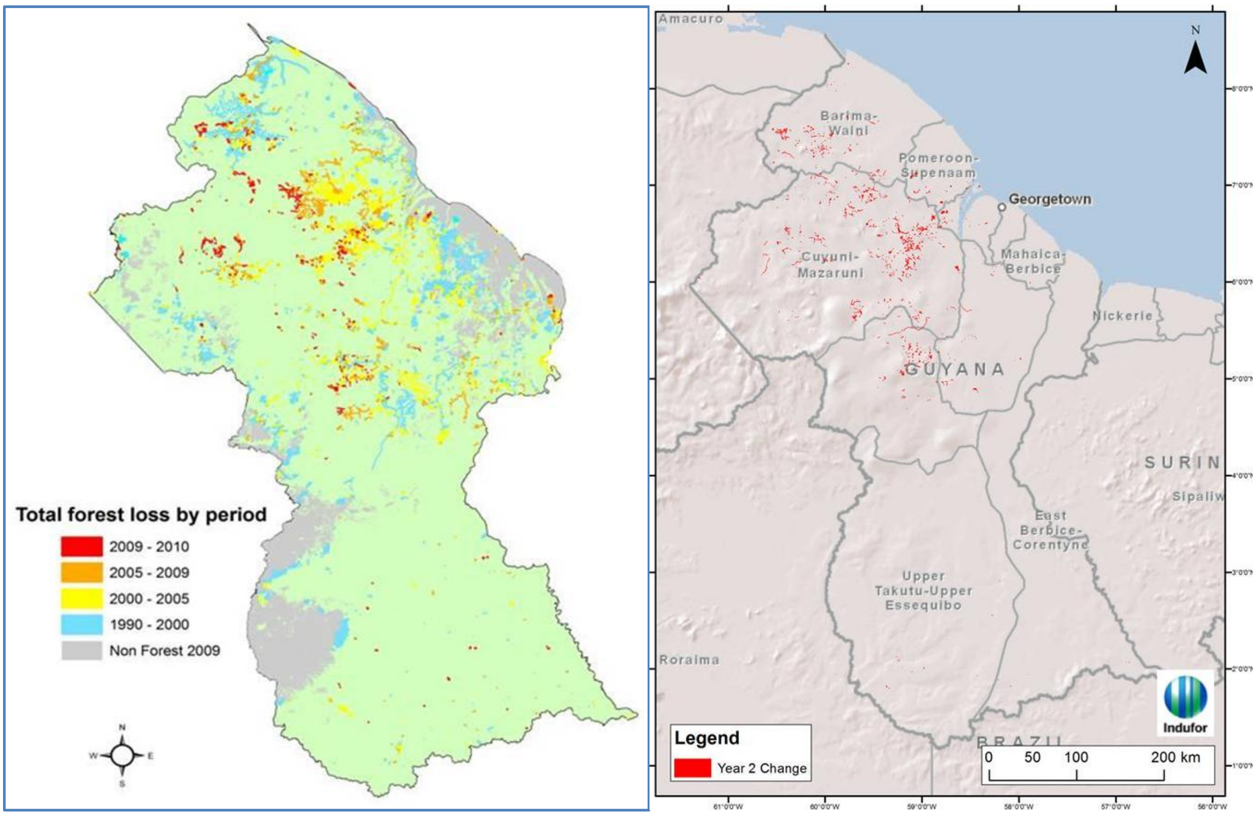
8.6 Deforestation & Degradation Patterns

The temporal analysis of deforestation from 1990 to 2011 is presented in Map 8-1. The map shows that most of the change is clustered[25] and that new areas tend to be developed in close proximity to existing activities.

All Year 2 deforestation activities fall inside the footprint of historical change areas.

[25]For the purposes of display the area of deforestation has been buffered to make it more visible.

Map 8-1: Historical &Year 2 Forest Change



The distribution pattern also shows that areas of increased activity tend to be clustered around the existing road infrastructure and navigable rivers as both provide accessibility. Historically very little change has been observed beyond central Guyana. This is also the case for Year 2 with little new change detected in southern Guyana.

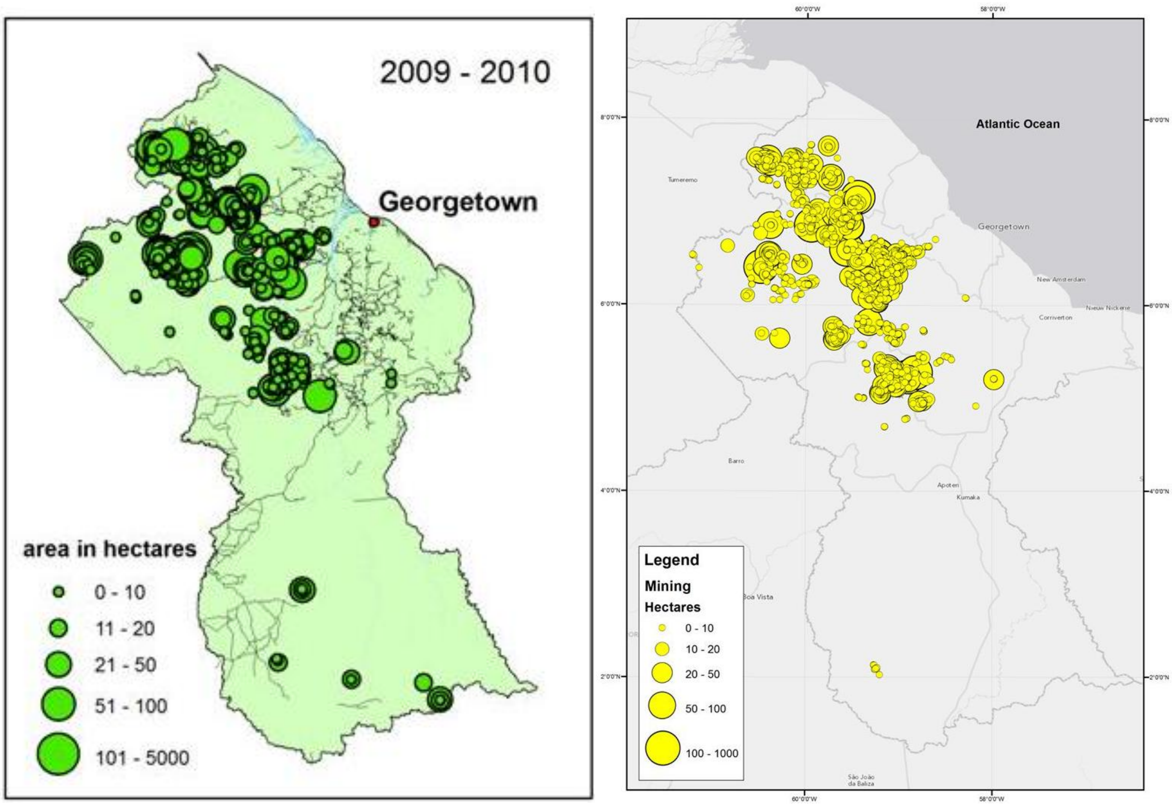
The following series of maps show the temporal and spatial distribution of deforestation by driver (mining, forestry and agricultural and biomass burning). The relative size of the change is represented by scaling the symbol proportional to the area it represents.

Mining

The spatial trend on Map 8-2shows that mining activities including associated road construction are concentrated in northwest of the country. Forest change associated with mining includes mining sites and any infrastructure associated with the operation. This includes any roads that lead directly to mining.

Most of the activity is within the SFA, with Year 2 mining activities consolidating in the centre of Guyana. Additional mining deforestation is observed to the west of the core mining area. In Year 2, less activity is observed along the Guyana/Brazil border.

Map 8-2: Mining Spatial & Temporal Distribution Years 1 & 2



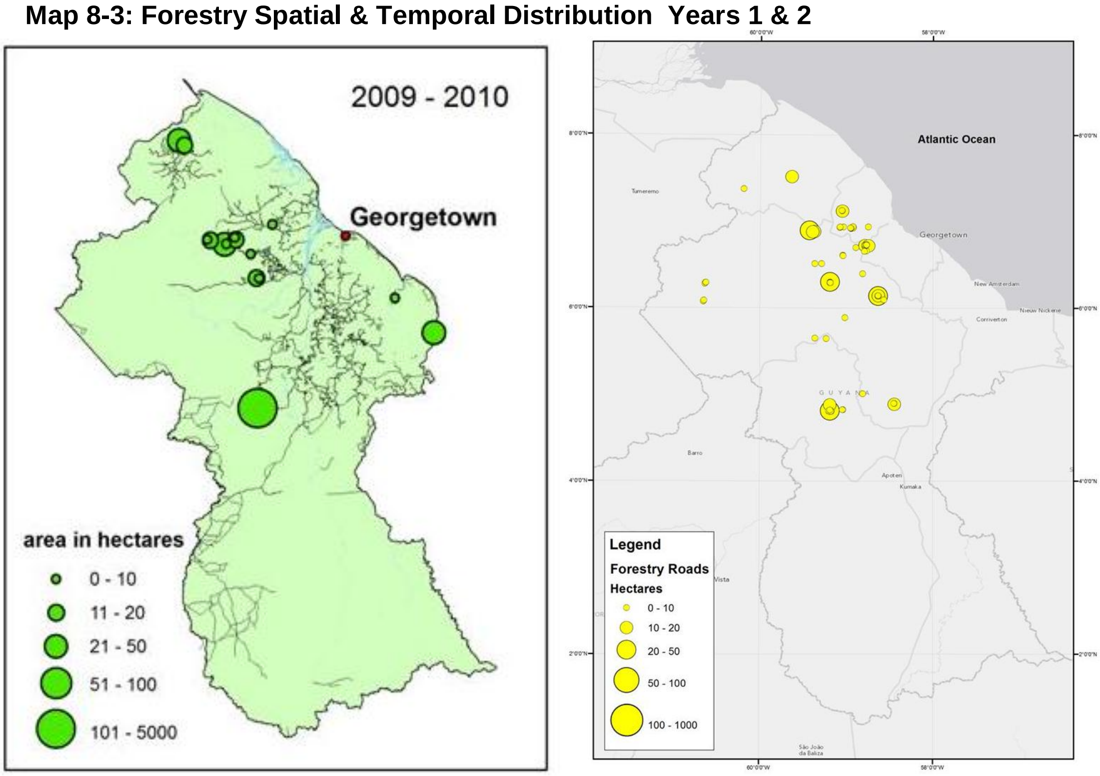
Forestry

Map 8-3 shows that a majority of forestry activities are located inside the SFA. During the Year 2 period, all deforestation events are associated with road construction activities.

Under the existing interim measures, forest harvesting is reported in terms of carbon removal (tCO_2) rather than spatially.

The spatial and temporal trend indicates that forestry activity is of a similar intensity to Year 1, and is focused in registered TSA and WCL concessions. A small amount of change is also noted in Amerindian areas to the northwest.

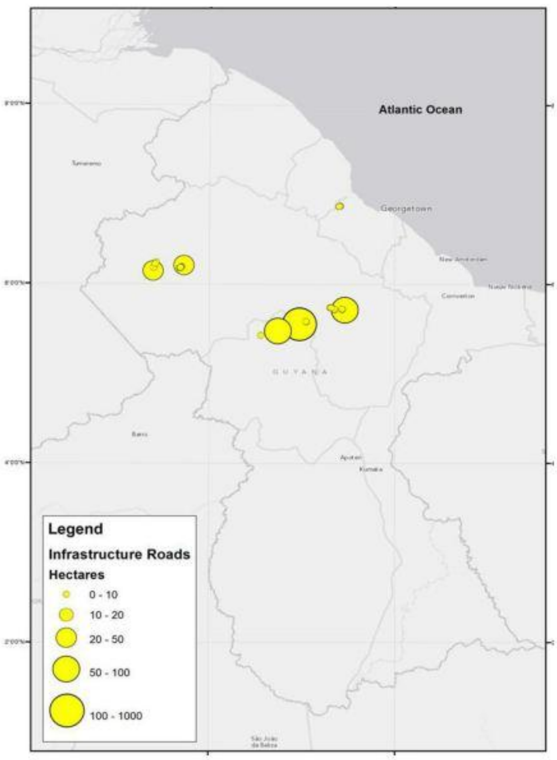
Map 8-3: Forestry Spatial & Temporal Distribution Years 1 & 2



Infrastructure

In Year 2, infrastructure developments have increased from 64 ha in Year 1 to 148 ha in Year 2. The main change is related to road construction activities. The following map shows the distribution of infrastructure developments. The map includes the Amaila falls road.

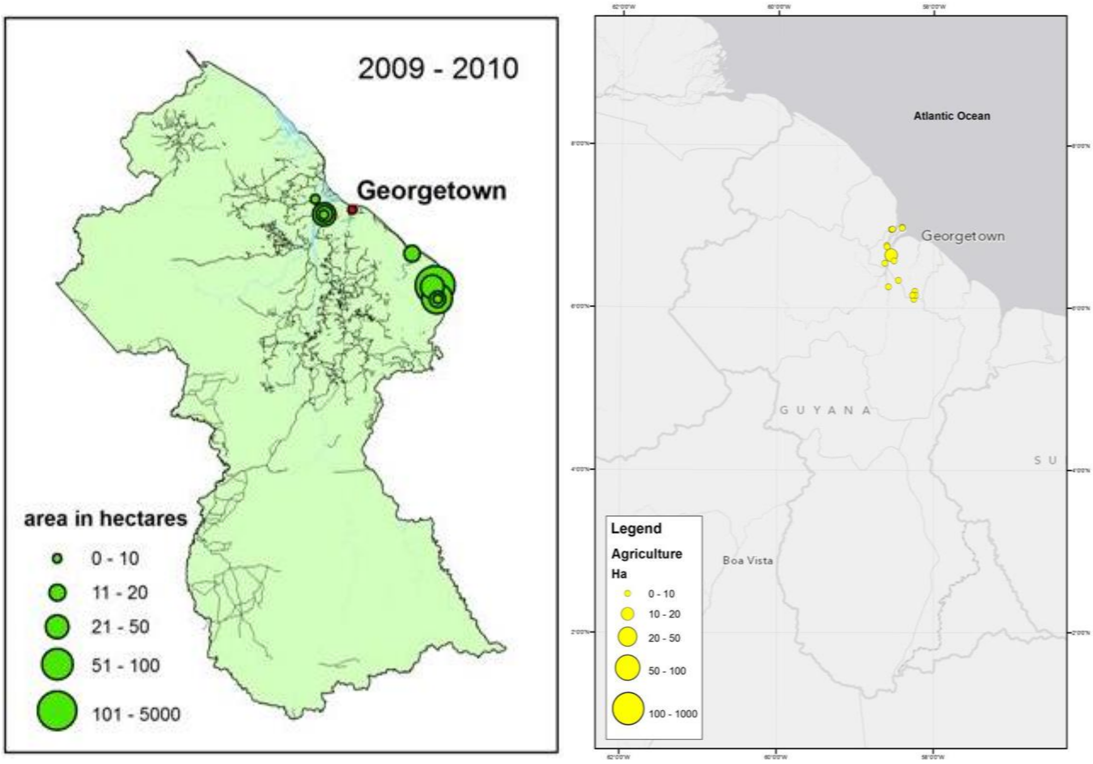
Map 8-4: Infrastructure Roads Year 2



Agricultural Development

In Year 2 agricultural developments leading to deforestation has reduced from Year 1 to around 52 ha. The main areas of development are located close to Georgetown or in close proximity to the river network. In Year 2, less development is seen around the coastal region close to Suriname (Map 8-5).

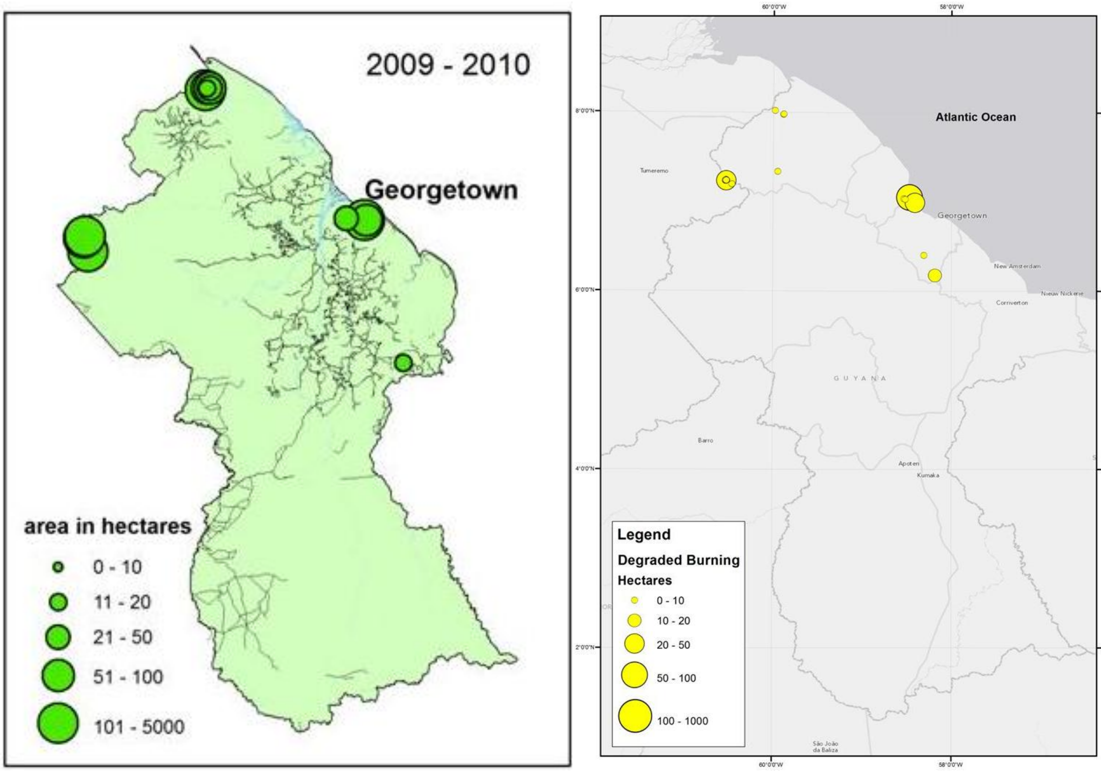
Map 8-5: Agriculture Spatial & Temporal Distribution Years 1 & 2



Biomass Burning - Fire

Figure 37shows the distribution of fires resulting in deforestation in Years 1 and 2. A majority of fire events occurred along the coastal zone close to Georgetown and in the white sand area surrounding Linden. Fire is also very common in the non-forest savannah areas to the south of the country (see Figure 9).

Map 8-6: Biomass Burning - Fire Temporal and Spatial Distribution Years 1 & 2



8.7 Changes in Guyana's LCDS Eligible Areas

Under the Memorandum of Understanding (MOU) between Guyana and Norway, not all land is included in Guyana's Low Carbon Development Strategy (LCDS). Only lands under the ownership of the State are initially included in the LCDS. This includes the State Forest Area and State lands.

The eligible area of forest which includes the State Forest Area (SFA) and state lands under LCDS is estimated at 15.43 million hectares. This has reduced from 15.5 million due to the re-categorisation of additional land from the State Forest Areas and State Lands to Amerindian villages.

This change does not impact on the overall forest change figures for Year 2, but the re-categorisation of land, does change the forest area reported for the State Forest Area, State Lands and Amerindian Villages for Year 2. The forest areas for Kaieteur National Park and Iwokrama have remained the same.

8.8 State Forest Area

Historical Change

In the previous assessment the total change in State Forest Area (SFA) between 1990 and 2009 was estimated at 63 646 ha. Overall the SFA accounted for 85% of all deforestation for the benchmark period. Annualised this represented a change rate of 3 200 ha/yr which is equivalent to a deforestation rate of - 0.03%/ yr. During the Year 1 period, deforestation in the SFA was calculated at 8 910 ha. Overall 87% of all change for year occurred inside the SFA.

Year 2

A similar trend is also seen in Year 2 with around 9 362 ha cleared, and a deforestation rate within this sub category of 0.076% (note that this is calculated as a proportion of the land area making up this sub category),very similar to Year 1. A small increase is due to the transfer of forested area under the State Forest Estate category, to Amerindian titled land.

Forest change is dominated by mining (94%) followed by forestry activities (2%). Infrastructure development, fire and agriculture are less prominent and contribute around3% of the deforestation observed. Degradation surrounding new infrastructure such as mining sites is estimated at 5 201 ha. This accounts for 97% of all the degradation mapped. The remaining degradation is accounted for by degradation around forestry roads, or from fire or from road construction activities not associated with forestry or mining operations.

Table 8-4 provides a breakdown of forest change by driver for the benchmark and Year 1and 2 periods. Degradation is also reported for the Year 2 period.

Table 8-4: SFA Total Forest Change by Driver from 1990 to 2011

Driver	Benchmark Period			Year 1 2009-10	Year 2 2010-11	
	1990 to 2000	2001 to 2005	2006 to 2009		Deforestation	Degradation
	Area (ha)					
Forestry	6 026	8 253	4 293	270	211	147
Agriculture	384	247	62	3	33	
Mining	10 122	19 930	12 007	8 582	8 788	5 038
Infrastructure	374	1 228	89	24	322	5
Fire (deforestation)	564	67		32	5	4
Area Deforested	17 470	29 725	16 451	8 910	9 362	5 194
Total Forested SFA Area (ha)	12 481 363	12 463 894	12 434 169	12 417 718	12 341 893[26]	
Total Forested SFA Remaining (ha)	12 463 894	12 434 169	12 417 718	12 408 807	12 332 530	
Period Deforestation rate (%)	0.01%	0.05%	0.03%	0.072%	0.076%	

8.9 Changes in Guyana's State Lands

Historical Change

For the period spanning 1990 to2009 a deforestation figure of 8 161 ha, was reported. This equated to approximately 11% of all deforestation for the benchmark period. Annualised this represented a change rate of 463ha/yr or equivalent deforestation rate of- 0.01%/ yr. For Year 1 deforestation in State Lands was calculated at 742 ha.

Year 2

In Year 2 the total area deforested has decreased to 202 ha. Like the SFA, the main contributor to deforestation is mining which accounts for approximately 59% of the change. This is followed by infrastructure in the form of roads, agriculture, firesand lastly forestry.

Overall, the change located in State Lands accounts for around 3% of the national total. Correspondingly, the area of degradation mapped around new infrastructure is also small. A total of 30 ha are mapped with 26 ha attributed to mining and the remaining area fire. Table 8-5, provides a breakdown by driver for the benchmark and Year 1 and 2 periods.

Deforestation associated with agricultural development dominates the benchmark and Year 1 period, but decreases in Year 2. Mining also decreases slightly while forest area lost to fire increases.

[26]Forest area adjusted to account for land reallocation to Ameridian areas

Table 8-5: State Lands Forest Change by Driver from 1990 to 2011

Driver	Benchmark Period			Year 1	Year 2 2010-11	
	1990 to 2000	2001 to 2005	2006 to 2009	2009-10	Deforestation	Degradation
	Area (ha)					
Forestry	24	93	30	24	7	
Agriculture	1 565	2 563	1 735	510	19	
Mining	306	814	190	175	120	26
Infrastructure	30	72	18	32	47	
Fire	720	1			9	4
Area Deforested	2 645	3 543	1 974	741	202	30
Forested State Land Area	3 095 485	3 092 840	3 089 297	3 087 324	3 084 306	
Forested State Land Area remaining	3 092 840	3 089 297	3 087 324	3 086 583	3 084 104	
Period Deforestation rate (%)	0.01%	0.02%	0.01%	0.02%	0.01%	

8.10 Areas Outside theLCDS

Forest change and degradation is also monitored outside of the LCDS area. For Year 2, no change was identified inside Iwokrama or Kaieteur National Park. Change has been mapped across the titled Amerindian areas. The trend indicates that deforestation has decreased relative to the benchmark and Year 1 periods. Mining dominates the change areas and contributes around 82% of the total change for Year 2. Similarly the greatest area of degradation is also seen around mining areas. Overall change inside Amerindian areas accounts for the balance of Year 2 change. This is around 326 ha which equates to 3% of total change for Year 2.

Table 8-6: Ameridian Forest Change by Driver from 1990 to 2011

Driver	Benchmark Period			Year 1	Year 2	
	1990 to 2000	2001 to 2005	2006 to 2009	2009-10	Deforestation	Degradation
	Area (ha)					
Forestry					15	
Agriculture	55	18	0	0	0	
Mining	415	694	426	627	267	216
Infrastructure	0	4	89	8	0	
Fire (deforestation)	425	166	0	0	44	20
Area Deforested	895	883	515	635	326	236
Forested Ameridian Lands	2 490 707	2 489 812	2 488 930	2 488 415	2 546 852	
Forested land Remaining	2 489 812	2 488 930	2 488 415	2 487 780	2 546 526	
Period Deforestation rate (%)	0.00%	0.01%	0.00%	0.03%	0.01%	

9. VERIFYING FOREST CHANGE MAPPING& INTERIM MEASURES

The scope of the Accuracy Assessment was to conduct an independent assessment of deforestation, forest degradation and forest area change estimates for the period 2011-2012. 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 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 31 October 2010 to 31 Dec 2011 (Interim Measures Period – Year 2). High spatial resolution imagery combined with low altitude photography and field visits are used to assess the wall-to-wall mapping of Guyana undertaken by Indufor Asia Pacific Ltd (IAP) and Guyana Forestry Commission (GFC).

In particular, imagery from the German RapidEye satellite constellation system, the Worldview-1 and -2 and Quickbird very high spatial resolution satellite data provided excellent sources for assessment of the Year 2 mapping period. A stratified sampling approach was adopted to help provide precise estimates of forest area. Two strata were selected according to "risk of deforestation", that is, land proximal to settlements, roads, logging concessions and known mining dredge sites, and other low risk land area. A 10 km by 10 km grid square was overlaid on the country and using available GIS data and grid squares containing any of the risk variables were tagged as high risk and the remainder as low risk. Interpretations of deforestation and degradation drivers were made from image interpretation of the highest available resolution satellite imagery.

For the Year 2 Forest/Non-forest map, the results show a correspondence (prevalence) between reference image interpretation and IAP/GFC mapping for all the 18,000 one hectare plots sampled from both strata. This demonstrates a very high level of agreement between the MRV maps and the reference data.

Table 9-1: Comparison of Forest Change Estimates

Source	Forest Year 1 (ha)	Forest Year 2 (ha)	Benchmark Rate (%)	Year 1 Rate (%)	Year 2 Rate (%)
GFC/ Pöyry - GIS Map Estimate	18,388,190		0.021	0.056	-
GFC/Indufor GIS Map Estimate		18,378,301	0.021	0.056	0.054
Durham Sample-based Estimate		18,381,099	0.021		0.053

The estimate of Year 2 forest area for Guyana, based on the stratified sampling design is 6,808,790± 79,629 hectares for the High Risk stratum and 11,562,537± 59,337 hectares for the Low Risk stratum.

The size of the sample is too small to estimate the area of Year 2 degradation with any certainty but the data suggests that the wall-to-wall mapping has overestimated the amount of degradation. Based on sampling, we estimate a Year 2 deforestation rate (15 months of change) of 0.053% compared with 0.054% derived by GFC and IAP.

Dredge mining and road construction are the principal causes of deforestation and degradation. Parts of Guyana are subject to shifting cultivation that accounts for a small amount of degradation although many areas previously mapped as non-forest are in fact degraded forest or areas of regrowth.

9.1 Accuracy Assessment Conclusions & Recommendations

The accuracy assessment concluded that the quality of the mapping undertaken by IAP-GFC based largely on interpretation of Landsat TM, ETM+ and RapidEye imagery was of a good standard. The prevalence statistic is a good measure of overall correspondence between the map and reference data. For Year 2, the prevalence was 0.986 or 98.6% agreement. This is a very high figure, much better than one would expect from automated classification of multispectral remotely sensed data, and is almost certainly explained by the meticulous and painstaking manual process of interpretation and on-screen digitizing.

We also note that the verification reference data are not perfect, about 14% of the sample area could not be used because of missing reference data or because the ground was obscured by cloud or cloud shadow. Missing reference data were excluded from the analysis.

Assessment of tropical deforestation and degradation is a far from trivial exercise that requires a high level of experience in satellite image interpretation, GIS data handling, spatial analysis and statistical estimation.

The MRVS GIS for Guyana contains many hundreds of satellite images and the vast majority of these are needed to undertake the assessment because single-period duplication helped circumvent cloud cover and multi-period imagery was needed to track changes as part of the interpretation process. The high spatial resolution imagery had large file sizes that made use of the GIS for map quality assessment, a slow and painstaking process.

The process of validation was based on 10 by 10 kmgrid squares randomly distributed within high and low risk strata. It took approximately 1.5-2 hours to interpret the 361 one hectare sample plots in each square. Time permitted a sample of 50 10 by 10 kmgrid squares within the terms of reference and the budget.

The interpreters underwent a training exercise designed to give a 'glimpse' of all the different satellite imagery and example of different types of deforestation driver. The group did a blind assessment of the same grids so that any disagreements could be highlighted, discussed and any interpretation bias removed before the validation process began.

The following recommendations are relevant to the Year 2 assessment and identify areas of improvement:

1. The RapidEye data are of generally excellent quality and ideally suited to for the task. It is recommended that the RapidEye data coverage be extended into the low-risk strata next year to help identify areas mapped as non-forest that are actually degraded or intact forest but were mislabelled from poor quality Landsat data in the past. It would greatly assist Accuracy Assessment if the planning for the acquisition of high resolution imagery used to validate the mapping over the Primary Sampling Units (PSU) grid squares could completed early in the Year 3 process (August to December).

2. The identification and addition of navigable water bodies to the GIS will assist in improving the mapping and should improve the definition of high risk strata by helping to predict areas of forest at risk. It is recognised that the acquisition of RapidEye data, as it extends to large areas of Guyana, will result in the need to update and improve the quality of the maps (back casting). This process is supported as it will result in better quality maps and area estimates.

3. Ensure that GFC staff are familiar with the validation process and have powerful workstations to be able to undertake some of this work in house.

4. Allow sufficient time for the independent validation. The sample size used in 2012 appears insufficient for a full quantitative analysis of degradation drivers, particularly when sampling low-risk strata. It is estimated that a sample of 80—100 Primary Sampling units will provide a sufficiently large sample to yield an area estimate, particularly if the additional PSUs are allocated to the high-risk stratum where Year 2 degradation is most like to found.

5. Perhaps design the over-flights and field work to take place after the photo-interpretation to allow particular areas of ambiguity or uncertainty to be validated.

6. GFC has continued to improve their standards of surveying and mapping with the Accuracy Assessment exercise presenting a good opportunity to evaluate these improvements. It is recommend that GFC will continue the effort and define standards for spatial data acquisition as clearly as possible and apply appropriate quality control measures.

10. INTERIM MEASURES

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 March 2011, a revised Joint Concept Note (JCN) under the Guyana/Norway Agreement was issued, and replaces the JCN of 2009. The revised JCN updated on 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[27].

The basis for comparison of a majority of the interim measures is the 30 September 2009 benchmark map[28]. The first reporting period (Year 1) is set from 1 Oct 2009 to 30 Sept 2010. The means of monitoring and estimation during the interim period are identified as medium resolution satellite images. This includes, a time series of Landsat TM and ETM+, a composite of daily acquired MODIS (250 m resolution) taken as close to the end of the benchmark reporting period September 2009.

For Year 2 RapidEye was tasked over the most actively changing areas. As with preceding periods Landsat, MODIS and ASAR radar data were also used to ensure a full national coverage.

A summary of the key reporting measures and brief description for these interim measures are outlined inTable 10-1. The calculations to determine the rate of deforestation (ref. measure 1) has been covered in Section 8. 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.

For measures such as forest degradation this is the first time this has been calculated using direct measurements. For the Year 1 assessment this was calculated by applying a 500 m buffer around mining sites and roads.

It is envisaged as the MRVS is expanded reporting methods will be developed to account for emissions from shifting cultivation and activities that result in carbon sinks i.e. SFM or enrichment plantings.

[27]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.

[28]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 10-1: Reported Interim Measures

Measure Ref.	Reporting Measure	Indicator	Reporting Unit	Reference Measure	Year 1 Period	Year 2 (Oct 1 2010 to Dec 31, 2011) 15 months	Difference Y2 and Benchmark or Y1 for Indicators 2, 2b and 5
1	Deforestation Indicator	Rate of conversion of forest area as compared to the agreed reference level.	*Rate of change (%)/yr^{-1}*	0.275%[29]	0.056%	0.054%	-0.002
2	Degradation Indicators	National area of Intact Forest Landscape (IFL). Change in IFL post Year 1, following consideration of exclusion areas.	*Million ha*	N/A	7.60 (refined to 5.59	5.59	0
2b		Determine the extent of degradation associated with new infrastructure such as mining, roads, settlements post the benchmark period.	*ha*	N/A	92,413[30]	5,460	-86,939
3	Forest Management	Timber volumes post 2008 as verified by independent forest monitoring (IFM). These are compared against to the mean volume from 2003-2008 and *reference level prorated for a period of 15 months.*	*t CO_2*	4,251 583[31]	N/A	3,685,376[32]	-566,207
4	Emissions resulting from illegal logging activities	In the absence of hard data on volumes of illegally harvested wood, a default factor of 15% (as compared to the legally harvested volume) *(and reference level prorated for a period of 15 months).*	*t CO_2*	547,179	N/A	18,289[33]	-528,890
5	Emissions resulting from anthropogenic forest fires	Area of forest burnt each year should decrease compared to current amount.	*ha/yr^{-1}*	NA	1 706[34]	28	-1 678

10.1 Interim Reporting Indicators

The following provides a description, justification and performance measurement for each of the seven indicators. At this stage only five of the seven measures are reported.

10.2 Gross Deforestation – Measure 1

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

[29]JCN March 2011 Pages 6 and 11.

[30]This indicator as is required by the Joint Concept Note of the Agreement between Guyana and Norway, includes a buffering of 500 km of all sides of all **new (this is define by all features that occur for the first time in the period under assessment - Year 1)** detected deforestation activities including, road and infrastructure developments, forestry, and mining. This area does not necessarily reflect degradation of forest in a practical sense but it is a provision as required by the interim indicator of the Joint Concept Note. Degradation will be comprehensively informed when the full MRVS is operational. This is therefore a conservative measure of degradation in the interim.

[31] Assessment completed based on Winrock International Report to the Guyana Forestry Commission, December 2011: ***Collateral Damage and Wood Products from Logging Practices in Guyana.*** This methodology only applies to emissions and not any removals due to re-growth of the logged forest. This has been updated from version 1 of the Report.

[32] Computed for the period October 1, 2010 to December 31, 2011. This has been updated from version 1 of the Report.

[33]Rate of illegal logging for the forest year October 1 2010 to December 31 2011 is informed by a custom designed database that is updated monthly, and subject to routine internal audits.

[34] Degradation from forest fires is taken from an average over the past 20 years.

combined represent approximately 75% of total carbon[35]. Several key performance indicators and definitions have been developed as follows.

Interim Performance Indicators

- 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.

Gross Deforestation Monitoring Requirements:

Using the benchmark forest cover map as a base (30 September 2009) the intention is to identify activity data related to

- Expansion of human infrastructure (e.g. new roads, settlements and mining and agricultural expansion.

Monitoring Approach

The accepted approach as outlined in the JCN uses medium resolution images to identify new areas of development at a one hectare scale. In Year 2 a combination of high (5 m) and medium resolution satellite images have been used. High resolution images have been acquired over ~12 million ha. This area is identified from historical analysis as an active change area.

10.3 Degradation Indicators7- Measure 2

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 extent of Intact forest has been determined at the end of September 2010 Year and also for Year 2. For the analysis, only those areas that meet the forest definition are included.

Within the areas that qualify as IFL, the following rules 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

[35]Indicative figures C/ha for tropical low land forest in Bolivia (GOFC-GOLD). This is not necessarily the case in peat soils, where this pool is more 'important' than below-ground biomass and in some strata may even be more important than above-ground bio-mass.

influence include local shifting cultivation activities, diffuse grazing by domestic animals, low-intensity village-based selective logging, and hunting.

Comment from Norwegian Ministry of the Environment & Rainforest Foundation, Norway

The basis for the reduction of IFL-area is somewhat unclear to us. It seems it has been reduced to reflect "anticipated future mining activities". Does this reflect areas for future possible exploration, or does it reflect already given and legally binding concessions? I.e. does it reflect anticipated mining activities, or confirmed mining activities? In general, we believe that areas that are not under legally binding concessions are better included in the IFL-area, whereas areas with confirmed future activities could probably justify exclusion.

Response to comment

The areas for reconnaissance will be subject to future mining allocation. The first step in this process is the allocation of these areas to a reconnaissance status.

These areas are therefore been excluded. Given that national wall-to-wall mapping has been implemented using high resolution satellite images GFC would prefer that this interim measure is phased out in Year 3. This is in keeping with the JCN desire to replace interim measures once methods become operational.

The rationale for this request is that spatial tracking of change from high resolution (5 m) satellite images at the national level provides an accurate and transparent method of calculating national forest change.

In contrast the current IFL extent is quite broad as it is delineated from medium resolution imagery (30 m) after applying a predefined set of criteria. Effectively the IFL has been superseded by high resolution wall-to-wall mapping.

Comment from Rainforest Foundation, Norway

Under 10.4, (Degradation indicator 7-measure 2), there is a problem with the interpretation of the definition of IFL, which lead to an incorrect calculation of the total IFL area in Guyana.

Inclusion of industrial-scale and selective logging operations in IFL.(Comment summarised)

Response to comment

Sustainable Forest Management (allocated State Forest Estate) areas have actually been excluded from IFL.

Our initial statement (page 86) refers to the fact that they were taken into consideration in IFL. Map 10-1 actually shows all allocated State Forest Estate excluded from IFL.

We will make this clarification in the revised Version 1 of the report – the statement can be found on page 86.

Please note that the computations remain the same, only the statement on page 86 required changing.

10.4 Degradation Monitoring Datasets & Approach

The monitoring approach adopted uses a combination of high resolution and medium resolution satellite images and supplementary GIS layers to map and identify the extent of the following features at 30 December 2011. The associated mapping and detection rules applied for features such as roads and forest to non-forest change by driver are provided in Section 7.

Settlements

The population of Guyana is approximately 770 000, of which 90% reside on the narrow coastal strip (approximately 10% of the total land area of Guyana). Guyana's coastal strip ranges from between 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.

Infrastructure, Mining & Navigable Rivers

Infrastructure used for transport was identified from medium resolution 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 and 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 and historical and current areas under sustainable forest management have been included as IFL. Shifting cultivation areas have been defined from medium resolution satellite imagery and areas under SFM are held by GFC in GIS format.

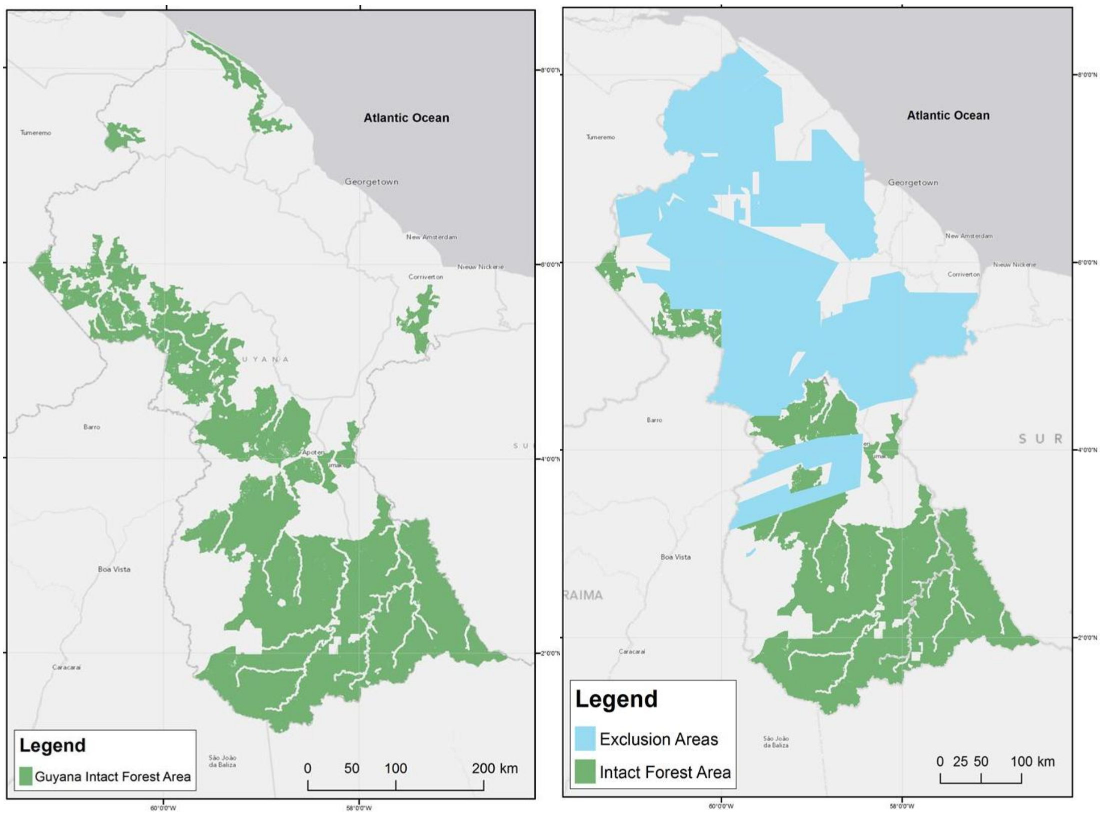
10.5 Calculation of the Year 2 Intact Forest Landscape

The requirement under interim measures is that the total area of intact forest must remain constant from the benchmark date (30 September 2009) onwards. Any change in area shall be accounted 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. The following map (left) shows the extent of the first IFL as created for the Year 1 period. In October 2010 at this point, the total intact forest landscape area in Guyana was estimated at 7.60 million ha.

New information provided by GGMC in 2010 indicates that the initial IFL area omitted areas allocated to mining reconnaissance and reserve areas. This layer provides the extent of anticipated future mining activities. Inclusion of this layer reduces the benchmark IFL from 7.60 to 5.59 million ha. For comparison, this map is shown next to the Year 1 map.

No change of the IFL area for Year 2 period was observed based on the refined extent. It is GFC’s intention to continue with the 5 m RapidEye acquisition over Guyana and possibly expand the capture to provide coverage of the forested area for the year 3 assessment period. This will improve the spatial coverage and provide a robust means of detecting changes associated with deforestation and degradation. This should enable the replacement of the IFL interim measure with a national monitoring process based on high resolution satellite imagery.

Map 10-1: Year 1 & Year 2 Intact Forest Landscape Maps



10.6 Carbon Loss as Indirect Effect of New Infrastructure – Measure 2b

The carbon loss associated with new infrastructure was determined by buffering the extent of areas detected in the medium resolution imagery by 500 m. This is the default option if the extent of degradation cannot be mapped. This was the case for Year 1 as there were a very limited number of high resolution scenes available over Guyana.

For the Year 2 assessment, high resolution 5 m imagery was tasked and over 12 million ha were acquired. This area covered the most actively changing areas. The approach taken for Year 2 was to visually assess the satellite imagery surrounding new infrastructure for signs of forest degradation. Analysis of the images and follow up field work indicated that degradation around new infrastructure was fragmented and was directly related to the deforestation activity. The degradation impact was localised and did not extend further than 40 m from the deforestation site. Based on these findings a conservative 100 m buffer was applied around all new Year 2 infrastructure. Any forest degradation observed inside this buffer was mapped.

10.6.1 Interim Performance Indicators

- Determine the extent of degradation associated with new infrastructure such as mining, roads and settlements.
- If it cannot be determined from medium resolution imagery (either directly, or using a remote sensing technique) then a buffer of 500 m is applied from the external edge of each Year 2deforestation site. A 50% loss in biomass is assumed.

The area of degradation for the Year 1 period (Oct 1 2009 to Sept 30 2010) was estimated at 92 413 ha. This area does not necessarily reflect degradation of forest in a practical sense.

The Year 2 area is considerably lower at 5 460 ha. This can be attributed to the method applied which is based on direct interpretation of high resolution satellite images rather than the calculation and application of a generic buffer to all new infrastructure.

10.7 Forest Management – Measure 3

10.7.1 Management

Under interim measures, 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 October 2010 to 31 December 2011:

- 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 holder. Upon declaration, the harvested produce is verified, permits collected and checked and sent to the GFC's Head Office for another level of audit, 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 the station level, at concession level and supplemented by random monitoring by 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 based on 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's offices with checks made at this stage on legality of origin, completion of relevant document including removal permit, production register and log tracking.

Removal permits require operators to 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 done 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 for 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 hectares) 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 as regards to 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 the GFC's head office where data entry is done. 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 for 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, a separate verifier, not involved in the data entry, validates all entries made as accurate and correct and posts validated data to secured storage areas in the database. There are security features at several levels of the database functioning including 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.

A continuous process of further development and strengthening of the GFC's databases has been identified. This will specifically focus on strengthening of the procedural and illegal logging databases and also on the Amerindian/Private Property production databases.

Forest Produce included in IMR: in tabulating the declared volumes for forest management, the following products were included as these are the primary products that are extracted from the forest:

- Logs
- Lumber (Chain sawn Lumber)
- Roundwood (Piles, Poles, Posts, Spars)
- Splitwood (Shingles, Staves)
- Fuelwood (Charcoal, Firewood)

The "true" volume of logs was used instead of the "hoppus" volume that is reported for charge of royalty payments. In year 1, the total of harvested volume was tabulated by increasing the declared "true" volume by the estimated percentage of collateral damage(25% added on to extracted volume) that is involved in the felling of that volume.

10.8 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 (S. Brown et al) 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:

- 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;
- 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:

Equation 1: *Emissions, t CO2/yr = {[Vol x WD x CF x (1-LTP)] + [Vol x LDF] + [Lng x LIF]}*3.67*

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

<u>Wood in long term products</u>

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.

Equation 2[36] $C_{WP} = C * (1 - WW) * (1 - SLF) * (1 - OF)$

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

This 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 (prorated to 15 months) and the assessment year of October 1, 2010 to December 31, 2011 is shown in the Table 10-2. For this period t CO_2 has reduced by 566 207 t CO_2.

Table 10-2: Interim indicator on Forest Management

Period	**Description**	**Volume (t CO_2)**
October 1, 2010–December 31, 2011 (15 months)	t CO_2emissions arising from timber harvesting	3 685 376
2003-2008 (annual average prorated to 15 months)	t CO_2emissions arising from timber harvesting	4 251 583
Difference	t CO_2	-566 207

Comment from Norwegian Ministry of the Environment

In the report "Collateral Damage and Wood Products from Logging Practices in Guyana" from 2011, it is stated that "It does not take into account imports and exports of wood that are addressed in IPCC Greenhouse Gas Inventory methods as decision on how to track emissions' from wood products that are imported and exported are still pending in the international arena." However, in the new LULUFC-decision from Durban it is stated that imported wood products are not to be included. As this implies that counties importing wood products from Guyana will not include these emissions, are you planning to revise the relevant calculations accordingly?

Response to Comment

The factor used in the Interim Measures Report year 2 includes exports and computations regarding carbon storage and Long Term Wood Products. Therefore formula in Winjum et al. 1998 was used with VCS approved methodology for wood products –6CP-W Wood Products November 2010).

Additionally, collateral damage includes all aspects of emissions associated with wood extracted.

We agree with your comment re decision regarding imports and exports and have removed that sentence from the report. The application of the collateral damage factors are applied to all production of timber from Guyana.

Although a decision regarding imports have been made under the LULUCF, how this issue will be applied to REDD+ carbon accounting has not been decided upon. We would like to point out that

[36]This is directly from the VCS (Verified Carbon Standard) approved methodology for wood products –6CP-W Wood Products November 2010

the logs are not a wood product per se but rather a raw material that could be exported and imported to developed countries.

The factor used in the Interim Measures Report year 2 includes exports and computations regarding carbon storage and Long Term Wood Products.

10.9 Emissions Resulting from Illegal Logging Activities – Measure 4

It is required that areas and processes of illegal logging 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 up and downwards pending documentation on illegally harvested volumes, inter alia from Independent Forest Monitoring. Additionally, medium resolution satellite can be used for detecting human infrastructure and targeted sampling of high-resolution satellite for selected sites.

In the historical reporting, the default level of 15% of harvested production of 705,347m^3 corresponding to 547 179 tCO_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 forest year October 2010 to December 31, 2011, 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. This level for the reporting period is 528 890 t CO_2 less than the historic period level. Reporting on illegal logging activities is done via the GFC's 26 forest stations located strategically countrywide, as well as 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's procedures. The infractions are recorded, verified and audited at several levels. All infractions are summarised in the illegal logging database and results in a total volume being reported as illegal logging for any defined time period.

A Database in SQL has been developed and tested following the FAR recommendation made in March 2011. This will enable reporting for year 3 in this database. The database is available for demonstration.

Comment from Rainforest Foundation, Norway

While it is positive that a database of illegal logging has been created, it seems wise to maintain a default value for illegal logging in the indicator for interim measure 4, as it is fair to assume that not all illegal logging is detected by the authorities and thus entered into the database.

Response to Comment

The independent verification assesses the systems in place to make this assertion regarding the robustness of the systems to track illegal logging. There is therefore that third part verification involved. This is in addition to Independent Forest Monitoring (IFM) also being in place.

10.10 Emissions from Anthropogenic Forest Fires – Measure 5

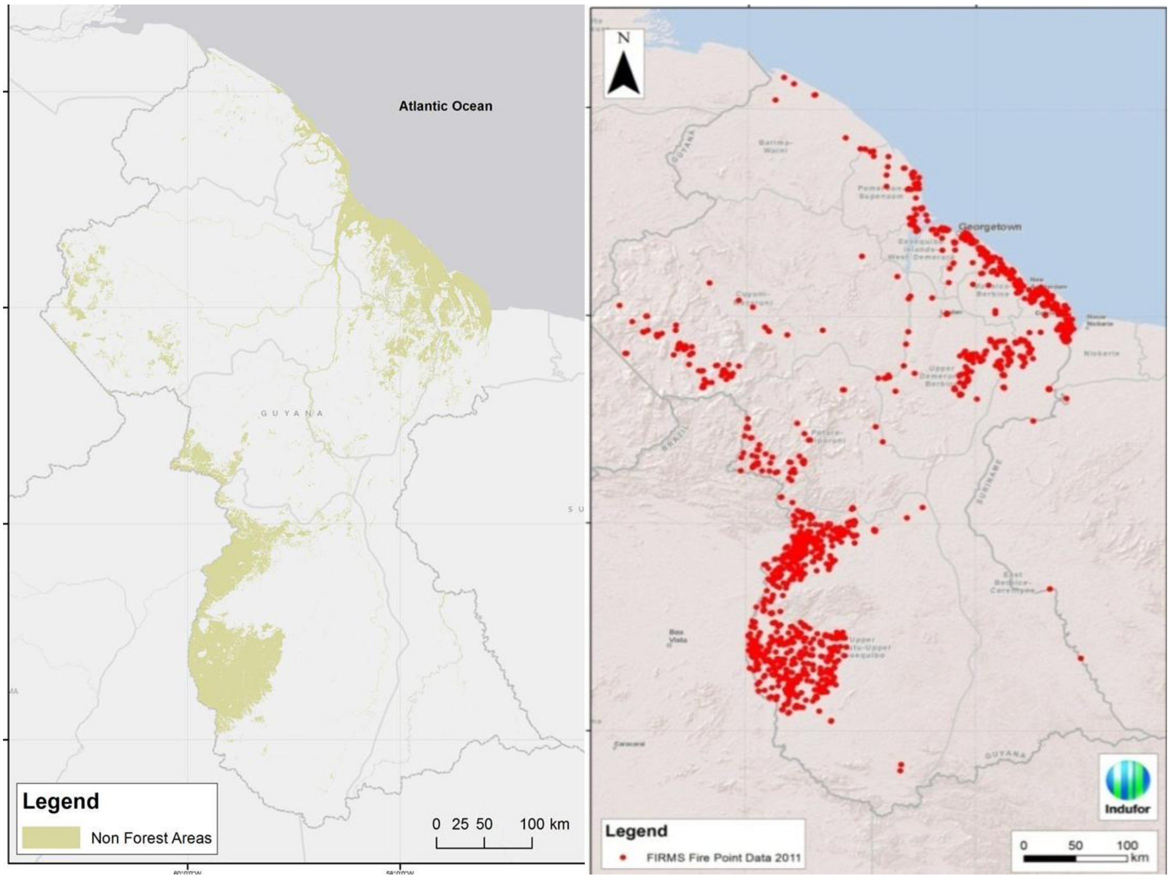
The FIRMS fire point data from MODIS was also used to identify potential fire locations (Map 10-2). In addition to a systematic review of all satellite imagery by operator's all fire points were checked against the Landsat or RapidEye imagery to validate the presence of fire and establish the extent. This is an accepted approach that is documented in GOFC-GOLD sourcebook.

The approach taken was to calculate the area burnt for the 1990 to September 2009 period. Over this period a total of 33 700 ha of forest was identified as degraded by burning[37]. This equated to a mean annual area of 1 700 ha. This area has been used as the Year 1 value.

The largest area burnt occurred between 1990 and 2000. This trend coincided with a prolonged dry period caused by the El Niño weather pattern.

In Year 2 a considerably lower value of 28 hahas been calculated. This suggests that the area recorded during the El Niño period is an atypical occurrence.

Map 10-2: Non Forest Area &FIRMS Fire Data 2010-2011



The spatial pattern of the fire locations from FIRMS also suggests that many of the fires detected from the MODIS sensor are located in the non-forest areas. The main non-forest areas as determined from 1990 Landsat images are located in the south along the border and the closer to Georgetown on the coastal fringe.

[37]This does not include areas deforested as a result of fire events. This has been recorded as deforestation.

11. ONGOING MONITORING PLAN& QA/QC PROCESSES

To adequately report change at a national-scale it is important to have access to a consistent supply of satellite imagery. To match previous assessments, the data needs to be similar in terms of spectral and spatial resolution, andextent and readily available, integrate easily into the current processing system and be available at low cost.

The availability of free data that meets these criteria has diminished with the failure of Landsat 5 in 2011and the scan line failure of Landsat 7 which makes it difficult to implement in semi-automated mapping process.

A proactive approach is required to ensure that reporting deadlines are met and to guarantee that a national-level change and the accuracy of these estimates can be reported. This involves tasking of satellite data to monitor change over at least the most active change areas.

For the Year 3 assessment the tasking period is scheduled to commence in August 2012 and run through to December 2012. This coincides with historical period of low cloud cover. As with Year 2 multiple scenes will be acquired over the same location to increase the useable area. Radar data from FCT will also be requested for the same period to provide national cloud-free coverage.

The following satellite systems/ sensors are considered appropriate for national monitoring of change and degradation (as identified using a *) or for reporting change accuracy. This selection considers combination of sensors with different spectral and spatial resolutions, spatial extent and revisit capabilities. Radar data is also a viable option given its ability to penetrate cloud.

National Monitoring - 2012:

- DMC
- RapidEye*
- SPOT 5*
- Formosat*
- Radar

Accuracy Assessment 2012

- Worldview
- IKONOS
- GeoEye

Additional options are expected to become available with the launch of several earth observation sensors as listed on GOFC-GOLD website (www.gofcgold.wur.nl).

Table 11-1: Planned Sensors Optical and Radar

Sensor	Satellite	Planned Launch																		Spatial resolution (m)	Bands	Spectrum	Swath (km)
		12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29				
GeoEye-2	GeoEye-2		■																	0,25-0,5	1 pan, 4 ms	0,450-0,920	15,2
HR-2	PLEIADES		■																	0,7	1 pan, 4 ms	VNIR	20
HRG	SPOT-6	■																		1,5-8	1 pan, 4 ms	0,450-0.890	60
HRG	SPOT-7		■																	1,5-8	1 pan, 4 ms	0,450-0.890	60
OLI (Operational Land Imager)	Landsat 8 (LDCM)		■																	15-30	1 pan, 8 ms	0,443-2,200	
SAR	Sentinel-1		■																	5*20	C-Band		250
MS	Sentinel-2 (two satellite constellation)		■																	10-20-60	12	VNIR-SWIR	>200

Source GOFC-GOLD

11.1 QA/ QC Processes

There are several Quality Assurance processes that were undertaken in developing the national change analysis results. The MRVS is currently not fully operational so further documentation and processes will be developed to ensure that the MRVS adheres to be best practice. Key components include;

- Development of the monitoring plan to ensure the provision of satellite data to cover the reporting period.
- Task higher resolution satellite imagery to ensure better delineation of change and detection of degradation.
- Facilitate data sharing between agencies through inter-agency training.
- Inclusion of over-flights and capture of geo-referenced oblique photos to confirm vegetation types and change.
- Upgrade of GPS units to assist with photographic documentation.
- Development of routines to automate processing of remote sensing datasets.
- Development of standardized toolbars to enable consistent attribution of change and documentation of drivers of change.
- Further development of training materials to assist with the attribution of change.
- Review of appropriate peer-review documentation to ensure best practices are adopted in developing methods.

QC Processes

The following processes were implemented in Year 2 in this area:

- Review of operators change decisions
- Topology checks of spatial data to ensure area estimates are correct - i.e. removal of overlaps and duplication.
- Commissioning of an independent accuracy assessment to assess the accuracy of the forest change and degradation results
- Independent audit of Interim measures.

12. REFERENCES

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Appendix 1

Forward Action Requests

Forward Action Request	Action Taken in Reporting Period
FAR 1 – strengthened database on Illegal Logging and procedural breaches with QA/QC measures in place. Non-binding – consideration of quality management system	These have both been done. A Database in SQL has been developed and tested following the FAR which was made in March 2011. This will enable reporting for year 3 in this database. The database is available for demonstration. Appropriate quality management system for MRVS activities requires strong QA/QC protocols, accuracy assessment and verifications. The IPCC speaks to these recommendations. These have all been made parts of the forest area assessment work in Guyana, and parts of Year 2 assessment. Although much of this would have been also included in Year 1 assessment, the accuracy assessment, for example, is now a part of the Year 2 assessment and not separate, thereby strengthening the main process of generation of the results. It is the view of the forest carbon and GIS/RS experts working with the GFC, as well as those of the Commission, that these are most appropriate and adequate for ensuring that reported figures are of high quality. At present, there are at least three separate layers of checks involved: QA/QA, Accuracy Assessment and then verification. All reports are published by the GFC for public consumption. Furthermore, the GFC has made, as a part of the process of finalisation of the Interim Measures Report, a period for public comments and feedback. This also is a strong mechanism for quality assurance.
FAR 2–For future monitoring periods; • Orthorectify all Landsat data, • Improve file and folder conventions • document GCPs • Develop SOP for GIS operations and QA/AC and archiving data.	This has been done. All Landsat satellite for the Year 2 assessment has been sourced from USGS. This is provided in an Ortho Corrected format. File naming conventions have been standardised for the imagery – as listed. GIS datasets are held in a Geodatabase structure which provides for QA/QC Procedures and includes archiving processes. SoP has been developed that addresses mapping, and includes a section on data archiving and QA/QC procedures.
FAR 3- Evaluate AVHRR/GOES hotspot data for 1990-2009 reporting period Non-binding recommendation	This has been done. The 1990-2009 reporting period is complete, so no retrospective assessment has been conducted.

	GFC made contact with INPE and also accessed the INPE datasets. Fire maps are freely available (http://sigma.cptec.inpe.br/queimadas/index). These were evaluated and a decision made to use the MODIS fire monitoring product. For year 2, MODIS data which is the recommended dataset for fire detection (GOFC GOLD) has been used. MODISis higher resolution, more readily available and in a format that can be directly ingested into the GIS system.
FAR 4- Time constraints for reporting Reporting period adjustment to in accordance with best available cloud-free image. Standardisation in reporting and verification. Non-binding recommendation	This has been considered. As appropriate Guyana and Norway have extended the reporting period. Also the assessment year has been extended to December. In addition RapidEye imagery has been tasked over the most active change areas. This has reduced the risk of cloud obscuring change. GFC has continued to progress in the MRV system and make improvements in methods and processing to detect change with greater accuracy. All reporting of results have been standardised. The GFC expects for the verification efforts to also be consistent and standardised.
FAR 5- Inclusion of the Accuracy assessment conclusions in Interim Measures Report (IMR) as related to forest/non-forest accuracy. Provision of an accuracy report prior to the verification teams arrival Further improvements in the EVI methodology	The findings of the accuracy assessment were included in the 2010 IMR report. The accuracy of the forest/non-forest delineation was estimated at 97.1% According to GOFC GOLD 2010 accuracies of 80 to 95% are achievable for monitoring with mid-resolution imagery to discriminate between forest and non-forest. This indicates that the forest cover mapping classificationbased on the EVI method is robust. The accuracy assessment has been included in the Year 2 Interim Measures Report. The EVI is used as the basis for detecting forest change over the area covered with 5 m RapidEye imagery. The automated results are systematically reviewed and edited as required.
FAR 6 – Indicators 3 and 4 be expressed in Carbon Units. Revision in Collateral Damage Factor.	This has been done and enabled by a technical Report conducted by Winrock International for the GFC.
FAR 7 – Strengthened stakeholder consultation mechanism for first draft of IMR Year 2.	This has been taken on board. 14 days were allowed for stakeholder feedback in Year 1. The report was published on the GFC's

	website. The GFC will allow for a 3 week period, and will publish the invitation for comments in the local media, send out email notices, and seek to further expand the reach of the invitation extended.
FAR 8 - Ensure that island polygons are removed from the Intact Forest Landscape (IFL). These are forest areas that fail the 10 km size or 2 km width.	This has been fulfilled, The IFL has been reviewed in Year 2. Consultation with GGMC has resulted in the removal of Mining Reconnaissance areas from the Year 1 IFL map. The IFL GIS layer was checked to ensure that it complied with the IFL criteria
FAR 9 - Further Digitising of Shifting cultivation areas	This has been fulfilled and even beyond what the JCN requires. Shifting cultivation is not reported in Year 2 as it not considered relevant until a MRV-system is operational. As with the previous assessment shifting cultivation was mapped as observed.A further review and consolidation of shifting cultivation areas is required. This is identified as an improvementarea and an approach will be formalised to enable future reporting for the operation MRVS.
FAR 10- As part of future improvements of the interim indicators 2, 2b and 5 an estimate of the uncertainty is recommended.	This has been done. An accuracy assessment has been conducted for the current assessment period as per the JCN. See Section 9 of the report.

Appendix 2

Joint Concept Note on REDD+ Cooperation between Guyana and Norway

Joint Concept Note

Background

On November 9th, 2009, Guyana and Norway signed a Memorandum of Understanding (MoU) regarding cooperation on issues related to the fight against climate change, in particular those concerning reducing emissions from deforestation and forest degradation in developing countries (REDD-plus[38]), the protection of biodiversity, and enhancement of sustainable, low carbon development.

An accompanying Joint Concept Note (JCN) set out the framework for taking the Guyana-Norway co-operation forward. It set out how Norway would provide Guyana with financial support for REDD-plus results, and formed the basis for the first payment from Norway to Guyana.

Since the Joint Concept Note was published, considerable progress has been made in the Guyana-Norway cooperation, and in other related international efforts. Of particular relevance is the agreements reached in the UNFCCC COP 16 in Cancun[39].

This current version of the Joint Concept Note incorporates progress made since November 9th, 2009, and replaces the November 9th 2009 version.

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[38] As defined in the Bali Action Plan (2/CP.13).

[39]The question of self-financing is not addressed in this JCN, as it is most appropriately addressed under the UNFCCC. This MoU will be adjusted as appropriate for the conclusions there reached.

The question of payment for forest-based eco-system services (other than carbon) may be addressed through future international or other mechanisms. This MOU will be adjusted as appropriate for any conclusions there reached.

Section 1: Introduction

This Joint Concept Note constitutes the overarching framework for taking the Guyana-Norway cooperation forward. Specifically, it addresses Paragraphs 2 (c), 3 and 4 of the MoU signed between Guyana and Norway on November 9th, 2009. The Joint Concept Note sets out how Norway is providing, and will continue to provide, financial support to Guyana, based on Guyana's delivery of results as measured, and independently verified, against two sets of indicators:

- *Indicators of Enabling Activities*: A set of policies and safeguards to ensure that REDD-plus contributes to the achievement of the goals set out in Paragraph2(c) of the MoU signed between Guyana and Norway on November 9th, 2009, namely "that Guyana's LCDS Multi-Stakeholder Steering Committee and other arrangements to ensure systematic and transparent multi-stakeholder consultations will continue and evolve, and enable the participation of all affected and interested stakeholders at all stages of the REDD-plus/LCDS process; protect the rights of indigenous peoples; ensure environmental integrity and protect biodiversity; ensure continual improvements in forest governance; and provide transparent, accountable oversight and governance of the financial support received." The enablers are described in more detail in Section 2 and table 1 below.

- *REDD-plus Performance Indicators:* A set of forest-based greenhouse gas emissions-related indicators, as described in more detail in section 3 below. These indicators will gradually be substituted as a system for monitoring, reporting and verifying (MRV) emissions from deforestation and forest degradation in Guyana is established. The time frame for this is established in the MRV roadmap.[40]

Norwegian financial support is being channelled through a multi-contributor financial mechanism – the Guyana REDD-plus Investment Fund (GRIF). The support is financing two sets of activities:

- The implementation of Guyana's Low Carbon Development Strategy (LCDS)

- Guyana's efforts in building capacity to improve overall REDD+ and LCDS efforts.

Section 4 sets out how the financial mechanism operates.

The first payment to the GRIF was made in October, 2010. The second payment will be determined in March 2011 for results achieved between October 1, 2009 and September 30, 2010. To allow the use of the most recent cloud free satellite imagery when reporting, the reporting period for subsequent years will be January 1st to December 31st. As a transition, reporting for 2011 will also include October–December 2010.

The contents of this concept note will be updated to include annual progress in developing the MRV system and in strengthening the quality of REDD-plus-related forest governance according to Guyana's REDD-plus Governance Development Plan, as well as to reflect increased knowledge and developments in negotiations under the UNFCCC and other related global efforts. The Government of Guyana is responsible for providing the necessary data for assessing performance against the given indicators.

[40] http://www.forestry.gov.gy/Downloads/Terms_of_%20Reference_for_Guyana's_MRVS_Draft.pdf

Section 2: Enabling Activities

The continuation of result-based financial support from Norway to Guyana will depend on independently verified progress against four key factors. Section 2.1 describes the four key factors, and Section 2.2 describes the verification process.

Section 2.1 Indicators of Enabling Activities

Performance in enabling activities will be measured against four key factors:

Strategic framework

All aspects of Guyana's planned efforts to reduce deforestation and forest degradation, including forest conservation, sustainable management of forests and enhancement of forest carbon stocks ("REDD-plus"), are being developed in a consistent manner, through an internationally recognized framework for developing a REDD-plus programme, and will continue to evolve over time. Currently, the UN REDD Programme and the Forest Carbon Partnership Facility (FCPF), managed by the World Bank, are two examples of this; the latter constitutes the framework under which Guyana is developing its REDD-plus efforts. Furthermore, all REDD-plus efforts will, at all stages, be fully integrated with Guyana's Low Carbon Development Strategy (LCDS). The contributions to Guyana's REDD-plus/LCDS from Norway and other contributors, including the FCPF, will be administered in a transparent manner. Information concerning all expenditures, both planned and implemented, will be publicly available on the relevant website of the Government of Guyana, and through national systems of public disclosure, including to the National Assembly.

Continuous multi-stakeholder consultation process:

The LCDS, including the REDD-plus strategy and prioritized LCDS funding needs, is subject to an institutionalized, systematic and transparent process of multi-stakeholder consultation, enabling the participation of all potentially affected and interested stakeholders at all stages of the REDD-plus/LCDS process. This process will continue to evolve over time. Particular attention will be given to the full and effective participation of indigenous peoples and other forest-dependent communities. The consultation process will continue to be monitored by an expert team appointed jointly by Guyana and Norway. This team will provide advice to all stakeholders and report on the quality, implementation and adequacy of processes and institutional arrangements to suit the relevant stage of the consultation process, e.g. through regular meetings of a representative multi-stakeholder steering committee.

Governance:

A transparent, rules-based, inclusive forest governance, accountability and enforcement system for forest governance in Guyana is being progressively strengthened, in accordance with Guyana's outline REDD-plus Governance Development Plan (RGDP) and the enabling activities for 2011 as outlined in table 1. The RGDP was developed and informed by recommendations from independent assessments performed by Centre for International Forestry Research (CIFOR) and the Food and Agriculture Organizations of the United Nation (FAO). The system for forest governance progresses the 23 thematic areas outlined in the RGDP.[41]

The rights of indigenous peoples and other local forest communities as regards REDD-plus

[41] www.forestry.gov.gy

The Constitution of Guyana guarantees the rights of indigenous peoples and other Guyanese to participation, engagement and decision making in all matters affecting their well-being. These rights will be respected and protected throughout Guyana's REDD-plus and LCDS efforts. There shall be a mechanism to enable the effective participation of indigenous peoples and other local forest communities in planning and implementation of REDD-Plus strategy and activities.

Guyana's policy is to enable indigenous communities to choose whether and how to opt in to the REDD-plus/LCDS process. This will take place only when communities wish to do so with their titled lands, in accordance with Guyana's policy of respecting the free, prior and informed consent of these communities.

Section 2.2 Assessing Progress Against Enabling Indicators

The November 9th, 2009 JCN set out how progress was measured against enabling indicators for Year 1 and Year 2 of the Guyana-Norway cooperation. These form part of the basis for the second payment under the cooperation.

Table 1 below sets out how progress will be measured in Year 3. These indicators are informed by the draft REDD+ Governance Plan. The REDD+ Governance Plan will be finalized in 2011, and thereafter updated as appropriate.

Guyana and Norway have agreed that annual independent overall assessments of progress against enabling indicators will be conducted by one or more neutral expert organizations, to be appointed jointly by the Participants. The assessment determines whether or not, and to what degree, the REDD-plus enablers have been met. For the period to September 30, 2010, the independent assessment was carried out by Rainforest Alliance, following an international tender process in accordance with Norwegian procurement regulations.

Section 3: REDD-plus performance indicators

Guyana is being paid for its performance through an incentive structure which rewards keeping deforestation below an agreed reference level, as well as avoiding increased forest degradation.

The Governments of Guyana and Norway strongly endorse the establishment of such an incentive structure under the United Nations Framework Convention on Climate Change (UNFCCC). To help facilitate such an agreement, the Governments have decided to pilot such an incentive structure on a national scale and in a pragmatic, gradually evolving, workable and hopefully replicable manner. Once an international regime is in place, the Guyana-Norway partnership will be adjusted accordingly. Section 3.1 sets out the incentive structure, while Section 3.2 outlines how performance is to be assessed.

Section 3.1 REDD+ incentive structure

The payments due to Guyana for a given year are paid post facto. They are calculated as follows:

1. Measure avoided deforestation by subtracting Guyana's observed deforestation rate against the agreed *reference level*. See Section 3.1.1
2. Determine avoided greenhouse gas emissions by applying a set of *carbon-density proxies* to:

   (i) convert the observed avoided deforestation rate into avoided greenhouse gas emissions;

   (ii) subtract increased emissions from forest degradation (based on agreed indicators of forest degradation (see table2)

   See Section 3.1.2
3. Apply an interim carbon price of US$5 per tonne of avoided emissions, providing Guyana does not exceed an agreed level of deforestation within the context of the Guyana-Norway partnership – see Section 3.1.3. If the deforestation rate is above the levels stipulated in section 3.1.3, payments will be reduced and ultimately cease.

Section 3.1.1 – Measuring Avoided Deforestation

For a global REDD+ mechanism to be effective it must incentivize both (i) reductions in deforestation in countries with high levels of deforestation and (ii) maintenance of low deforestation rates in countries that have maintained their forest cover. If only countries with high deforestation rates are compensated for improving their forest protection under an international climate regime, deforestation pressures will move to countries with currently low deforestation, like Guyana, and the overall emissions reduction effect will be diluted or lost.

On the other hand, if a global incentive structure does not ensure global additionality, the international community will be paying for "hot air" and there will be no mitigation impact.

This point is broadly accepted within the UNFCCC negotiations, and there is general agreement that a REDD-mechanism must provide genuine incentives for forest conservation in low deforestation countries, as well as ensure global additionality.

Therefore, Norway and Guyana have – pending the determination of a UNFCCC reference level methodology – decided to use the "combined reference level" methodology to set a provisional reference level, based on an equal weighting of Guyana's mean 2000 - 2009 deforestation rate and the mean 2005 – 2009 rate in developing countries with deforestation. The "combined reference level" methodology provides incentives for all categories of forest countries, and ensures that emissions from deforestation and forest degradation are reduced cumulatively at a global level.

In setting a historical deforestation baseline for Guyana under the Guyana-Norway REDD+ partnership, the mean value for the 2000-2009 period is used; 0,03% (see box 1 for background). This adheres to the principles used for setting the historical deforestation baseline in the Brazilian Amazon Fund.

The "global average deforestation rate" is calculated[42] across 85 developing forested countries by dividing the sum of reported forest area loss in only those countries which lost forest by the starting area of forest across all countries, Data on forest loss is taken from FAOs Forest Resources Assessment 2010 (FRA 2010). For the period 2005-2010 the "global average deforestation rate" was 0.52%. This figure will be subject to revision given new data from future FAO FRA's or from the IPCC.

The reference level for Guyana is the mean value of these two measures, that is, 0.275%.

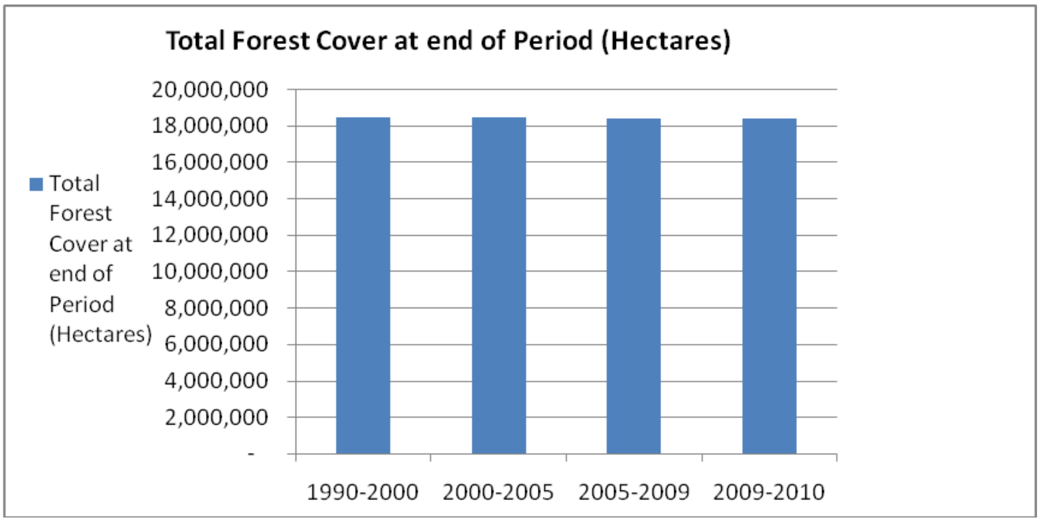
[42]The open source Osiris database was used for these calculations (www.conservation.org/osiris). Note that this is an underestimate because it does not include deforestation that occurred within countries that had a net gain in forest, nor does it account for all deforestation in countries that lost forest as some countries' reported forest area loss are net values.

Box 1:
To improve knowledge on historical deforestation rates in Guyana, an analysis of forest area change since 1990 to September 2009 has been undertaken, using archived Landsat-type satellite data that met the IPCC Good Practice Guidelines for Land Use, Land Use Change and Forestry (LULCF). The analysis was conducted by Poyry–New Zealand, upon assignment by the Guyana Forestry Commission. The report was subsequently subject to independent verification by the Det Norske Veritas (DVN). The reports can be downloaded at www.regjeringen.no/guyana or www.forestry.gov.gy

		Benchmark period		
	1990 to 2000	2001 to 2005	2006 to 2009	Year 1 (09-10)
Driver		Area (ha)		
Forestry	6 094,50	8 419,56	4 784,13	294,34
Agriculture	2 030,39	2 852,22	1 797,24	512,94
Mining	10 843,45	21 438,30	12 623,74	9 384,07
Infrastructure	590,46	1 304,39	195,21	63,65
Fire	1 708,19	234,71	-	32,12
Area deforested	21 267,00	34 249,18	19 400,32	10 287,12
Total forest area of Guyana	18 473 394,08	18 452 127,08	18 417 877,90	18 398 477,58
Total forest area of Guyana remaining	18 452 127,08	18 417 877,90	18 398 477,58	18 388 190,47
Deforestation %	0,012	0,037	0,022	0,056

The estimates include all forest to non-forest change, i.e. detected mining, road infrastructure, agricultural conversion and fire events that result in deforestation. They do not include degradation caused by selective harvesting, fire or shifting agriculture. It should be noted that the numbers are annualized, but that firm enough data to establish actual rates for any given year are not available. Insights gathered from countries where such data exists, indicate that there is most probably a fairly significant year-on-year variation.

A key conclusion to be drawn from the study is that forest cover in Guyana has remained relatively stable over the 20-year benchmark period, as illustrated below:



Section 3.1.2 Converting to Avoided Greenhouse Gas Emissions

Guyana is working to implement an IPCC-compliant MRV-system for emissions or removals of carbon from Guyana's forest sector. Until such a system is in place, a set of basic interim (proxy) indicators will be used to assess Guyana's performance. As a more sophisticated forest carbon accounting-system is implemented, these basic indicators will be gradually phased out. The set of interim performance indicators is based on the following assumptions:

- They provide justification and prioritization for near-term implementation of REDD-plus efforts.
- They are based on conservative estimates while encouraging the development of a more accurate MRV system over time through building national capacities.
- They will contribute towards the development of a national MRV-system, based on internationally accepted methodologies and following the IPCC reporting principles of completeness, consistency, transparency, uncertainty, comparability, and encourage independent international review of results.

When calculating reduced emissions from avoided deforestation, an interim default value of 100 tons of Carbon is applied. This interim carbon figure corresponds to 367 tons of CO2. When calculating emissions caused by forest degradation, a default value of 400 tons per hectare is applied, which corresponds to 1468 tons of CO_2. These conservative carbon values help to ensure that emission reductions from deforestation are not over-estimated and emissions from forest degradation are not under-estimated.

The interim indicators are described in table 2 below.

Section 3.1.3 Calculating Payment

Payments due to Guyana will be calculated by applying an interim carbon price of US$5/ton CO2, as established in Brazil's Amazon Fund.

However, this price will only be applied if Guyana's observed deforestation rate is below the agreed level. This is explained in the following section.

Agreed maximum level of Deforestation

If designed for maximum effectiveness and efficiency, a future global incentive system could allow for significant variations in individual countries' deforestation rates while still ensuring global additionality.

However, in the absence of a global system, such an approach alone would imply that Guyana would be eligible for significant payments even if it were to increase its deforestation along a business-as-usual trajectory towards the agreed reference level of 0.275%.

However, neither Norway nor Guyana wishes to see such an increase in deforestation, and in November 2009 the Joint Concept Note clearly stated that:

"(…) the Participants agree that Norwegian financial support from 2011 onwards is also dependent on no national-level increase in deforestation over an agreed level that should be as close to historical levels as is reasonable in light of expanded knowledge of these historical rates and the quality of that knowledge. Such a level can only be set when more robust data is available concerning current and historic deforestation."

At the same time, Guyana's national development requires limited but strategic use of forest assets to enable (i) a limited amount of economic activity to take place within the forest, where the economic value to the nation of such activity is very valuable; (ii) a limited amount of essential national infrastructure to be constructed where this is in line with critical development goals; (iii) support for the sustainable development of forest villages. Guyana is reaching a stage of economic development where experience from other countries suggests that enabling these objectives brings further deforestation pressures.

Therefore, pending the introduction of a global incentive system, it would defeat the purpose of making REDD+ an attractive development option for forest countries if this REDD+ agreement meant that no increases at all be allowed in Guyana's historically low deforestation rates. First, the rates are so small that the margin of error of measurements in itself could yield significant annual variations (as measured in per cent). Second, insisting on such strict limitations would probably yield an insufficient incentive structure for the people of Guyana to stick to a low-deforestation development path, as the economic downsides would be disproportionate to the incentive offered. Third, the relevance of historical trends when deforestation rates are extremely low is not as useful a predictor of future pressures on the forest as it is in countries with higher historic rates of deforestation.

There is no given mathematically correct answer to how these concerns should best be balanced. Guyana and Norway have chosen a model that on the one hand enables Guyana to exercise careful, strategic use of limited forest areas for high value economic activity, the construction of essential national infrastructure and sustainable development of forest villages. On the other hand, the model puts in place incentives that would quickly penalize an upward trend in deforestation(see box 2).

The essence of this approach has two implications:

(i) one-off predictable and controllable deforestation events will be allowed for critical national infrastructure that is part of Guyana's transition to a low carbon development path.[43] During the duration of the current Guyana-Norway partnership, the only such event will be the construction of the Amaila Falls hydro-electricity plant. This plant is the flagship of Guyana's Low Carbon Development Strategy, and is expected to eliminate over 92% of the country's energy-related emissions, after the emissions associated with its construction are accounted for[44].

It will only go ahead after Guyana and Norway have agreed that the necessary Environmental and Social safeguards have been met, and an independent verification agreed by Guyana and Norway confirms the overall beneficial effects of the project from a climate change perspective.

[43] The exception is only from the 'agreed maximum level of deforestation' provision. The emissions resulting from such activities would still be part of the total deducted from the reference level to determine total payments due to Guyana. I.e., emissions from Amaila would still count as deduction in total amount due to Guyana in the years when Amaila was established.

[44] The January 2011 ESIA for the Amaila Falls project can be found at http://amailahydropower.com/latest-news/key-project-documents. Section 5 details how a 92% reduction in net greenhouse gas emissions is calculated.

Box 2: Mechanism for reducing results based payments if deforestation rate exceeds the agreed maximum level (0,056%)

Deforestation rates (%)	Up to .056	0.057-.062	0.063-.080	0.081-.090	0.091-0.1
Reduced compensation (% per 0.0015 increased deforestation)	0	1,5	2,0	2,5	3,0

Examples of reductions in compensation at levels above agreed maximum level:

Deforestation rate (%)	Up to 0.056	0.07	0.08	0.09	0.1
Reduced compensation (%)	0	25	45	70	100

(ii) economic activities will be permitted within the forest, within a ceiling on deforestation of 0.056 per annum, without any financial penalty apart from the reduction in compensation caused by a smaller margin between the reference level and the verified deforestation level. For any deforestation rate up to this level, Guyana will be eligible for payments equalling the full margin between the reference level and the verified deforestation level. For deforestation rates between 0,056 per cent and 0,1 per cent (unless they relate to the Amaila Falls project as described above), eligibility for payments would be calculated as a gradually decreasing percentage of the payments that would be due if only the margin between the reference level and the verified deforestation level were taken into account, as set out below. At deforestation rates at or above 0,1 percent, no payments would be due to Guyana for that given year.

This approach is compatible with the Government of Guyana's declared long-term strategy to maintain the maximum amount of forest cover in Guyana, if an appropriate incentive structure is in place to make this strategy viable. This is being done through a balanced mix of maintaining forests under full protection (areas where only small-scale subsistence farming by forest dependent communities is allowed) and sustainable commercial forest management (where existing forestry concessions can operate within the terms of their licenses and the GFC's sustainable forest management guidelines).

In sum, this means:

a) that a ceiling on the level of deforestation that can take place before 2015 with any incentives still flowing, has been set at only around 35 per cent of the level of deforestation that the reference level would imply;
b) the accommodation of limited annual upward variations to ensure that the incentive structure still makes REDD+ a positive development choice for Guyana; and
c) that Guyana is incentivized to maintain more than 99.5 per cent of its forest cover for the duration of the partnership.

See box 3 for a summary description of how performance based payments will be calculated.

Norwegian support to GRIF – alone or in combination with other contributors – will not exceed the sum calculated on the basis of the above described methodology (neither in 2010 nor in future years).

It is also likely that while support from Norway will be sufficient to provide majority funding for results delivered by Guyana, in a given year, it is unlikely to equal the total sum owed to Guyana. Therefore, to ensure that the incentives which underpin the partnership are fully in place, Guyana and Norway will work together to seek to get other Participants to join the partnership. The Participants' goal is to reach agreement with other Participants by the end of August 2011. Based on progress at that point, this JCN will be updated by the end of September 2011.

Once other Participants are in place with sufficient commitments to the Partnership, this will enable Norwegian (and other Participants') contributions to vary directly with performance, i.e. a reduction in estimated emissions will lead to relatively higher contributions, increases to relatively lower contributions.

Box 3: How will results based payments be calculated?

To calculate the results based payments due to Guyana based on the results in any given year, the following steps will be followed:

1. Subtracting Guyana's reported and verified deforestation rate from the agreed interim reference level of 0.275%;

2. Calculating the carbon emission reductions achieved through avoided deforestation (as compared to the agreed reference level) by applying an interim and conservatively set estimate of carbon loss of 100tC/ha. This value will be replaced once a functional MRV system is in place. The interim carbon loss figure corresponds to 367tCO^2/ha.

3. Subtracting from that number changes in emissions – on a ton-by-ton basis – from forest degradation as measured against agreed indicators, as specified in Table 2.. In calculating the carbon effects of forest degradation, an interim and conservatively set carbon density of 400 tC/ha will be applied. Upon agreement under the UNFCCC on how to estimate and account for emissions from degradation, this approach will be adjusted accordingly;

4. The tons of "avoided emissions" is then multiplied with an interim carbon price of US$ 5/ton CO2, as established in Brazil's Amazon Fund.

5. If the deforestation rate in a given rate exceeds 0,056, the payments will be gradually reduced as a proportion of the sum derived through step 1-4 above, or cease (if at or exceeding 0,1 per cent), as stipulated in section 3.1.3, box 2.

Section 3.2 Monitoring Progress Against reducing emissions and enhancing removals of carbon in Guyana's forests

Progress against reducing emissions and enhancing removals of carbon in Guyana's Forests will in time be measured through the MRV system that is being put in place as set out in the MRV-system Road-map[45].

Pending the implementation of the MRV-system, Table 2 sets out the interim REDD+ performance indicators described above. Guyana and Norway 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.

A roadmap for the establishment of a national MRV system and accompanying Terms of Reference for the system have been developed to provide a framework for verifiable, performance monitoring, set against international best practice and nationally appropriate circumstances. In years 1 and 2 (2009-2010), implementation has also commenced in a number of administrative and technical areas. Broad based MRV-system Steering and Technical Committees have been established and initial technical work has commenced in forest area and forest carbon stock assessment and monitoring. The framework has been created for annual reporting on deforestation and forest degradation in accordance with interim REDD+ Performance Indicator that will evolve into a full MRV system. The first product has been the completion of historic reporting on forest/non forest cover and deforestation by driver, over the period 1990 to 2009, accompanied by annual reporting of forest/non forest cover and deforestation and forest degradation results in accordance with REDD+ Interim indicators set out in the JCN. Concurrently, work has also commenced for field based assessments of forest carbon stock assessment and monitoring, the establishment of demonstration activities, and detailed technical studies on reference level setting and forest degradation, as well as other areas.

During 2009 and 2010, significant improvements to Guyana's ability to measure deforestation indicators were made. In particular, it was determined (and independently verified) that deforestation rates were extremely low.

Progress was also made to gain a greater understanding of how degradation is to be measured, and this is leading to further work in 2011, when new scientifically-based knowledge will enable progress on refining the reporting on indicators to assess mining and infrastructure-related degradation.

Guyana and Norway have agreed that annual independent verification of REDD+ performance indicators will be conducted by one or more neutral expert organizations, to be appointed jointly by the Participants. The assessment determines what results Guyana has delivered according to the established indicators for REDD-plus performance. For the period to September 30, 2010, the initial measurement of progress was carried out by Pöyry on behalf of the Guyana Forestry Commission, and independent verification was carried out by DNV. DNV was selected on the basis of an international tender process in accordance with Norwegian procurement regulations.

[45] http://www.forestry.gov.gy/Downloads/Terms_of_%20Reference_for_Guyana's_MRVS_Draft.pdf

Section 4: Financial mechanism:

The Guyana REDD+ Investment Fund (GRIF) is channelling REDD-plus financial support from Norway and other potential contributors to the implementation of Guyana's LCDS.

Pending the creation of an international REDD+ mechanism, the Guyana REDD+ Investment Fund (GRIF) represents an effort to create an innovative climate finance mechanism which balances national sovereignty over investment priorities with ensuring that REDD+ funds adhere to globally accepted financial, environmental and social safeguards.

The World Bank's International Development Association (IDA) was invited by Guyana and Norway to act as Trustee and is responsible for providing financial Intermediary services to the GRIF.

The Trustee (i) receives payments for forest climate services provided by Guyana; and (ii) transfers these payments and any investment income earned on these payments, net of any administrative costs, to Partner Entities, for projects and activities that support the implementation of Guyana's LCDS. Transfer of funds takes place on approval by the GRIF Steering Committee, which consists of Guyana and Norway, with observers from Partner Entities, and Guyanese and Norwegian civil society.

Partner Entities provide operational services for the approved LCDS investments, and apply their own globally accepted operational procedures and safeguards. As of March 2011, Guyana and Norway have approved as Partner Entities the Inter-American Development Bank (IDB), the World Bank and the United Nations Development Group.

More information on the operation of the GRIF is set out in the Administration Agreement between the Government of Norway and the World Bank46.

[46]http://www.regjeringen.no/upload/MD/Vedlegg/Klima/klima_skogprosjektet/Guyana/aa.pdf or http://lcds.gov.gy/guyana-redd-investment-fund-grif.html

Key REDD+ Efforts in 2011*:*

Improved REDD+ Governance

In 2009 and 2010, the Government of Guyana continued to improve governance standards within the REDD+-related forest dependent sectors. These efforts to improve REDD+ -related governance, will continue in 2011. During 2011, the draft REDD+ Governance Development Plan (RGDP) produced in 2010 will be updated and improved with more specific expected results, indicators and timeframes, addressing among other issues all aspects of Table 1 of the November 9th 2009 Joint Concept Note. It will draw on recommendations from relevant sources, including the 2011 independent assessment of REDD+ enabling indicators. It will detail specific measures to advance REDD+ governance, and progress, among others, the following actions:

- Development of an IPCC-compliant national system for measuring, reporting and verification (MRV) of emissions and removals of carbon in Guyana's forests will continue. Progress in 2011 will be measured against the MRV-roadmap established in 2009.
- An initial structure for an Independent Forest Monitoring mechanism shall be in place by mid-2011. Its first report shall be due by the end of 2011.
- Stakeholder consultation on the European Union Forest Law Enforcement, Government and Trade (EU-FLEGT) process will continue. The Government of Guyana and the European Commission will, by September 2011, initiate negotiations on a Forest Law Enforcement, Government and Trade Voluntary Partnership Agreement, in a manner that is consistent with the outcomes of this consultation where applicable.
- The development of a national, inter-sectoral system for coordinated land use will continue. The system shall serve to maximize benefits to society and development, while minimizing negative impacts on the environment, from land-use decisions. By mid November 2011, Guyana's Special Land Use Committee, comprising stakeholders from the Government and forest dependent sectors, will have identified - and established a plan for implementation of - the necessary measures, including enforcement measures, to be implemented in the relevant forest dependent sectors, including forestry and mining. These will ensure that these sectors can operate at the standards necessary to sustainably protect Guyana's forest. Recognizing that sustainable, well coordinated land use is a continuous challenge, further mechanisms will be established and/or strengthened to ensure such coordination, where necessary. Key measures to be implemented by the end of 2011 will on that basis be agreed by the partners by mid November 2011 as an addendum to this JCN.
- Stakeholder consultation on the Extractive Industries Transparency Initiative (EITI) will continue until June 2011. Based on the outcomes of this consultation, a plan for the implementation of the EITI principles will be in place by mid November 2011. These next steps will address the introduction of EITI, if the conclusions from the 2011 stakeholder consultation support this goal, or an alternative approach to the same effect if that is decided. Based on the outcome of those consultations, an addendum to this JCN will be agreed on this issue by mid November 2011.
- Based on the outcomes of a scientific study to determine the extent of degradation caused by mining and infrastructure, the Government of Guyana will work with the forest dependent sectors to agree specific measures to reduce forest degradation by these activities. Based on this, an addendum to this JCN, including end of 2011 as well as 2012 deliverables, will be put in place by mid November 2011.
- Undertake mapping of priority areas for biodiversity in Guyana's forests, based on, inter alia, the criteria established in 2010. By mid -November 2011, Guyana will release a policy statement on how it plans to meet its CBD obligations. Based on the forest related elements of this statement, an addendum to this JCN will be agreed by mid November 2011.

Improved Financial Intermediation

For global efforts on REDD+ to function well, it is critical that effective financial intermediation functions are available to forest countries and the broader international community. Existing models of ODA-financing are not designed for this purpose.

Since 2009, significant progress has been made in understanding the global channels inherent in the establishment of such mechanisms to channel results-based finance for REDD+. The experience gained in the setting up and implementation of the GRIF has been valuable in this context – although its establishment was challenging and took far longer than Guyana and Norway expected.

In 2011, Guyana and Norway will work with the Trustee and Partner Entities of the GRIF to identify how the GRIF mechanism can function in a way that is fit for the purpose of channelling results-based international support to the implementation of Guyana's low carbon development strategy in an effective, efficient and equitable manner. Moreover, like all other elements of the Guyana-Norway partnership, the financial intermediary function should be independently evaluated to ensure that it meets the needs of stakeholders within Guyana, and that useful lessons are generated to inform the global debates on REDD+.

Therefore:

- Guyana and Norway will invite the other partners involved in the Guyana REDD+ Investment Fund (GRIF) – the World Bank, The Inter American Development Bank, and the UNDP; within the framework provided by the structure of the GRIF (including the GRIF Governance Framework document, the Administrative Agreement and the Transfer Agreements) –to participate in an independently facilitated process, which will be initiated by Guyana and Norway to: (i) help to accelerate the disbursement of funds from the GRIF, in a manner which is in accordance with the AA and the TAs of the GRIF, and in a manner satisfactory to all concerned; (ii) identify potential short-term improvements in the processes and practices of the GRIF and all its partners in the GRIF context. This facilitated process will start by mid-May 2011.
- Guyana and Norway will – as part of the annual review process of the partnership – appoint an expert organization to assess the overall performance of the GRIF and make recommendations for its improvement.
- Transparency around funding is also critical for REDD+ to function well. To facilitate such transparency, the Government of Guyana will – by the end of April 2011 – establish a dedicated website, containing an overview of all committed international funding for activities relevant to REDD+ and LCDS efforts in Guyana. This will ensure easy access to transparent information on contributors to Guyana's REDD+ and LCDS efforts. The website will track pledges of funding, commitments of funding, and actual disbursements.

Table 2: Interim Indicators for REDD+ performance in Guyana[47]

Source of emissions or removals	Justification	Interim performance indicator	Monitoring and estimation	IPCC LULUCF reporting
Deforestation Indicator: Gross deforestation	Emissions from the loss of forests are among the largest per unit emissions from terrestrial carbon loss.	Rate of conversion of forest area as compared to agreed reference level. Forest area as defined by Guyana in accordance with the Marrakech accords: • Minimum 30% tree cover • At a minimum height of 5 meter • Over a minimum area of 1 ha. Conversion of natural forests to tree plantations shall count as deforestation with full carbon loss. Forest area converted to new infrastructure, including logging roads, shall count as deforestation with full carbon loss.	Forest cover as of September 2009 will be used as baseline for monitoring gross deforestation. Reporting to be based on medium resolution satellite imagery and in-situ observations where necessary. Monitoring shall detect and report on expansion of human infrastructure (e.g. new roads, settlements, pipelines, mining/agriculture activities etc.)	Activity data on change in forest land
Degradation indicators:				
Loss of intact forest landscapes[48]	Degradation of intact forest through human	The total area of intact forest landscapes within	Using similar methods as for forest area change	Changes in carbon stocks in

[47]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. Based on experiences from the first reporting and verification exercise, some adjustments have been made in this table. However, the process has identified a need to develop further detail on the operationalisation of the indicators. A process to this end will be completed before work on the second result report is started.

[48]Intact Forest Landscape (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)." (See www.intactforests.org)

Source of emissions or removals	Justification	Interim performance indicator	Monitoring and estimation	IPCC LULUCF reporting
	activities will produce a net loss of carbon and is often the pre-cursor to further processes causing long-term decreases in carbon stocks. Furthermore, preserving intact forests will contribute to the protection of biodiversity.	the country should remain constant. Any loss of intact forest landscapes area[49] shall be accounted as deforestation with full carbon loss. The IFL Baseline map developed in the first reporting period will be used to assess future changes.	estimation.	forests remaining as forests
Forest management (i.e. selective logging) activities in natural or semi-natural forests	Forest management should work towards sustainable management of forest with net zero emissions or positive carbon balance in the long-term.	All areas under forest management should be rigorously monitored and activities documented (i.e. concession activities, harvest estimates, timber imports/exports). Increases in total extracted volume (as compared to mean volume 2003 – 2008) will be accounted as	Data on extracted volumes is collected by the Forestry Commission. Independent forest monitoring will contribute to verify the figures.	Changes in carbon stocks in forests remaining as forests

[49]When assessing loss of IFL, the established elimination criteria will be applied:

- Settlements (including a buffer 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 (in-cluding a buffer of 1 km on each side);
- Areas used for agriculture and timber production;
- Areas affected by industrial activities during the last 30-70 years, such as logging, mining, oil and gas exploration and extraction, peat extraction, etc.

The threshold values for IFL-patches (500 km2, min. width 10 km) will not be applied in assessing IFL loss.

Source of emissions or removals	Justification	Interim performance indicator	Monitoring and estimation	IPCC LULUCF reporting
		increased forest carbon emissions[50] unless otherwise can be documented using the gain-loss or stock difference methods as described by the IPCC for forests remaining as forests. In addition to the harvested volume, a default expansion factor (to be established) shall be used to take account of carbon loss caused by collateral damage, etc, unless it is documented that this has already been reflected in the recorded extracted volume.		
Carbon loss as indirect effect of new infrastructure.	The establishment of new infrastructure in forest areas often contributes to forest carbon loss outside the areas directly affected by constructions.	Unless a larger or smaller area or greenhouse gas emission impact can be documented through remote sensing or field observations, the area within a distance extending 500 meters from the new infrastructure (incl. mining sites, roads, pipelines,	Medium resolution satellite to be used for detecting human infrastructure (i.e. small scale mining) and targeted sampling of high-resolution satellite for selected sites.	Changes in carbon stocks in forests remaining as forests

[50] The participants agree on the need to create incentives for net-zero or carbon positive forest management practices in Guyana. This will require a sophisticated MRV system to assess the carbon effects of forestry activities. This will be an objective of the MRV system under development. In the interim period, focus will be on incentives for avoiding increased emissions from forest management activities.

Source of emissions or removals	Justification	Interim performance indicator	Monitoring and estimation	IPCC LULUCF reporting
		reservoirs) shall be accounted with a 50% annual carbon loss through forest degradation.		
Emissions resulting from subsistence forestry, land use and shifting cultivation lands (i.e. slash and burn agriculture).	Emissions resulting from communities to meet their local needs may increase as result of *inter alia* shorter fallow cycle or area expansion.	Not considered relevant in the interim period before a proper MRV-system is in place.		Changes in carbon stocks in forests remaining as forests
Emissions resulting from illegal logging activities	Illegal logging results in unsustainable use of forest resources while undermining national and international climate change mitigation policies	Areas and processes of illegal logging should be monitored and documented as far as practicable.	In the absence of hard data on volumes of illegally harvested wood, a default factor of 15% (as compared to the legally harvested volume) will be used. This factor can be adjusted up- and downwards pending documentation on illegally harvested volumes, inter alia from Independent Forest Monitoring. Medium resolution satellite to be used for detecting human infrastructure and targeted sampling of high-resolution satellite for selected sites.	Changes in carbon stocks in forests remaining as forests

Source of emissions or removals	Justification	Interim performance indicator	Monitoring and estimation	IPCC LULUCF reporting
Emissions resulting from anthropogenically caused forest fires	Forest fires result in direct emissions of several greenhouse gases	Area of forest burnt each year should decrease compared to current amount	Coarse-resolution satellite active fire and burnt area data products in combination with medium resolution satellite data used for forest area changes	Emissions from biomass burning
Indicator on increased carbon removals:				
Encouragement of increasing carbon sink capacity of non-forest and forest land	Changes from non-forest land to forest (i.e. through plantations, land use change) or within forest land (sustainable forest management, enrichment planting) can increase the sequestration of atmospheric carbon.	Not considered relevant in the interim period before a proper MRV-system is in place but any dedicated activities should be documented as far as practicable. In accordance with Guyanese policy, an environmental impact assessment will be conducted where appropriate as basis for any decision on initiation of afforestation, reforestation and carbon stock enhancement projects.		Activity data on change to forest land and changes in carbon stocks in forests remaining as forests

Appendix 3

Year 2 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 shown in the table below. This archive is dynamic and will be continually added to over time.

Image Catalogue Naming Conventions

Image Stack Name	Image name in the following format: Satellite (2-3), Path (4), Row (1-3) _ Image Date (YYMMDD)_Image Provider (U= USGS, R=RapidEye, D=DMC, MO=Modis, GF= Geo Fct,)_Processing level (1-2, O=Orthorectified, W=Warped)
Mapping Stream	The mapping stream that the imagery is for.
Data Provider	The name of the data provider.

Summary of 2011 Satellite Datasets

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
Mosaic Base					
GeoCover_Mosaic_Clip.img		Multi	Landsat	Base Map	Global Landcover Facility
DMC					
DBP010R499_100830_D_O.tif	8	2010	DMC Beijing	Year 1	DMC
DBP020R499_100830_D_O.tif	8	2010	DMC Beijing	Year 1	DMC
DBP020R499_101228_D_O.tif	12	2010	DMC Beijing	Year 1	DMC
DBP030R499_100830_D_O.tif	8	2010	DMC Beijing	Year 1	DMC
DBP030R499_101104_D_O.tif	11	2010	DMC Beijing	Year 1	DMC
DBP030R499_101109_D_O.tif	11	2010	DMC Beijing	Year 1	DMC
DDP015R499_100910_D_O.tif	9	2010	DMC Deimos	Year 1	DMC
DUP015R499_100912_D_O.tif	9	2010	DMC UK2	Year 1	DMC
DUP015R499_101004_D_O.tif	10	2010	DMC UK2	Year 1	DMC
DUP015R499_100921_D_O.tif	9	2010	DMC UK2	Year 1	DMC
Landsat 5					
L5P229R58_110817_U_O.tif	8	2011	L5	Year 2	USGS
L5P229R59_110817_U_O.tif	8	2011	L5	Year 2	USGS
L5P230R56_110808_U_O.tif	8	2011	L5	Year 2	USGS
L5P230R57_110808_U_O.tif	8	2011	L5	Year 2	USGS
L5P230R58_110808_U_O.tif	8	2011	L5	Year 2	USGS
L5P230R59_110808_U_O.tif	8	2011	L5	Year 2	USGS
L5P231R56_110831_U_O.tif	8	2011	L5	Year 2	USGS
L5P231R57_110831_U_O.tif	8	2011	L5	Year 2	USGS
L5P231R58_110831_U_O.tif	8	2011	L5	Year 2	USGS
L5P231R59_110831_U_O.tif	8	2011	L5	Year 2	USGS
L5P232R56_111025_U_O.tif	10	2011	L5	Year 2	USGS
L5P232R57_111009_U_O.tif	10	2011	L5	Year 2	USGS
Landsat 7					

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
L7P229R58_111028_U_O.tif	10	2011	L7	Year 2	USGS
L7P229R59_111028_U_O.tif	10	2011	L7	Year 2	USGS
L7P230R56_110901_U_OW.tif	09	2011	L7	Year 2	USGS
L7P230R57_110901_U_O.tif	09	2011	L7	Year 2	USGS
L7P230R57_111206_U_O.tif	12	2011	L7	Year 2	USGS
L7P230R58_110816_U_O.tif	08	2011	L7	Year 2	USGS
L7P230R58_110901_U_O.tif	09	2011	L7	Year 2	USGS
L7P230R58_111206_U_O.tif	12	2011	L7	Year 2	USGS
L7P230R59_110816_U_O.tif	08	2011	L7	Year 2	USGS
L7P230R59_111206_U_O.tif	12	2011	L7	Year 2	USGS
L7P231R55_110908_U_OW.tif	09	2011	L7	Year 2	USGS
L7P231R56_110831_U_OW.tif	08	2011	L7	Year 2	USGS
L7P231R56_110908_U_O.tif	09	2011	L7	Year 2	USGS
L7P231R57_110908_U_O.tif	09	2011	L7	Year 2	USGS
L7P231R58_110908_U_O.tif	09	2011	L7	Year 2	USGS
L7P231R58_110924_U_O.tif	09	2011	L7	Year 2	USGS
L7P231R59_110908_U_O.tif	09	2011	L7	Year 2	USGS
L7P232R54_110814_U_O.tif	08	2011	L7	Year 2	USGS
L7P232R55_110915_U_OW.tif	09	2011	L7	Year 2	USGS
L7P232R56_110915_U_OW.tif	09	2011	L7	Year 2	USGS
L7P232R57_110915_U_OW.tif	09	2011	L7	Year 2	USGS
L7P233R55_111008_U_O.tif	10	2011	L7	Year 2	USGS
L7P233R56_110906_U_O.tif	09	2011	L7	Year 2	USGS
RapidEye					
RE2141610_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141611_110901_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141612_110901_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141710_110901_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141711_110901_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141712_110901_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141811_110901_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141812_110901_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141813_110830_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141905_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141911_110901_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141912_110901_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141913_110902_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142005_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142006_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
RE2142006_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142011_110901_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142012_110806_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142105_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142106_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142111_110806_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142111_110831_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141610_110901_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141610_110811_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141913_110901_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142011_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142111_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142011_111006_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2141813_110901_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142012_110901_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2140506_110831_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140507_110831_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140508_110817_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140509_110817_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140510_111016_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2140511_111016_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2140606_110831_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140607_110831_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140608_110817_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140609_110830_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140610_110830_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140611_111016_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2140704_111010_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2140705_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140705_111010_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2140709_110830_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140710_110830_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140711_110830_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140803_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140804_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140805_110806_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140806_110831_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140806_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140809_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
RE2140810_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140811_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140904_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140905_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140906_110831_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140906_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140907_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140909_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140910_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141005_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141006_110911_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141006_110908_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141007_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141008_110911_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141010_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141104_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141105_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141106_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141106_110911_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141107_110911_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141108_110911_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141109_110806_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141110_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141203_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141204_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141205_110807_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141205_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141206_110820_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141206_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141207_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141208_110911_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141209_110831_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141210_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141211_111016_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2141303_111205_R_OW.tif	12	2011	RapidEye	Year 2	RapidEye
RE2141304_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141304_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141305_110820_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141305_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
RE2141306_110820_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141306_110908_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141307_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141307_110930_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141308_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141308_110911_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141309_110831_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141309_111222_R_OW.tif	12	2011	RapidEye	Year 2	RapidEye
RE2141310_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141311_111016_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2141402_111002_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2141403_111205_R_OW.tif	12	2011	RapidEye	Year 2	RapidEye
RE2141403_111002_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2141404_111205_R_OW.tif	12	2011	RapidEye	Year 2	RapidEye
RE2141404_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141405_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141405_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141406_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141407_110811_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141408_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141409_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141410_110806_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141410_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141411_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141412_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141413_110807_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141502_111002_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2141502_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141504_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141504_110905_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141505_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141505_110820_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141506_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141506_110820_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141507_111223_R_OW.tif	12	2011	RapidEye	Year 2	RapidEye
RE2141507_110811_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141508_110811_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141509_110811_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141510_111124_R_OW.tif	11	2011	RapidEye	Year 2	RapidEye

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
RE2141510_111110_R_OW.tif	11	2011	RapidEye	Year 2	RapidEye
RE2141511_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141511_110830_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141512_110807_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141513_110807_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2041728_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2041826_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2041827_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2041828_110814_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2041828_111012_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2041925_110803_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2041926_110803_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2041926_111012_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2041927_111012_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2041928_110814_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2041928_111012_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2042025_110904_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2042026_110920_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2042027_111012_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2042027_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042028_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042028_111008_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2042125_110904_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2042125_110920_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2042126_110920_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2042127_110814_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042127_111008_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2042128_111012_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2042128_111030_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2042225_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042226_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042226_110904_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2042227_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042227_110803_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042228_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042228_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042326_110927_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2042326_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042327_111030_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
RE2042327_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042328_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042328_111012_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2141601_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141601_110828_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141602_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141603_110905_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141603_110915_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141604_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141701_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141702_110828_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141702_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141703_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141704_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141704_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141801_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141802_110828_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141802_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141803_110828_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141803_110905_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141804_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141804_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141901_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141901_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141902_110828_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141902_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141903_111002_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2141903_110828_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141904_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141904_110828_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142001_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142002_110915_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142002_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142003_110828_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142003_111002_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142004_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142101_111012_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142102_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142103_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
RE2142103_110828_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142104_110915_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142104_110828_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142201_111008_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142201_110814_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142202_111011_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142202_110915_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142203_111011_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142203_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142204_110915_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142204_110905_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142301_111012_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142301_110814_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142303_110915_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142303_110828_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142304_110915_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142304_110828_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042426_110904_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2042427_111012_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2042427_110803_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042428_111026_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2042428_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042526_110904_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2042527_110803_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042527_111030_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2042528_111008_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2042528_110803_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042626_110904_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2042627_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042627_110904_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2042628_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042628_110814_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042726_110904_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2042727_110904_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2042728_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042728_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2042828_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142401_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142401_111008_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
RE2142402_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142402_111011_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142403_110915_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142403_111011_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142404_110915_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142404_111011_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142405_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142405_110905_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142406_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142406_110905_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142407_110820_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142407_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142408_111223_R_OW.tif	12	2011	RapidEye	Year 2	RapidEye
RE2142501_111008_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142501_111012_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142502_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142502_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142503_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142503_111011_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142504_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142504_110828_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142505_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142505_110915_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142506_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142508_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142601_110814_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142601_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142602_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142602_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142603_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142603_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142604_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142604_110915_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142605_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142606_110905_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142701_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142702_110814_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142702_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142703_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
RE2142703_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142704_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142704_111011_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142705_110905_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142706_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142801_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142802_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142802_111008_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142803_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142803_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142804_110828_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142805_110810_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142901_111030_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142902_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142903_111011_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2141605_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141605_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141606_111223_R_OW.tif	12	2011	RapidEye	Year 2	RapidEye
RE2141606_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141607_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141607_110806_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141608_110811_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141609_110811_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141705_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141705_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141706_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141706_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141707_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141707_111126_R_OW.tif	11	2011	RapidEye	Year 2	RapidEye
RE2141708_110811_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141708_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141709_110811_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141709_110930_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141805_110820_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141805_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141806_110820_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141806_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141807_110820_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141807_110923_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
RE2141808_111120_R_OW.tif	11	2011	RapidEye	Year 2	RapidEye
RE2141808_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141809_110930_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141809_110831_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141906_111205_R_OW.tif	12	2011	RapidEye	Year 2	RapidEye
RE2141906_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141907_110923_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141907_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141908_111105_R_OW.tif	11	2011	RapidEye	Year 2	RapidEye
RE2141908_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141909_110911_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141909_110930_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2141910_111006_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142007_110807_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142007_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142009_110911_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142010_111006_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142107_110827_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142107_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142108_110923_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142108_111126_R_OW.tif	11	2011	RapidEye	Year 2	RapidEye
RE2142109_111203_R_OW.tif	12	2011	RapidEye	Year 2	RapidEye
RE2142109_111006_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142110_111006_R_OW.tif	10	2011	RapidEye	Year 2	RapidEye
RE2142205_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142206_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142207_110812_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142207_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142208_110813_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142209_110813_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142210_110809_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142306_111205_R_OW.tif	12	2011	RapidEye	Year 2	RapidEye
RE2142306_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142307_110815_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142307_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142308_110813_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142305_110909_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142305_110905_R_OW.tif	09	2011	RapidEye	Year 2	RapidEye
RE2142008_110827_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
RE2142008_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142013_111229_R_OW.tif	12	2011	RapidEye	Year 2	RapidEye
RE2141814_110807_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141914_111109_R_OW.tif	11	2011	RapidEye	Year 2	RapidEye
RE2141614_111205_R_OW.tif	12	2011	RapidEye	Year 2	RapidEye
RE2141714_110807_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141613_110807_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141713_110807_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141614_111109_R_OW.tif	11	2011	RapidEye	Year 2	RapidEye
RE2140608_110831_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140808_110831_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140807_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140708_110830_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140707_110817_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140707_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2140706_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141009_110805_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2141009_110831_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
RE2142507_110808_R_OW.tif	08	2011	RapidEye	Year 2	RapidEye
MODIS					
MO_h12v08_111210_MO.hdf	12	2011	MODIS Terra	Year 2	USGS
MO_h11v08_111203_MO.hdf	12	2011	MODIS Terra	Year 2	USGS
ESA ASAR					
AS_46303_0001_110107_GF.tiff	1	2011	ASAR	Year 2	ESA
AS_46303_0002_110107_GF.tiff	1	2011	ASAR	Year 2	ESA
AS_46461_0003_110118_GF.tiff	1	2011	ASAR	Year 2	ESA
AS_46461_0004_110118_GF.tiff	1	2011	ASAR	Year 2	ESA
AS_46461_0005_110118_GF.tiff	1	2011	ASAR	Year 2	ESA
AS_46734_0006_110206_GF.tiff	2	2011	ASAR	Year 2	ESA
AS_46734_0021_110206_GF.tiff	2	2011	ASAR	Year 2	ESA
AS_46935_0022_110220_GF.tiff	2	2011	ASAR	Year 2	ESA
AS_46935_0023_110220_GF.tiff	2	2011	ASAR	Year 2	ESA
AS_47165_0007_110308_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47165_0008_110308_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47165_0009_110308_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47208_0010_110311_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47366_0011_110322_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47366_0012_110322_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47481_0013_110330_GF.tiff	3	2011	ASAR	Year 2	ESA

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
AS_47481_0014_110330_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47481_0015_110330_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47596_0016_110407_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47596_0017_110407_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47596_0018_110407_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47596_0019_110407_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47596_0020_110407_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47165_0406_110308_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47208_0407_110311_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47481_0408_110330_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47639_0363_110410_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47639_0364_110410_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47639_0365_110410_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47639_0366_110410_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47639_0367_110410_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47639_0368_110410_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47639_0369_110410_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47711_0370_110415_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47711_0409_110415_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47711_0371_110415_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47754_0372_110418_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47754_0410_110418_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47754_0373_110418_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47754_0374_110418_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47754_0375_110418_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_48070_0411_110510_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48070_0376_110510_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48070_0377_110510_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48070_0412_110510_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48070_0378_110510_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48142_0379_110515_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48142_0413_110515_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48142_0380_110515_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48185_0381_110518_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48185_0420_110518_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48185_0382_110518_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48185_0383_110518_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48185_0421_110518_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48185_0384_110518_GF.tiff	5	2011	ASAR	Year 2	ESA

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
AS_48185_0385_110518_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48228_0386_110521_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48228_0422_110521_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48300_0387_110526_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48300_0388_110526_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48343_0423_110529_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_48458_0389_110606_GF.tiff	6	2011	ASAR	Year 2	ESA
AS_48458_0390_110606_GF.tiff	6	2011	ASAR	Year 2	ESA
AS_48616_0424_110617_GF.tiff	6	2011	ASAR	Year 2	ESA
AS_48616_0391_110617_GF.tiff	6	2011	ASAR	Year 2	ESA
AS_48616_0392_110617_GF.tiff	6	2011	ASAR	Year 2	ESA
AS_49320_0414_110805_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49320_0393_110805_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49320_0394_110805_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49363_0395_110808_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49363_0396_110808_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49363_0397_110808_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49435_0398_110813_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49435_0399_110813_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49435_0400_110813_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49435_0401_110813_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49593_0402_110824_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49593_0302_110824_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49593_0304_110824_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49593_0305_110824_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49593_0415_110824_GF.tiff	8	2011	ASAR	Year 2	ESA
AS_49952_0306_110918_GF.tiff	9	2011	ASAR	Year 2	ESA
AS_49952_0307_110918_GF.tiff	9	2011	ASAR	Year 2	ESA
AS_50225_0416_111007_GF.tiff	10	2011	ASAR	Year 2	ESA
AS_50225_0308_111007_GF.tiff	10	2011	ASAR	Year 2	ESA
AS_50225_0309_111007_GF.tiff	10	2011	ASAR	Year 2	ESA
AS_50225_0417_111007_GF.tiff	10	2011	ASAR	Year 2	ESA
AS_50656_0310_111106_GF.tiff	11	2011	ASAR	Year 2	ESA
AS_50656_0311_111106_GF.tiff	11	2011	ASAR	Year 2	ESA
AS_50656_0418_111106_GF.tiff	11	2011	ASAR	Year 2	ESA
AS_50656_0312_111106_GF.tiff	11	2011	ASAR	Year 2	ESA
AS_50656_0301_111106_GF.tiff	11	2011	ASAR	Year 2	ESA
AS_50656_0303_111106_GF.tiff	11	2011	ASAR	Year 2	ESA
AS_50814_0419_111117_GF.tiff	11	2011	ASAR	Year 2	ESA

Dataset	Month	Year	Sensor	Mapping Stream	Data Provider
AS_50814_0405_111117_GF.tiff	11	2011	ASAR	Year 2	ESA
AS_47165_0406_110308_GF.tiff	1	2011	ASAR	Year 2	ESA
AS_47208_0407_110311_GF.tiff	1	2011	ASAR	Year 2	ESA
AS_47481_0408_110330_GF.tiff	1	2011	ASAR	Year 2	ESA
AS_47639_0363_110410_GF.tiff	2	2011	ASAR	Year 2	ESA
AS_47639_0364_110410_GF.tiff	2	2011	ASAR	Year 2	ESA
AS_47639_0365_110410_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47639_0366_110410_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47639_0367_110410_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47639_0368_110410_GF.tiff	3	2011	ASAR	Year 2	ESA
AS_47639_0369_110410_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47711_0370_110415_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47711_0409_110415_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47711_0371_110415_GF.tiff	4	2011	ASAR	Year 2	ESA
AS_47754_0372_110418_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_47754_0410_110418_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_47754_0373_110418_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_47754_0374_110418_GF.tiff	5	2011	ASAR	Year 2	ESA
AS_47754_0375_110418_GF.tiff	5	2011	ASAR	Year 2	ESA

Appendix 4

GIS (Spatial) Datasets

Existing GFC GIS Geo-database layers

Feature Class	Feature Dataset	Created/ Update freq	Description
Admin	GY_Boundary_2009	August 2010	Updated country boundary for Guyana.
Agricultural Leases	GFC_AGLeases	August 2010	Agricultural lease areas as provided by GL&SC
Amerindian Areas	Ameridian_ areas_GL&SC	NA	Titled Amerindian areas in Guyana. Divided into administrative regions. From GL&SC.
	Amerindian_areas_GL_SC_Year2	February 2012	Update to Amerindian areas in Guyana as provided by GL&SC.
FIRMS	Historical_Fire_Locations	August 2010	Historical point locations of fires as derived from the MODIS based FIRMS dataset.
	Year1_Fire_Locations	August 2010	FIRMS Point fire locations for year 1 analysis from October 2009 – October 2010
	Year2_Fire_Locations	January 2012	FIRMS Point fire locations for year 2 analysis from October 2012 – December 2011
Forest Reserves	Bio_reserves_dd_Iwokrama	August 2010	Designated forest reserves Iwokrama and Kaieteur.
	Bio_reserves_dd_Kaiteur	August 2010	
Hydro	waterbody	August 2010	Waterbodies layer, digitised from geocorrected Landsat imagery.
Managed Forest Areas	State_Forest_2006	2006	Layer showing state forest boundary.
	TSA_WCL_Merged	6 monthly	A merged layer showing all active TSA's and Wood Cutting Leases (WCL) (large forest concessions)
	activeSFEP_Merged	6 monthly	A merged layer of all active State Forest Exploratory Permits.
	activeSFPs_Merged	6 months	Active State Forest Permits (small forest concessions). By Division – Demerara, Essequibo, Berbice, North West
	logging_Camps	NA	Point location of logging camp sites, based on the Annual Operating plan.
	harvest_Areas	NA	Polygons showing extent of harvest activities (pre 2008, 2008 & 2009)
Mining Areas	LRG_Scale_Aug2010_Region	6 months	Point file showing mining dredge sites and polygon file showing medium to large scale mining and planned mining areas.
	MED_Scale)Aug2010_region		
	Mining_dredges and Mining Reconnaissance areas		
Population	Municipalities	Aug2010	Polygon file showing area covered by the municipalities of Guyana
	Placenames		Point file showing places of interest
Roads	gps roads_dd	3-6 months	All GPS roads and trails as at August 2010.
Soil &Vegetation	soil_data	1960s	National Soil map of Guyana. produced by NARI.
	GY_Vegetation_Map	2001	National vegetation map of Guyana. Produced by Dr ter Steege.
REDD Datasets	GY_Forest_Degradation_Year1	2010	Buffer Generated Year 1 degraded forest areas.
	GY_Intact_Forest	2010	Year 1 initial IFL layer

	GY_Intact_Forest_Y2_Update	2011	Year 2 Updated IFL Layer
	GY_Land_Classes	2010	Year 1 administrative land class layer
	GY_Land_Classes_Y2	2011	Year 2 update to Year 1 administrative land class layer
	GY_LandClass_Non_Forest	2010	Year classes split by forest and non-forest areas.
	GY_Land_Classes_NonF_Rivers_Y2	2011	Year 2 land classes of forest non forest areas updated for year 2 areas.
	GY_NonForest_Rivers	2010	1990 Non Forest areas and Rivers as produced from Landsat data.
	Master_Change_Detection	2011	Master landcover change layer from year 1 analysis and year 2 update consolidated
	Y3_Improvement_Process_LandChange	2011	Incomplete preliminary dataset that will be the starting point for the Y3 improvement processes.
Persistent Cloud Layers	Persistent_cloud		The area covered by cloud in all available image data sets.
	Persistent_cloud_over_noChange_area	April 2012	Persistent cloud coverexcept over those areas which were mapped as non-forest earlier.
	Pre_Y2_change_area		Area that were mapped as non-forest earlier.
	Cloud_block1_2	April 2012	Persistent cloud cover except over those areas which were mapped as non-forest earlier in respective blocks
	Cloud_block3	April 2012	
	Cloud_block4	April 2012	
	Cloud_block5	April 2012	
	Cloud_block6	April 2012	
	Cloud_landsat_area	April 2012	

2011 Forest Concession Datasets held by GFC

Directory	Shapefile Name	Created/ Updated	Description
AMS-TSA0685			
	Blocks Inventoried& harvested_2011.shp	2011	These are blocks that were proposed in Annual Operational Plan (AOP) were inventoried in 2011 and harvested.
	blocks_logged_2010_re-entry2011.shp	2010	These were blocks that were approved and logged in 2010 that did not utilise the maximum allowable cut and the remainder of volume was logged in 2011.
	Blocks_to_be_Inventoried_2011.shp	2011	These are block for 100% pre-harvest inventory.
	Replacement_blocks_to_be_harvested_2011.shp	2011	Switched blocks proposed for harvesting.
	roads to be maintained_2011.shp	2011	Roads constructed in previous/current years for maintenance.
	Sign_Boards.shp	2011	It identifies the boundaries of concession, notices and or block numbers of the concession.
BCL-TSA0491			
	Blocks_approved_2010_reapplied_2011.shp	2010	These blocks were approved in 2010 , however since harvesting operations were not conducted they were reapplied for in 2011.
	Blocks_for_enumeration_2011.shp	2011	These are blocks for 100% pre-harvest inventory.
	Blocks_for_harvest_2011.shp	2011	Blocks to be harvested for operational year.
	Enumeration_retag_for_2011_harvest.shp	2011	100% pre-harvest was re-done by company and proposed for harvesting in operational year.
	Existing_Roads.shp	2010	These are roads that were constructed to provide needed access to the forest.
	Existing_Sub_Camp.shp	2011	This is a temporary camp to house employees.
	Incomplete_2010_reapplied_2011.shp	2011	These blocks were approved in 2010, however since harvesting operations were not conducted they were reapplied for in 2011.
	Proposed_road.shp	2011	These are roads that are proposed for construction.
	Proposed_Roads.shp	2011	These are roads that are proposed for construction.
	Roads_annual_plan.shp	2011	These are roads that are proposed for construction in operational year.
DTL-TSA0291			
	blks to be harvested 2011.shp	2011	Blocks to be harvested for operational year.
	blks to invent 2011_harvest 2011 if necess.shp	2011	These are blocks for 100 % pre-harvest inventory to be harvested in operational year.
	Signposts.shp	2011	It basically identifies the boundaries of concession, notices and or block numbers of the concession.
DTL-TSA0391			
	Blocks_approved_harvesting_2010-to_be_harvested_2011.shp	2011	These blocks were approved in 2010 , however since harvesting operations were not conducted they were reapplied for in 2011.
	Blocks_Inventoried_2010_to_be_harvested_2011.shp	2011	These are blocks where 100 % pre-harvest inventory was carried out and to be harvested in operational year.
	Blocks_partially_harvested_2010-to_be_harvested_2011.shp	2011	These were blocks that were approved and logged in 2010 that did not utilise the maximum allowable cut and the remainder of volume is to be logged in operational year.
	Blocks_to_be_Inventoried_2011_to_be_harvested_2012.shp	2012	These are 2011 inventoried blocks proposed for harvesting in operational year 2012.
	Existing_Roads.shp	2011	These are roads that were constructed to provide needed access to the forest.
	Roads_constructed&maintained_2011.shp	2011	Roads constructed in previous/current years for maintenance.

	Sign_boards.shp	2011	It basically identifies the boundaries of concession, notices and or block numbers of the concession.
FEL-TSA0100			
	Base_Camp.shp	2011	Usually permanently built buildings for administrative and operational purposes within the concession that controls the operations of the company in the forest.
	Blks_to_be_harvested_2011_revised.shp	2011	Blocks to be harvested for operational year.
	Blocks_to_be_harvested_2011.shp	2011	Blocks to be harvested for operational year.
	Blocks_to_be_Inventoried_2011.shp	2011	These are blocks for 100% pre-harvest inventory.
	Roads_to_be_constructed_&_maintained_2011.shp	2011	Roads constructed in previous/current years for maintenance.
	Sign_Boards.shp	2011	It basically identifies the boundaries of concession, notices and or block numbers of the concession.
Ganesh Singh Blks-A-TSA0109			
	Base_Camps.shp	2011	Usually permanently built buildings for administrative and operational purposes within the concession that controls the operations of the company in the forest.
	Blocks_Inventoried_2010_to_be_harvested_2011.shp	2011	These are 2010 inventoried blocks proposed for harvesting in operational year 2011.
	Blocks_to_be_Inventoried_2011.shp	2011	These are blocks for 100% pre-harvest inventory.
	Re-entry_Blocks_2011.shp	2011	These were blocks that were approved and logged in 2010 that did not utilise the maximum allowable cut and the remainder of volume was logged in 2011.
	Road_to_be_constructed_&_maintained_2011.shp	2011	Roads to be constructed and maintained in current year.
	Sign_Boards.shp	2011	It basically identifies the boundaries of concession, notices and or block numbers of the concession.
Haimorakabra Logging-TSA0111			
	Base_camp.shp	2011	Usually permanently built buildings for administrative and operational purposes within the concession that controls the operations of the company in the forest.
	blk re-enum 2011 har2012.shp	2012	These are blocks for 100% pre-harvest inventory to be re-done and harvested 2012.
	blk to be har 2011.shp	2011	Blocks to be harvested for operational year.
	Existing_Road.shp	2011	These are roads that were constructed to provide needed access to the forest.
	Forward_camp.shp	2011	These are temporarily constructed near to blocks to be harvest in the operational year.
IFI-TSA0385			
	Additional Blocks to be Harvested_2011.shp	2011	Request of additional Blocks for harvest in the operational year to facilitate company's business operation
	Base_camp.shp	2011	Usually permanently built buildings for administrative and operational purposes within the concession that controls the operations of the company in the forest.
	Blocks to be Harvested_2011_rev.shp	2011	Blocks to be harvested for operational year.
	Blocks_to_be_harvested_2011.shp	2011	Blocks to be harvested for operational year.
	Blocks_to_be_Inventoried_2011.shp	2011	These are blocks for 100% pre-harvest inventory.
	Existing_Roads.shp	2011	These are roads that were constructed to provide needed access to the forest.
	Forward_Camps.shp	2011	These are temporarily constructed near to blocks to be harvest in the operational year.
	Inventoried completed-proposed harvesting 2011.shp	2011	These are inventoried blocks proposed for harvesting in operational year.

	Proposed harvesting_2011.shp	2011	Blocks to be harvested for operational year.
	Re-entry_Blocks_2011.shp	2011	These were blocks that were approved and logged in 2010 that did not utilise the maximum allowable cut and the remainder of volume was logged in 2011.
	Roads_to_be_constructed_2011.shp	2011	Roads proposed to be constructed in operation year
	Roads_to_be_maintained_2011.shp	2011	Roads constructed in previous/current years for maintenance.
	Sign_Boards.shp	2011	It basically identifies the boundaries of concession, notices and or block numbers of the concession.
	twelve sub-eleven app 2011.shp	2011	Description pending
	twelve sub-five app 2011.shp	2011	Description pending
	Un Logged Blocks 2010 for harvesting2011.shp	2011	Approved Blocks not harvested in 2010 are proposed for harvesting in 2011
Jaling-TSA0205			
	Base_Camp.shp	2011	Usually permanently built buildings for administrative and operational purposes within the concession that controls the operations of the company in the forest.
	Blocks_to_be_harvested_2011.shp	2011	Blocks to be harvested for operational year.
	Blocks_to_be_Inventoried_2011.shp	2011	These are blocks for 100% pre-harvest inventory.
	Existing_main_Roads.shp	2011	These are roads that were constructed to provide needed access to the forest.
	Sign_Boards.shp	2011	It basically identifies the boundaries of concession, notices and or block numbers of the concession.
Kuruduni-TSA0297			
	5_Blocks to be harvesting_2011.shp	2011	Blocks to be harvested for operational year.
	Base_Camp.shp	2011	Usually permanently built buildings for administrative and operational purposes within the concession that controls the operations of the company in the forest.
	Blocks to be harvested_2011.shp	2011	Blocks to be harvested for operational year.
	Blocks_harvested_&Inventoried_2010_to_be_re-entered_2011.shp	2011	These were blocks that were approved and logged in 2010 that did not utilise the maximum allowable cut and the remainder of volume was logged in 2011.
	Blocks_Inventoried_2010_to_be_harvested_2011.shp	2011	These are 2010 inventoried blocks proposed for harvesting in operational year 2011.
	Blocks_to_be_Inventoried&harvested_2011.shp	2011	These are blocks where 100 % pre-harvest inventory will be carried out and also proposed for harvesting in operational year 2011.
	Re-entry Blocks.shp	2011	These were blocks that were approved and logged in 2010 that did not utilise the maximum allowable cut and the remainder of volume was logged in the following year
	Re-entry_blocks_2011.shp	2011	These were blocks that were approved and logged in 2010 that did not utilise the maximum allowable cut and the remainder of volume was logged in 2011.
	Roads_constructed_2010_to_be_maintained_2011.shp	2011	Roads constructed in previous/current years for maintenance.
	Roads_to_be_constructed_2011.shp	2011	Roads proposed and to be constructed in operation year
	Sign_boards.shp	2011	It basically identifies the boundaries of concession, notices and or block numbers of the concession.
Kwebanna-TSA0409			
	Base_camp.shp	2011	Usually permanently built buildings for administrative and operational purposes within the concession that controls the operations of the company in the forest.
	Blocks to be harvested 2011.shp	2011	Blocks to be harvested for operational year.

	Blocks_to_be_Inventoried_&Harvested_2011.shp	2011	These are 2010 inventoried blocks proposed for harvesting in operational year 2011.
	Existing_roads.shp	2011	These are roads that were constructed to provide needed access to the forest.
	Proposed_roads.shp	2011	These are proposed roads that are to be constructed to provide needed access to the forest.
	Replacement blks_2011.shp	2011	Switched blocks proposed for harvesting in 2011.
	Sign_boards.shp	2011	It basically identifies the boundaries of concession, notices and or block numbers of the concession.
Linear Woods-WCL0307			
	Base_camp.shp	2011	Usually permanently built buildings for administrative and operational purposes within the concession that controls the operations of the company in the forest.
	Blocks_to_be_harvested_2011.shp	2011	Blocks to be harvested for operational year.
	Blocks_to_be_Inventoried_2011.shp	2011	These are blocks for 100% pre-harvest inventory.
	Roads_to_be_constructed_2011.shp	2011	These are roads to be constructed 2011 to provide needed access to the forest.
	Roads_to_be_maintained_2011.shp	2011	Roads constructed in previous/current years for maintenance.
	Sign_Boards.shp	2011	It basically identifies the boundaries of concession, notices and or block numbers of the concession.
Nagasar Sawh-TSA0490			
	Base_Camp.shp	2011	Usually permanently built buildings for administrative and operational purposes within the concession that controls the operations of the company in the forest.
	Blocks_approved_for_harvested_2011.shp	2011	Blocks to be harvested for operational year.
	Blocks_to_be_Inventoried&_harvested_2011.shp	2011	These are blocks where 100 % pre-harvest inventory will be carried out and also proposed for harvesting in operational year 2011.
	Existing_Roads.shp	2011	These are roads that were constructed to provide needed access to the forest.
	Forward_Camps.shp	2011	These are temporarily constructed near to blocks to be harvest in the operational year.
	Re-entry_blocks_2011.shp	2011	These were blocks that were approved and logged in 2010 that did not utilise the maximum allowable cut and the remainder of volume was logged in 2011.
	Roads_constructed2010-to_be_maintained_2011.shp	2011	Roads constructed in previous/current years for maintenance.
	Sign_Boards.shp	2011	It basically identifies the boundaries of concession, notices and or block numbers of the concession.
Puruni Woods-TSA0107			
	Base_Camp.shp	2011	Usually permanently built buildings for administrative and operational purposes within the concession that controls the operations of the company in the forest.
	Blocks_to_be_Inventoried&_Harvested_2011.shp	2011	Blocks for 100 % pre-harvest inventory and also proposed for harvesting in operational year.
	Blocks_to_be_Inventoried_2011.shp	2011	These are blocks for 100% pre-harvest inventory.
	Roads_to_be_constructed_2011.shp	2011	These are constructed to provide needed access to the forest.
	Sign_Boards.shp	2011	It basically identifies the boundaries of concession, notices and or block numbers of the concession.
Roads_Nov29			
	Roads.shp	2011	These are constructed to provide needed access to the forest and are obtained using GPS tracking

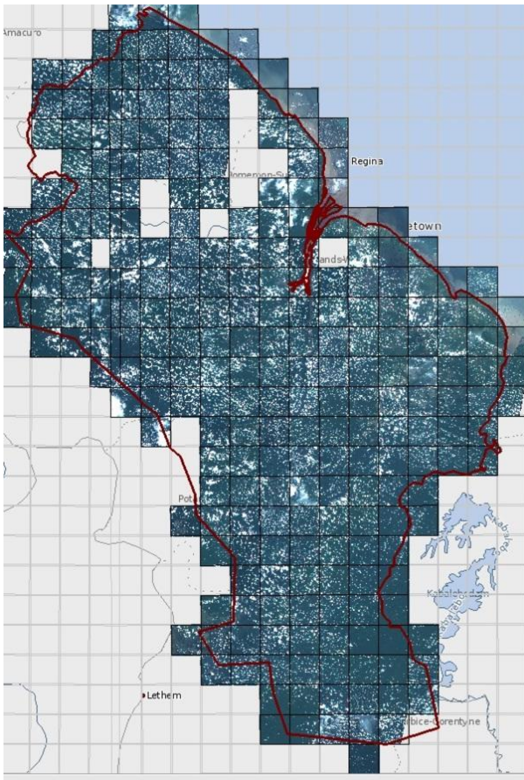
TPL-Manaka-TSA0485			
	Additional_Blocks_to_be_harvested.shp	2011	Request of additional Blocks for harvest in the operational year to facilitate company's business operation
	Base_Camp.shp	2011	These are permanently built within the concession that controls the operations of the company in the forest.
	blks 2 b harv 2011.shp	2011	Blocks to be harvested for operational year.
	Blks_to_be_harvested_2011_revised.shp	2011	Blocks to be harvested for operational year.
	Blocks_to_be_harvested_2011.shp	2011	Blocks to be harvested for operational year.
	Blocks_to_be_Inventoried_2011.shp	2011	These are blocks for 100% pre-harvest inventory.
	Forward_Camp.shp	2011	These are temporarily constructed near to blocks to be harvest in the operational year.
	FTC-Base_Camp.shp	2011	Forest Training Centre
	Replacement_Blocks.shp	2011	Switched blocks proposed for harvesting.
	Roads_to_be_Maintained-2011.shp	2011	Roads constructed in previous/current years for maintenance.
	Sign_Boards.shp	2011	It basically identify the blocks, concession boundaries and/or notices.
TPL-Takatu-TSA0485			
	Blocks_to_be_Harvested_2011.shp	2011	Blocks to be harvested for operational year.
Vaitarna Holdings-TSA0110			
	Blocks_to_be_Inventoried&Harvested_2011.shp	2011	Blocks for 100 % pre-harvest inventory and also proposed for harvesting in operational year.
	Forward_Camp.shp	2011	These are temporarily constructed near to blocks to be harvest in the operational year.
	Road_to_be_constructed_2011.shp	2011	Roads proposed to be constructed in operation year
	Sign_Boards.shp	2011	It basically identify the blocks, concession boundaries and or notices.
VW&GH Ltd-WCL0107			
	Blocks_Inventoried_2010_to_be_harvested_2011.shp	2011	These are 2010 inventoried blocks proposed for harvesting in operational year 2011.
	Blocks_to_be_Inventoried_2011.shp	2011	These are blocks for 100% pre-harvest inventory.
	Forward_Camp.shp	2011	These are temporarily constructed near to blocks to be harvest in the operational year.
	Notice_Boards.shp	2011	It basically identify the blocks/concession and or notices.
	Replacement_block.shp	2011	Switched blocks proposed for harvesting.
WAICO-TSA0199			
	Additionals_Blocks_approved_harvested_2011.shp	2011	Request of additional Blocks for harvest in the operational year to facilitate company's business operation
	Blocks_approved_harvesting_2010_to_be_harvested_2011.shp	2011	These are 2010 inventoried blocks proposed for harvesting in operational year 2011.
	Blocks_inventoried_2010_to_be_harvested_2011.shp	2011	These are 2010 inventoried blocks proposed for harvesting in operational year 2011.
	Existing_Roads_to_be_Maintained_2011.shp	2011	Roads constructed in previous/current years for maintenance.
	Forward_Camps.shp	2011	These are temporarily constructed near to blocks to be harvest in the operational year.
	GFC_Camp.shp	2011	These are permanent structures within the concession for GFC personnel.
	Main_Camp.shp	2011	These are permanently built within the concession that controls the operations of the company in the forest.

	Proposed_signboards.shp	2011	Proposed signs to identify the blocks/concession
Wanatobo-TSA0507			
	Base_Camp.shp	2011	Usually permanently built buildings for administrative and operational purposes within the concession that controls the operations of the company in the forest.
	Blocks_Inventoried_2010_to_be_harvested_2011.shp	2011	These are 2010 inventoried blocks proposed for harvesting in operational year 2011.
	Blocks_to_be_Inventoried&harvested_2011.shp	2011	Blocks for 100 % pre-harvest inventory and also proposed for harvesting in operational year.
	Blocks_to_be_Inventoried_2011.shp	2011	These are blocks for 100% pre-harvest inventory.
	Existing_roads_to_be_maintained_2011.shp	2011	Roads constructed in previous/current years for maintenance.
	Forward_Camp.shp	2011	These are temporarily constructed near to blocks to be harvest in the operational year.
	Main_roads_to_be_maintained_2011.shp	2011	Roads constructed in previous/current years for maintenance.
	Proposed_Forward_Camp.shp	2011	These are proposed temporary camps near to blocks to be harvest in the operational year.
	Road_to_be_constructed_2011.shp	2011	Roads proposed to be constructed in operation year
	Secondary_roads_to_be_maintained_2011.shp	2011	Roads constructed in previous/current years for maintenance.
	Signboards.shp	2011	It basically identifies blocks and concession boundaries and or notices.
WTT-TSA0191			
	Base_Camp.shp	2011	Usually permanently built buildings for administrative and operational purposes within the concession that controls the operations of the company in the forest.
	Blocks_Inventoried_2010_to_be_Harvested_2011.shp	2011	These are 2010 inventoried blocks proposed for harvesting in operational year 2011.
	Blocks_to_be_Inventoried&Harvested_2011.shp	2011	These are blocks that were proposed in Annual Operational Plan (AOP) were inventoried in 2011 and harvested.
	Road_to_be_maintained_2011.shp	2011	Roads constructed in previous/current years for maintenance.
WTT-TSA1085			
	Base_Camp.shp	2011	Usually permanently built buildings for administrative and operational purposes within the concession that controls the operations of the company in the forest.
	Blocks_Inventoried_2010_to_be_harvested_2011.shp	2011	These are 2010 inventoried blocks proposed for harvesting in operational year 2011.
	Blocks_to_be_Inventoried&Harvested_2011.shp	2011	
	Major_Roads_Maintenance_2011.shp	2011	Roads constructed in previous/current years for maintenance.
	Re-entry_Blocks__2011.shp	2011	These were blocks that were approved and logged in 2010 that did not utilise the maximum allowable cut and the remainder of volume was logged in 2011.
	Roads_to_be_Constructed_2011.shp	2011	Roads proposed to be constructed in operational year
	Roads_to_be_Maintained_2011.shp	2011	Roads constructed in previous/current years for maintenance.
	Signboards.shp	2011	It basically identifies the boundaries of concession/notices and or block numbers of the concession.

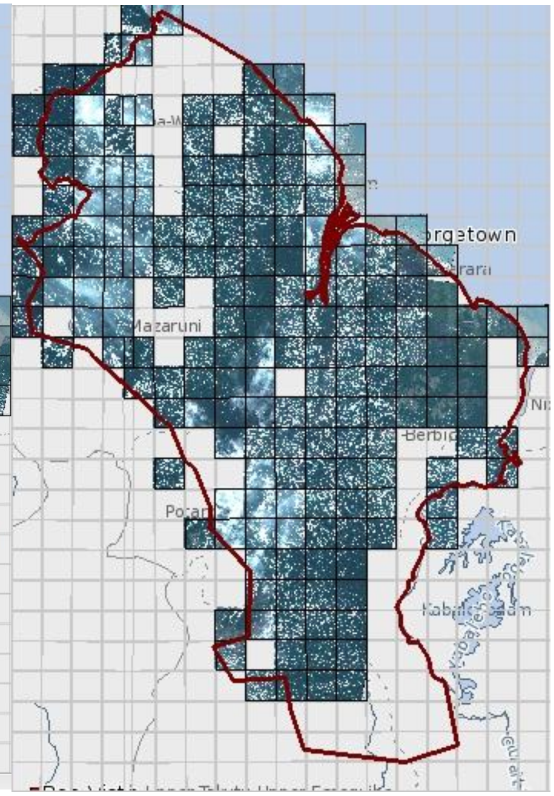
Appendix 5

Monthly RapidEye Acquisitions

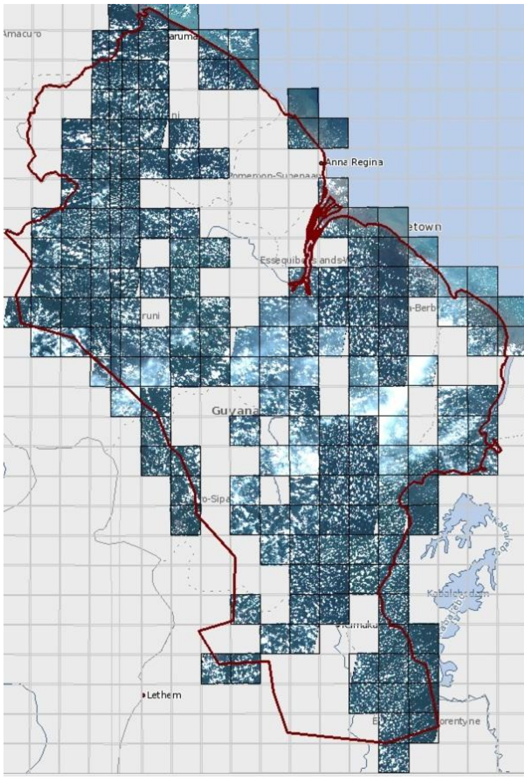
August RapidEye Coverage

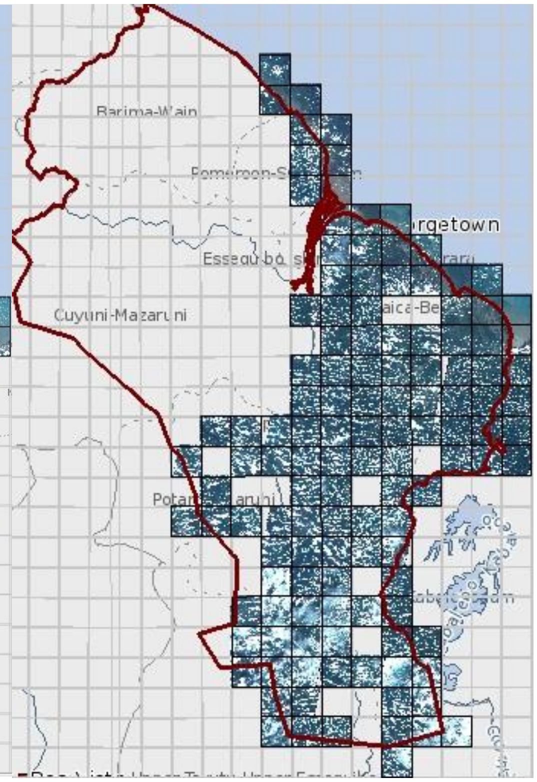


September RapidEye Coverage

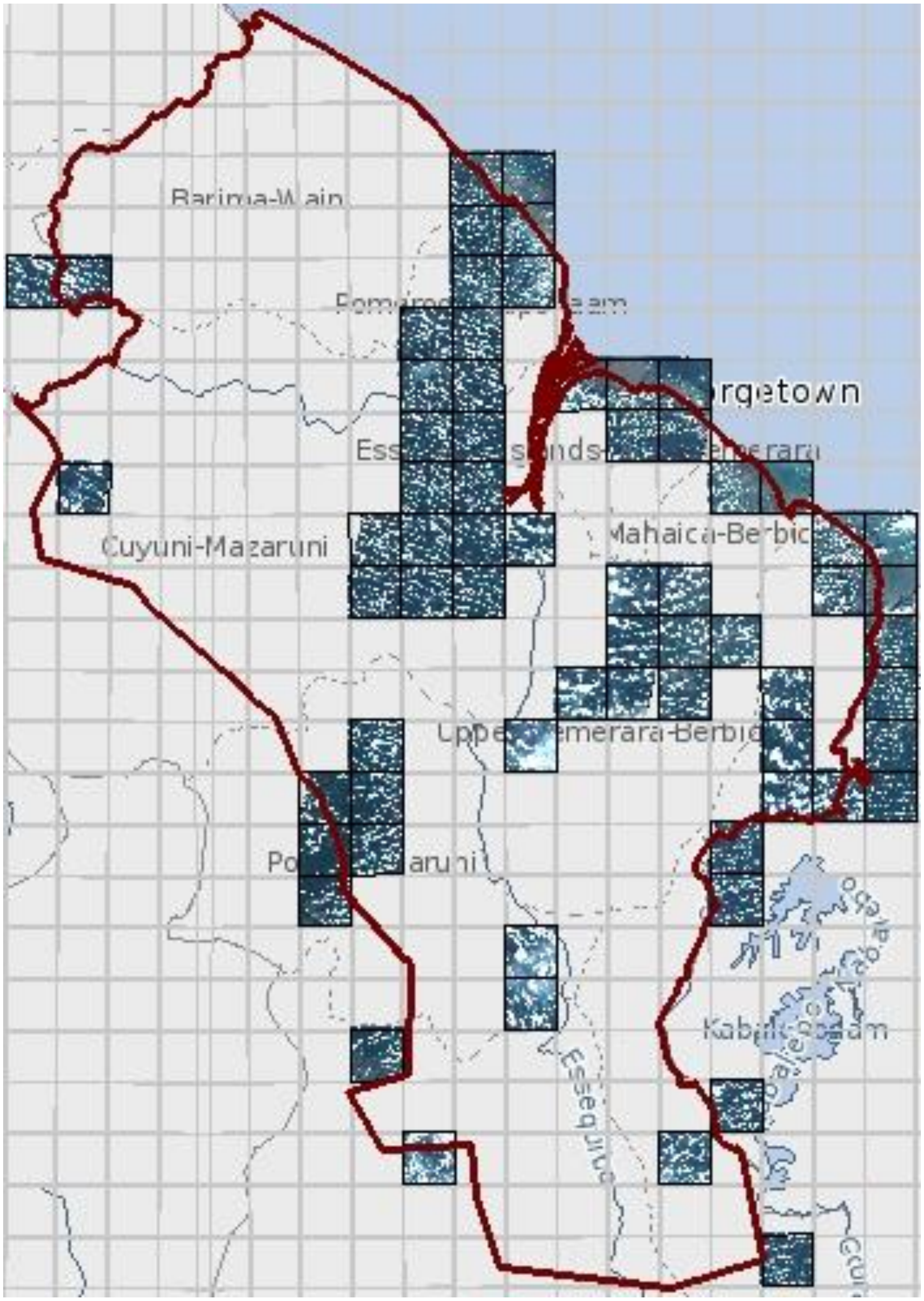


October RapidEye Coverage **November RapidEye Coverage**





December RapidEye Coverage



Appendix 6

Land use Classes

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.

- 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).

- 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.

- 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

- 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.

- 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

- 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	2010 map classes
Forest Land	Mixed forest	1 to 1.4 & 1.8	Class 1
	Wallaba/Dakama/Muri Shrub Forest	2 to 2.6	Class 2
	Swamp/Marsh forest	3.1 to 3.3	Class 3
	Mangrove	4.1	Class 4
	Savannah >30% cover	5, 6	Class 5
	Montane & steep forest	1.5 -1.7[51], 7.1, 7.2. 8.1	Class 6
	Plantations	Locations in GFC's GIS	Area insignificant
Grassland	Savannah <30% cover	Non forest classes grouped and not mapped out individually	
	Grassland		
Cropland	Cropland		
	Shifting Agriculture		
Wetland	Wetland open water		
	Herbaceous wetland		
Settlements	Settlements		
Other land	Other land		

Previous 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.

[51] This class (1.7) has also been identified as potentially threatened by fire.

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 in to the National Map on the basis of the regional FIDS maps. In other cases large forest areas classified to be wet forest were reclassified into mixed forest in accordance with FIDS coverage.

In the South West 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[52]. 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).

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[52]The rivers base layer has subsequently been improved as part of the MRVS implementation

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 4).

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 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 Shrub 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

1. Open swamps

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

2. 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.

3. 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, either 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* 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 – 1500m, 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 (1500-2000m) 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.

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Appendix 7

Applied Geosolutions and Winrock International Report on A Pilot Study to Assess Forest Degradation Surrounding New Infrastructure

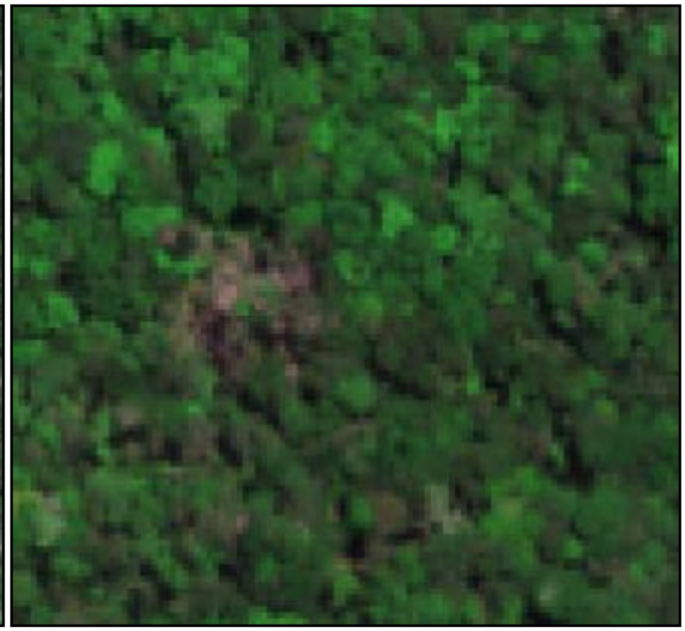
APPLIED GEOSOLUTIONS

A Pilot Study to Assess Forest Degradation Surrounding New Infrastructure

Report Submitted to Guyana Forestry Commission

By

W. Salas, S. Hagen, B. Braswell, and M. Palace

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Winrock International

February 2012

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EXECUTIVE SUMMARY

This report explores technical methods for detecting and quantifying forest degradation using satellite remote sensing image data. The ultimate goal of these methods is to enable reliable space-based measurements of greenhouse gas impacts associated with the creation of new infrastructure. This report examines both traditional and experimental remote sensing techniques, and compares results based on using high resolution data. Although high resolution data are somewhat more costly and less readily available, they can detect changes on the scales of individual trees. With moderate resolution data that is cheaper and more readily available, the finer details must be indirectly inferred.

We found that both high-resolution and moderate resolution imagery can be used to discriminate logged versus unlogged areas, but that the high-resolution results are more accurate and show more promise for quantifying the extent of removal.

With the moderate resolution remote sensing we compared a number of techniques for measuring degradation in two separate cases: (1) degradation as a function of time since logging, and (2) degradation as a function of buffer distance from a new road. The two cases are related in that the buffer distance analysis used statistics calibrated from the logging analysis. The principal comparison was between change metrics derived from spectral unmixing ("Souza method") and change metrics using simple vegetation indices such as enhanced vegetation index (EVI). We found that methods using EVI performed at least as well as the more complex linear unmixing techniques, though a comprehensive evaluation would require more field based data.

The results of the study on degradation as a function distance from roads showed that nearly all of the degradation associated with new infrastructure occurred in the first 100 m buffer around the road. The fact that the radius of observable degradation seen in this analysis is limited to only 100 meters is not surprising given that significant losses of trees, and associated biomass, in principle should only be associated with direct effects of installing new infrastructure. Indirect effects will be limited to subtle changes in forest structure and biogeochemistry and will be due to: (1) drying from increased exposure; (2) altered turbulence and wind patterns; (3) invasion of gap species, out-competing low light species; and (4) temperature changes. All of these factors occur at close proximity to the edge itself and require actual penetration of altered light and moisture regimes into the canopy at distance. Therefore, viable mechanisms for removing biomass carbon in the 10-50% range would require large scale extraction of stems and crownsthathas been demonstrated to be visible in the remote sensing imagery.

One implication of these results is that satellite imagery whose resolution, cost, and availability sits in between the high resolution and Landsat scales (e.g. RapidEye) might provide the ability to use and/or merge technical approaches that are currently used for just one or the other data type. Another implication is related to the specific open source tools that were employed to perform the analysis which shows potential for development of relatively low-cost automated systems.

Background Issue

From the Joint Concept Note on REDD+ cooperation between Guyana and Norway carbon loss as indirect effect of new infrastructure is addressed as follows: "The establishment of new infrastructure in forest areas often contributes to forest carbon loss outside the areas directly affected by construction. Unless a larger or smaller area or greenhouse gas emission impact can be documented through remote sensing or field observations, the area within a distance extending 500 meters from the new infrastructure (including mining sites, roads, pipelines, and reservoirs) shall be accounted with a 50% annual carbon loss through forest degradation."

Objectives of this pilot project

Forest degradation is defined as a change in forest quality and condition (e.g. reduction in biomass), while deforestation is a change in forest area. Our premise is that if we can detect logging at various levels of intensity equivalent to less than 50% removal, then we can apply this approach to examine degradation surrounding new infrastructure. For this preliminary degradation analysis, we examine two Landsat 5 TM images and two high-resolution scenes from GeoEye andQuickbird from central Guyana. The TM scenes include several concessions, in logging compartments and the high resolution scenes are contained within the region of the concessions. The goal is to examine areas known to be recently logged (i.e. degraded) and quantify the signal in the remote sensing data from this activity. In this analysis, we compare pre-logging imagery to imagery acquired approximately post-logging. Our specific objectives and tasks are:

1. Evaluate the use of high resolution (<1meter) optical data for mapping changes in canopy gap fraction and crown size distribution.
2. Evaluate the effectives of vegetation index change detection and spectral un-mixing of moderate resolution optical data (e.g. Landsat) for assessing forest degradation. Tree inventory data from logging is used to assess degree of degradation for calibrating and validating spectral un-mixing.
3. Apply and evaluate vegetation index change detection and spectral un-mixing in areas surrounding new infrastructure to assess the degree of forest degradation.
4. Assess impact of scaling from high resolution imagery to moderate resolution Landsat imagery for distinguishing logged versus unlogged forest.

Task 1: Evaluate the use of high resolution (<1meter) optical data for mapping changes in canopy gap fraction and crown size distribution

1.1 Gap-fraction Change Analyses

The purpose of the task was to evaluate the potential for high spatial resolution remote sensing data (~1 meter) to be used to detect disturbance and quantify removals associated with logging in a tropical forest. The spatial domain of this analysis is a small portion of the concession in mid-southern Guyana. This area was selectively logged annually from 2008-2011. We used available high resolution imagery from November 2010 (from GeoEye) and November 2011 (from QuickBird), an interval that we assume brackets the 2011 logging, to detect and estimate formation of new gaps based on observed patterns of the panchromatic imagery. The image data were co-registered to a resolution of 0.5 m to facilitate our analysis across the two data sources. No additional pre-processing of this imagery was performed prior to analysis. All the analysis and visualization for this section was performed using open source software, i.e., custom Python code for analysis and Quantum GIS for visualization.

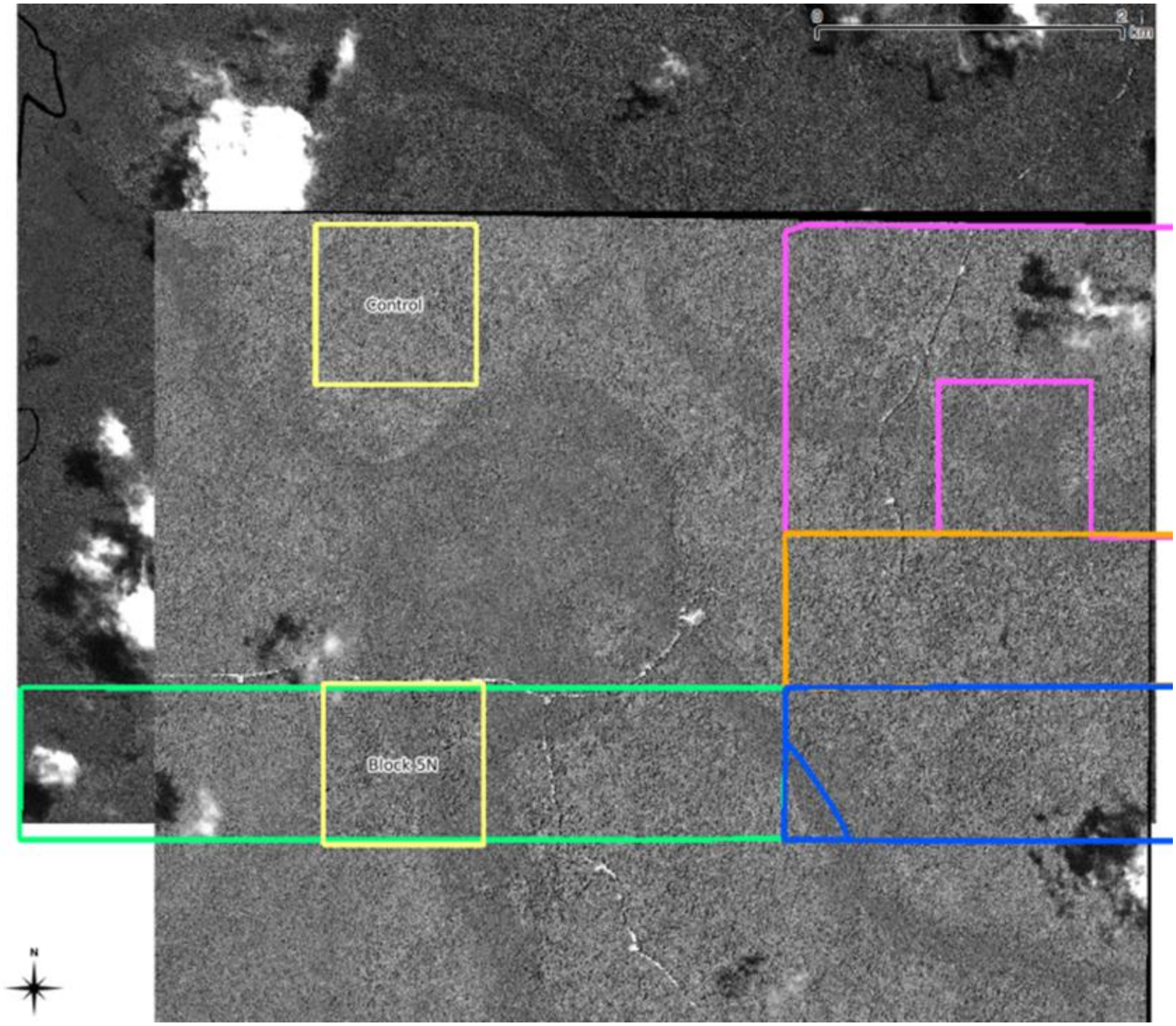


Figure 1. Two high resolution scenes co-registered with logging concessions overlaid (2008=orange; 2009=pink; 2010=blue; 2011=green). The yellow squares correspond to our initial gap detection analysis regions (northern = control block; southern = logging block 5N). High resolution remote sensing data were only available for 2010 and 2011.

The ground-based data set used in this part of the analysis was the set of pre-harvest inventory point vector files. This data set contains the location, DBH, and species for hundreds of trees within each logging block. While this data set could not be used directly to compare with imagery, it was extremely valuable for deriving several working assumptions regarding the likely spatial distribution of logged trees, and inferred properties of the logged trees, including crown area and biomass.

We used a simple three step, two parameter image processing analysis designed to detect the formation of new gaps that are large enough to be associated with logging. First the data are thresholded, locating all dark pixels by comparing brightness values to a prescribed threshold value. The threshold parameter is given in terms of overall brightness percentile value. This threshold is meant to identify and select the darkest pixels of the image as representing shadows, potentially associated with canopy caps. The result of the thresholding is a binary image corresponding to gaps and non-gap pixels. Note that this calculation is in some sense scene-independent because the threshold parameters are relative, not absolute, percentile values. Therefore normalization is not necessary. Second, a binary closing morphological operator was then applied to the thresholded images to remove small gaps. This function uses a circular-shaped structure array of a specified length scale (structure size parameter). The structure size parameter corresponds to the minimum allowed gap size. Further details on parameter selection are provided in the next paragraph. The third and last step is to re-grid the binary gap images to 50 x 50 m tiles and calculate the difference between pre- and post-logging gridded “gapiness”.

Parameter selection was undertaken as objectively as possible. We used a structure size of 14 pixels (~38.5 m2; area = pi * r^2 = pi * (0.5 m * (14 pixel diameter/2))^2) in all cases. The structure size of 14 was chosen to be commensurate with mean tree crown size, inferred from the available inventory data using allometric relationship: WIDTH = 1.19 + 0.17*DBH (unpublished data Maria Hunter). This resulted in the elimination of all new gaps smaller than 37 m2. The percentile brightness threshold value was selected, using structure size of 14, and varying the brightness threshold over a large but plausible range (1 - 2%; i.e. the darkest 1 - 2 percent of the pixels) based on visual inspection. From this range we selected the threshold showing greatest difference in total new gap fraction between the control block and logging block 5N (1.2%).

The results of the gap change analysis area are as follows. Note that by "gap" we are referring to contiguous areas of shadow detected larger than the area roughly corresponding to the structure size parameter. Various factors can lead to differences in detected gaps, including illumination and atmospheric conditions. The estimated gap area pre-logging was zero. Visual inspection of the area confirms that, though there are a number of smaller gaps in this block, there appear to be no gaps larger than the chosen minimum area. The estimated gap area (and also change in area) was 10,636 m2 (1.64 Ha). The resulting gap sizes, produced as an intermediate product of the analysis, were in the range of 37 - 211 m2 (note the minimum area is roughly the value calculated based on the structure parameter as expected), with a mean of 71 m2. The number of new gaps formed was 150, considerable fewer than the approximate number of trees removed (roughly estimated to be 427 trees based on the ratio of max allowable cut to inventory volume). However, we note that logging practices often fell trees into existing gaps in an effort to avoid secondary hits of trees and also aid in the removal of logs with skidders (personal observation). Also, the number of inventory trees in 50 x 50 m tiles with estimated gap change greater than zero was 408, very close to the approximate number of trees removed. Using a field based relationship between gap size and carbon removed (provided by Winrock International) of 0.106 tC m^{-2}, we estimate a removal of 1,127 t C in Block 5N in 2011.

In order to evaluate our estimate of carbon removed from block 5N between the two image dates, we produced two independent estimates of carbon removed based on inventory data and a few general assumptions. First, we used the mean crown area based on the above-mentioned allometric relationship applied to the inventory data (83 m^2), combined with the estimated number of trees removed (427) and the Winrock gap-carbon ratio (0.106 tC m^{-2}) to estimate a carbon removal of 3,757 tC. Second, we used an assumed wood carbon density of 0.47*667 kg m^{-3} and multiplied this number by the max allowable cut (833 m3), to get an estimated carbon removed of 261 tC. The regional value used for the density of living wood in this case is from Chave et al. 2006. We further adjust this value up by a factor of 2.7 to account for the emissions associated with collateral disturbance based on a Winrock analysis, which yields an estimate of 783 tC. This roughly factor of 5 difference in carbon removed based on the ancillary non-remote sensing information (783 - 3,757) is larger than expected but likely related to the grossness of the assumptions made. In any case, our remote sensing based estimate of 1,127 falls somewhat between the two independent estimates.

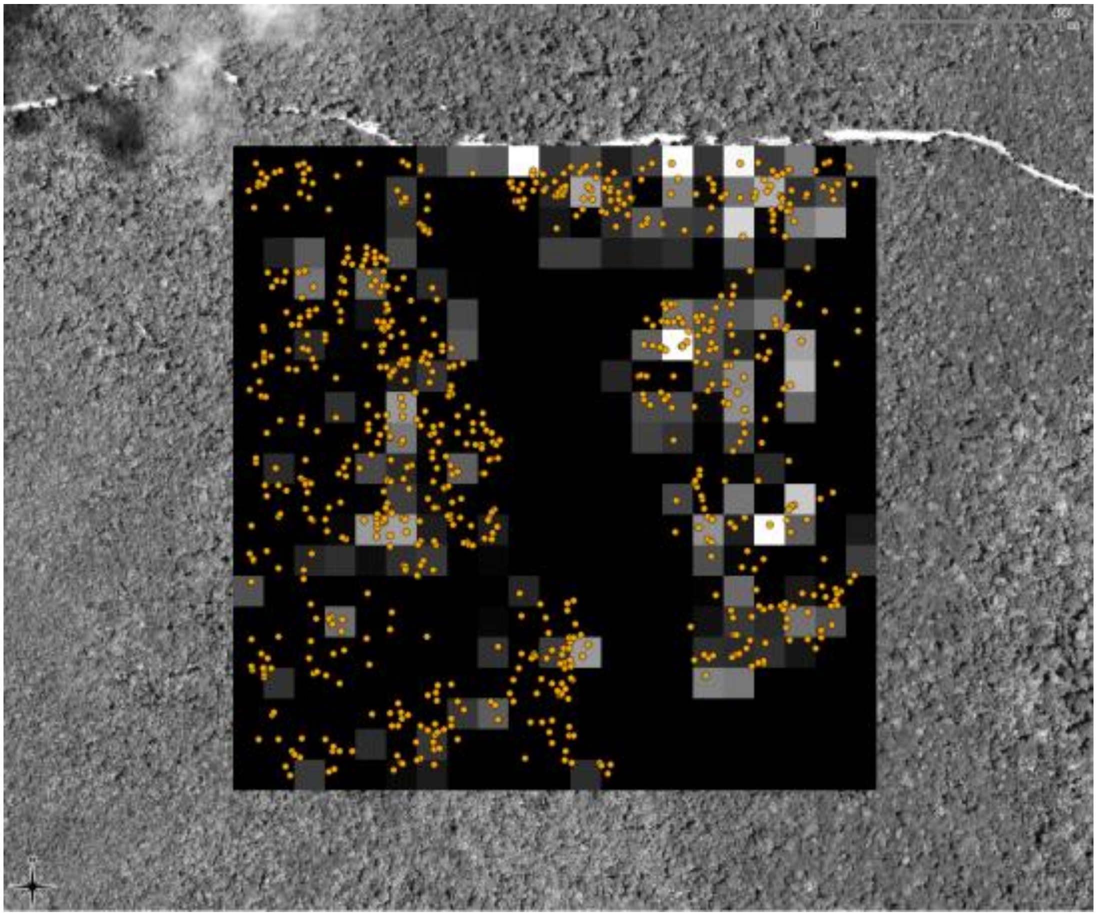


Figure 2. Close view of the 1 x 1 km logging block 5N showing the inventory trees, and the result of the gap analysis algorithm. Bright cells (grey-to-white) show as much as 0.1-10% new large gap area formed in the period bracketing the logging in this area.

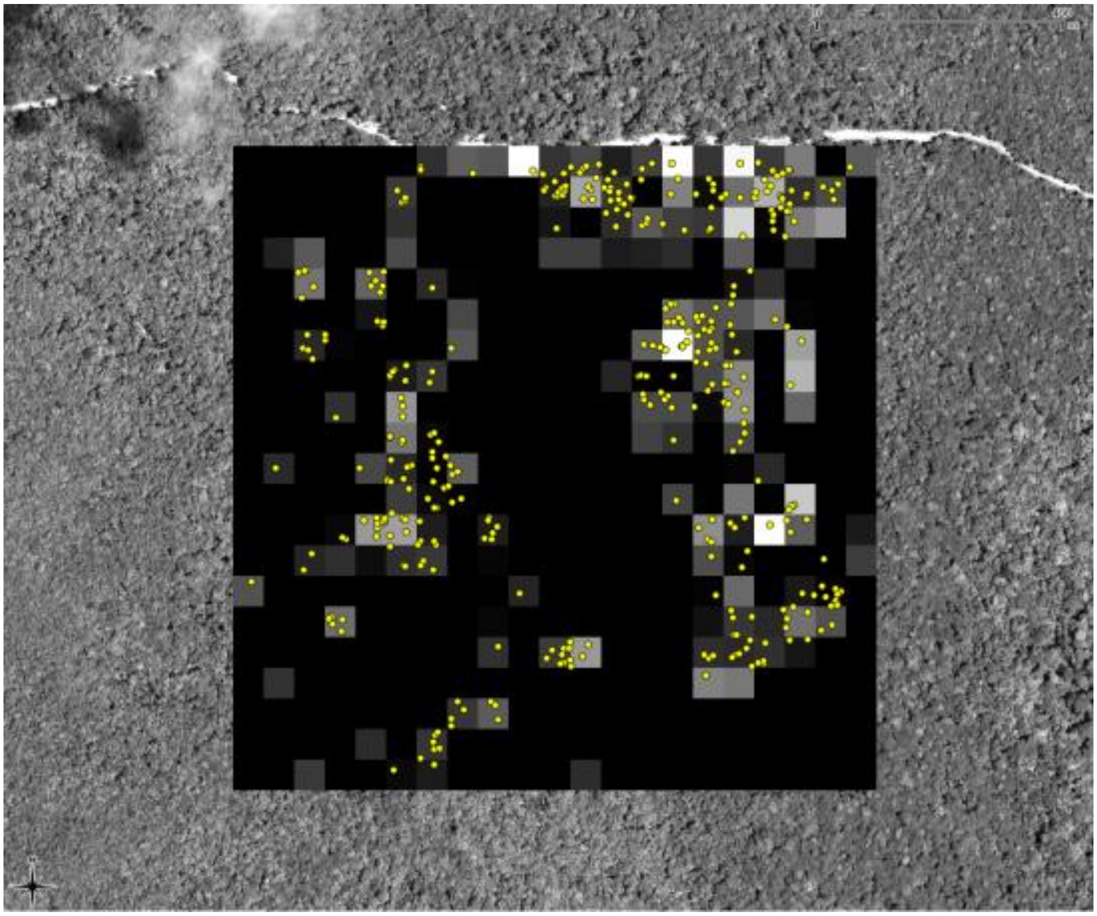


Figure 3. Same view of the gap analysis in Block 5N, except showing the spatial distribution of selected inventory trees, subsetted to yield approximately the amount of volume removed (822 m3) and a best fit with the gap results.

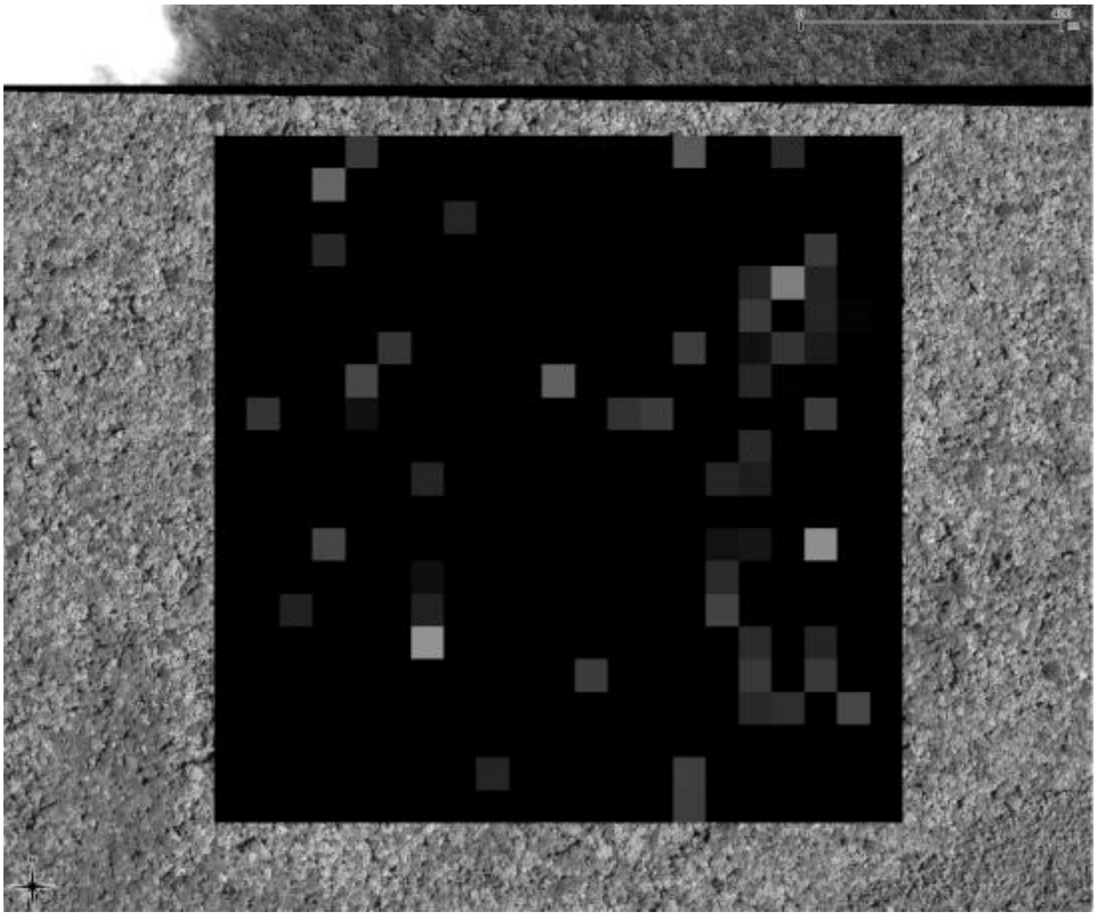


Figure 4. The gap change analysis results for the control block (compare with Figure 3). Note that this block was selected subjectively based on distance from the new roads and other disturbance that can be seen in the post-logging image. We do not know if this block was logged before or between the imagery dates. The estimated gap area before logging is 318 m2, and after logging is 2,848, so the change is about 2,530 which is roughly a quarter of the change observed in the 5N block. See also Figure 5.

Because the spatial patterns of disturbance change estimated from the remote sensing are not directly comparable with the inventory data, we iteratively removed trees from the inventory database from individual 50 x 50 m cells within which the image analysis showed no new gap formation. This resulted in 408 trees with a spatial pattern matching more closely (by design) the pattern of the image analysis (Figure 3). These inventory points were converted to an image by convolution with a Gaussian kernel of size commensurate with the assumed mean crown area of 38 m2. The resulting correlation between the gap change detection image for 5N and the sub-setted inventory image was still quite low ($R^2 = 0.24$).

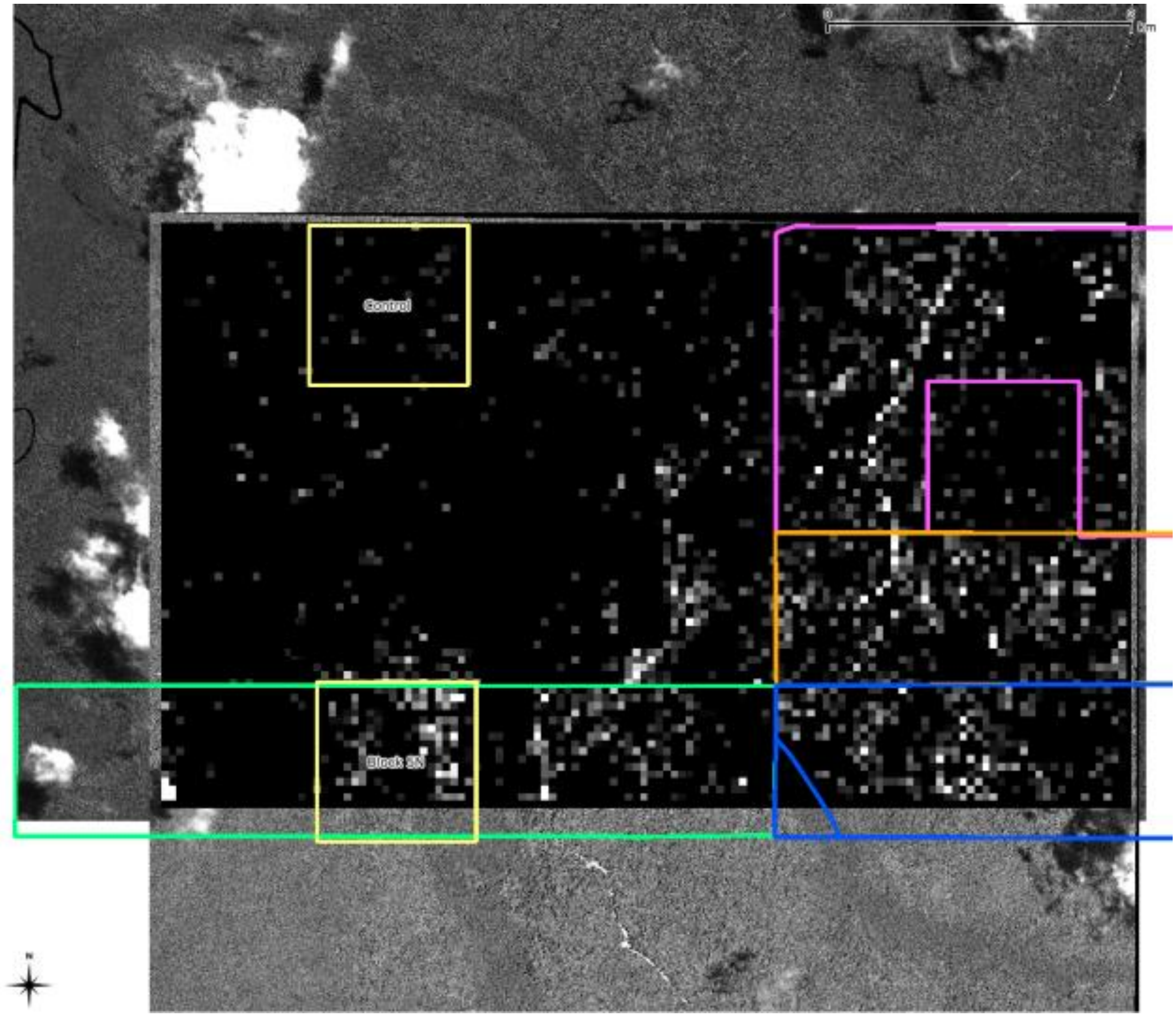


Figure 5.Same view of the imagery as in Figure 1, showing the logging concessions, two regions of interest (control, and Block 5N), and an overlay of the results of the gap analysis for the entire area of overlap between the pre- and post-logging scenes. The new disturbance in 2011 and the persistent effect of the road and somewhat reduced effect of the logging in previous years can be clearly seen.

We were able to use the high resolution imagery to detect and to some extent quantify the degree of logging disturbance in one portion of the logging concession (Figure 5). We applied an image processing sequence to detect changes in large canopy gaps based on the spatial distribution of dark/ shadowed pixels in the scene. A more comprehensive evaluation of the skill of the approach, and of parameter selection could be performed with additional data (co-located high resolution imagery over known areas of forest degradation). The spatial scale of the reported results in this case was 50 x 50 meters to be large enough to capture image registration uncertainty and to be close to the spatial scales of tree removal. The effects of the choice of this grid size could also be evaluated in future work. The areas of the greyscale overlay in Figure 5 show the detected gap change for the entire overlap of the two high resolution scenes. The grey-to-white cells show approximately 5-10% of the area of that cell (125 - 250 m2) formed new large canopy gaps. Our focus in this report has been on a case study of logging block 5N, but we can also see significant disturbance in the areas previously logged (2008 - 2010), as well as disturbance associated with the new road. Interestingly, the intensity of new gap formation appears to be as high in the previously logged areas as in the newly logged ones. We do not know if there was repeat logging in the pre-2011 areas. A timeline of removal for all the areas would help improve our understanding of the limits of detectability of this approach. One possible explanation for the observed changes in the pre-2011 logged areas is that the observed shadows associated with canopy gaps appeared to be lengthened by differences in sun-sensor geometry. For the 2010 scene, the view elevation angle was 70 degrees and the sun elevation was 67 degrees. For the 2011 scene, the view elevation angle was 83 degrees and the sun elevation was 61 degrees. There was very little change in solar angle, which would directly affect the inferred gap distribution. The approximately 10 degree difference in view angle is somewhat more difficult to interpret but could possibly lead to differences in observed shadows in the scene.

There are a number of significant issues and uncertainties associated with evaluating quantitative estimates of carbon removal using high resolution data, some general, and some specifically related to this work. Note that we believe all the following uncertainties could be addressed appropriately with additional data and evaluation. First, limited data were available on the spatial distribution of trees extracted within blocks (52 stumps total, most not in Block 5N). The pre-harvest inventories were available for only two 1x1 km2 blocks (5N and 7N), and pre-harvest inventory volumes approximately two times max allowable. Only two high resolution scenes were available to capture pre- and post-logging conditions, with a scene overlap of only 25 km2. There was significant cloud cover in the pre-logging scene, especially over block 7N. Thus, the analysis scope was limited primarily to Block 5N. Somewhat less importantly, the high-resolution scenes are from instruments with different spatial resolutions (0.5 and 0.6 m). For evaluation purposes, no information was available on areas where logging did not occur within scenes. Lastly, there are conceptual uncertainties regarding definitions of removed volume versus disturbed volume regarding the difference between field measured gaps and satellite estimated gaps.

Subsequent analyses would benefit greatly from additional imagery for testing, but the most critical data for improved quantitative estimates would be spatially explicit and co-located information on trees removed, the degree of disturbance (gap area observed from the ground associated with a large spatial sample) and the amount of wood/ carbon removed.

Additional work would focus on refining the image processing technique, testing the ability of the approach to retrieve gap fraction under known (or simulated) conditions, and evaluating the sensitivity and means of selecting the parameters (e.g. threshold and minimum gap size). Clearly the focus would be not just on refining the currently quite good detection skill, but to also provide improved skill estimating carbon removed. Also, we would develop a means to quantify the uncertainty in the technique, allocating likely errors to sources, including georegistration, illumination/ viewing and atmospheric conditions, and spatial scale, where possible. Alternate methods would also be evaluated, including statistical approaches that use image texture and pattern detection algorithms. Specifically we are interested in the relationship between traditional image processing based methods (e.g. the current analysis), and methods which identify and characterize individual features of the image, either gaps, crowns, or both. In the next section we present an application of a crown detection algorithm to the concession's high resolution data set. As this approach is refined in future work, it will be important to understand how to interpret the results quantitatively in terms of trees removed and carbon emitted. Finally we would also explore how the image analysis and pattern detection methods might be used synergistically to obtain better results.

1.2 Crown Detection Algorithm Analysis

We ran an automated crown characterization algorithm (Palace et al. 2008, Broadbent et al. 2008, Gonzalez et al. 2010) on block 5N and three blocks assumed to be unlogged. This algorithm combines local maximum and minima finding methods. Three parameters can be varied in the algorithm, the derivative threshold (method for determining local minima),endmax (smallest local maximum analyzed), and drop amount (the percent difference from the local maximum). We set the derivative threshold at 0.01, endmax at 0.30, and the drop amount at 0.6. These values gave reasonable estimates of tree numbers and average crown widths based on field based studies done in the tropics (Asner et al. 2001). We note a lack of field based data from this region in the tropics and stress the limitation of the crown delineation algorithm. Because of this limitation in application, we used this algorithm specifically to examine changes in forest canopy as an indicator of forest degradation due to selective logging.

We ran the algorithm on both the pre-logging GeoEye image and the post-logging Quickbird image. This included both a logged area and three control areas in an effort to account for the changes in crowns estimated due to image differences. The algorithm performed slightly differently between the two images due to differences in sun angle and overall crown shadowing. Areal density of trees was different between the two images, so we used the normalized crown distribution as a method for comparing logged and control areas.

We found that the mean crown radius metric decreased 0.7 m in the logged area and 0.3 m in the control areas. Error bars are not provided for the logged results because there was only one logged block for comparison. We also compared the difference in normalized crown width frequency (number of individuals) for each individual crown radius bin. Logged areas showed an increase in the number of smaller trees and fewer medium to larger trees when compared to the three control blocks (Figure 6). The increase in smaller trees is likely due to the removal of larger trees, thereby exposing smaller understory trees. The decrease in the medium sized trees is likely due to direct removal of trees due to logging. Our automated crown characterization appears to discern differences in forest structure due to logging in tropical forests, although further testing is recommended.

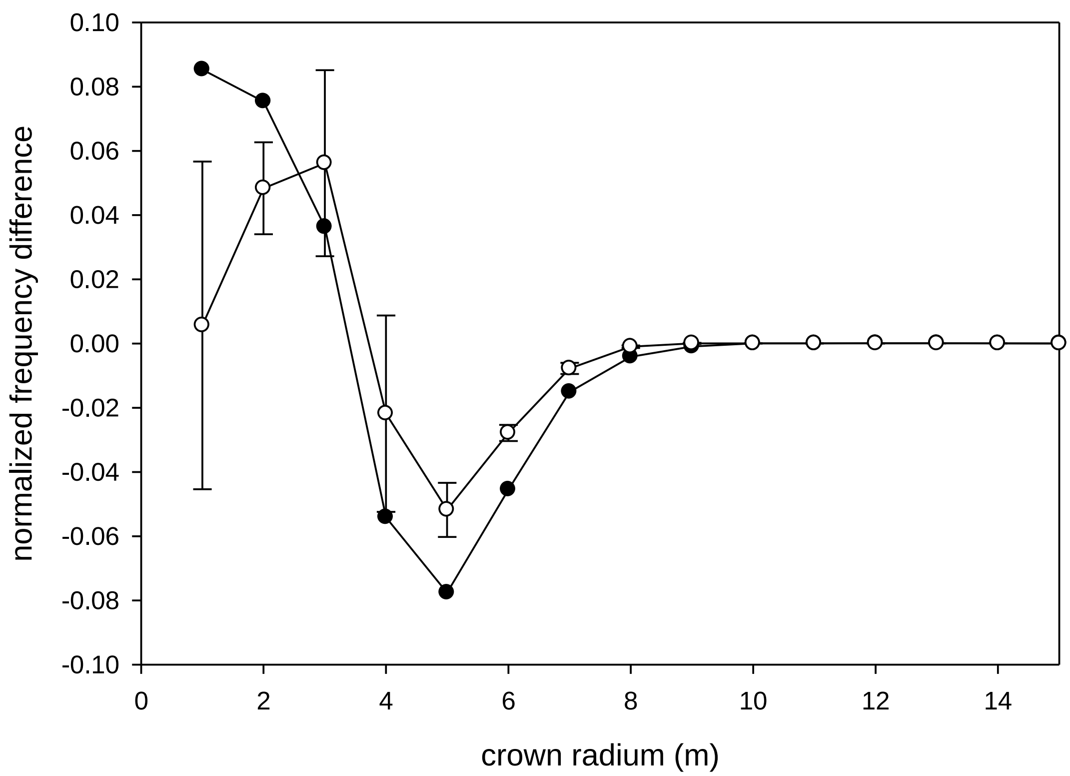


Figure 6. Normalized differences in crown frequency for crown radius (m) estimated from our crown characterization algorithm. Black circles represent the logged area 5N and open circles are three control areas. Error bars are standard deviation.

1.3 Texture Analyses

We explored the use of textural methods that examine the spatial relationship of pixel values as a means to discern logged areas and begin to quantify carbon loss due to selective logging. We examined lacunarity (gapiness of image), entropy, semi-variance, standard deviation and mean as moving windows, and power spectrum analysis.

We ran these textural analyses on both the pre-logging GeoEye image and the post-logging Quickbird image. This included both a logged area and three control areas in an effort to account for the changes in canopy estimated due to image differences. All analyses were run at window size of 50 pixels. We then calculated the difference in estimated values between pre-logging and post-logging images. We found a poor relationship for all methods when comparing the difference between images and the kernel developed to indicate where logged trees would impact the canopy. Entropy performed the best of all methods but was still poor. Due to this poor response we did not further explore this as a means for estimating canopy damage and indirectly carbon loss due to selective logging. The methods were useful in teasing out some forest structure on the landscape scale.

1.4 Cost and Availability of High-Resolution Data

The utility of high-resolution data for large-scale inventories is limited by cost and availability (small footprint and revisit frequency). In addition, monitoring work that requires new tasking and repeated samples over a number of years requires even a higher investment of time and cost. For the purposes of informally evaluating this cost, we assumed that a sample size of 5 percent of the land area of Guyana (~9889 km2) is needed for examination for forest degradation. We used this baseline area to estimate the total cost for various high-resolution satellite imagery. The table below shows the cost for tasking satellites for new imagery. Archived imagery is 20-40% less expensive, but note that archived coverage of Guyana is currently relatively low with most of these data sets situated along the coast. Thus, for our hypothetical 5% sample size the total cost would be US$197-375K for new tasking and US$98-316K for archived data.

Platform	Cost per sq km	Resolution / Data Type
Ikonos	$20	1m pan, 4m 4-band MS
GeoEye-1	$25	50cm pan, 2m 4-band MS
Quickbird	$23	50 - 60cm pan + 2m - 2.4m 4-band MS Bundle
WorldView 1	$20	50 - 60cm pan + 2m - 2.4m 4-band MS Bundle
WorldView 2	$35	2m 8-band MS
WorldView 2	$38	50cm pan + 2m 8-band MS Bundle

Acquiring cloud and cloud shadow free image data is also a major concern. Based on work by Asner (2001) and others we assume a low probability of clear images for a given location in the forested areas of Guyana, with nearly zero probability during the wet seasons. As an example, for this report, we tasked the Quickbird satellite for a new acquisition over our study area in Guyana, starting in the dry season. It took four attempts to acquire a relatively cloud free image, so in this case we have an "effective" repeat frequency of 1 month, but this time will vary due to the request queue and off-nadir view angle tolerance.

Task 2 Application of spectral un-mixing of moderate resolution optical data for assessing forest degradation

In this section we describe the step-by-step approach for using spectral unmixing to assess changes in canopy characteristics as an indicator for forest degradation. For this analysis we used two co-registered Landsat 5 TM scenes from 2005 and 2011.

Step 1: Image pre-processing

Our first step in this analysis is the conversion of the original digital numbers to radiance values using the gain and offset, followed by a conversion of these values to top-of-the-atmosphere reflectances using sun sensor geometries. The geometric registration as conducted by the USGS was of sufficient accuracy via a comparison between visible roads and the road vectors provided by the Guyana Forest Commission (GFC) and the two images were confirmed to be co-registered via examination of roads and rivers within a half of a pixel (i.e., 15 meters). Clouds and cloud shadows were identified and masked.

Note: In this analysis, we applied a post processing normalization to the data. The analysis included areas known to have been both affected (i.e., logged) and unaffected (i.e. not logged) within the same Landsat path/row. All measurements of effects are compared against the baseline of unaffected areas. This made unnecessary a full image-to-image normalization. In future work across multiple TM scenes an image normalization would be critical and we would suggest using a basic Chavez (1996) COST method.

Step 2: Image processing

We estimated the subpixel mixture of four components in the pre- and post-logging imagery using a linear mixture analysis (See Asner et al. 2002 and Souza et al. 2005 for technical details of this mapping logging with spectral un-mixing of moderate resolution data). The four components include photosynthetic vegetation (PV), non-photosynthetic vegetation (NPV), soil, and shade. We conducted two separate analyses, one for the pre-logging image and one for the post-logging image. Endmembers, or pixels best representing pure examples of these four components, were selected in each image using a pixel purity index (ENVI software). This routine identified approximately 600 pixels in each image as candidate pure pixels. We clustered these pure pixels into four classes using a k-means clustering algorithm (R software). The mean spectral response of each cluster was used as the endmember spectral response and the data from the two years were averaged to calculate a mean spectral response for each endmember (Figure 7). This library of endmember spectral response was used in a linear mixture analysis (ENVI software) to estimate the fractional components within each pixel in each image. Pixels with negative fractions were truncated to zero and the fractions within each pixel were reapportioned by dividing the fraction by the sum of the four components on a pixel-by-pixel basis. At this stage, we have fractional mixtures between 0 and 1 summing to 1.0 for each pixel for pre- and post-logging.

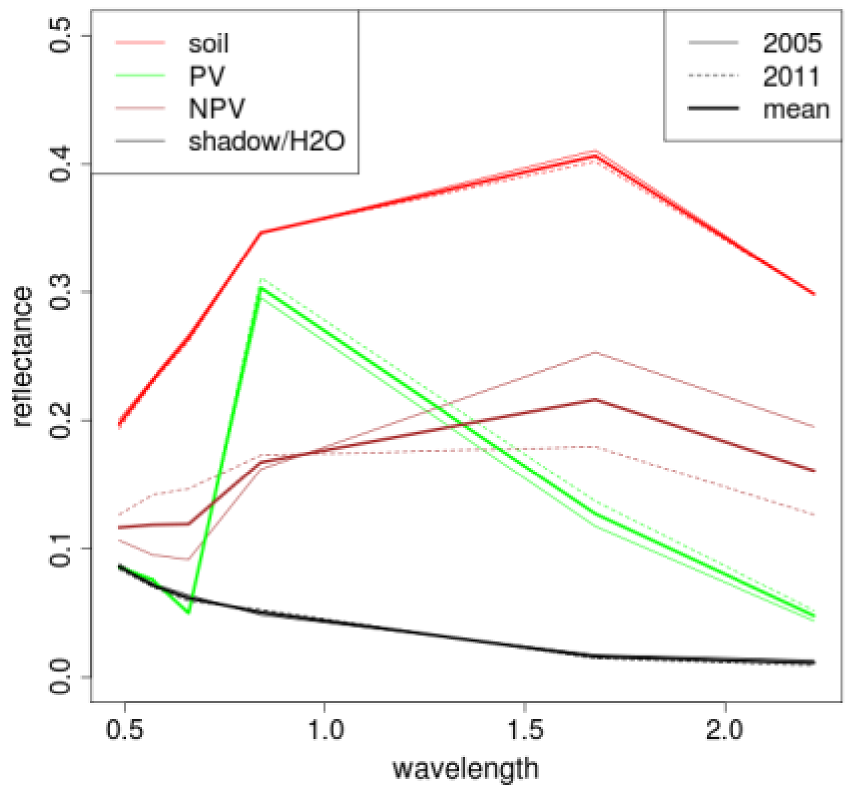


Figure 7.Endmember spectralreflectances for each Landsat scene show significant differences in NPV only; soil, PV, and shadow (or water) are consistent from scene to scene.

From these mixtures, we calculate two metrics to be used in the degradation analysis:

(1) NPVSoil = NPV + Soil

(2) NDFI = $(GV_{shade}$ - NPVSoil) / $(GV_{shade}$ +NPVSoil),

where

$GV_{shade} = PV_{100}$ - Shade

Additionally, we calculated the enhanced vegetation index (EVI) for each image, using the following canonical formula:

EVI = 2.5 * (NIR – RED) / (NIR + 6.0 * RED - 7.5 * BLUE + 1.0)

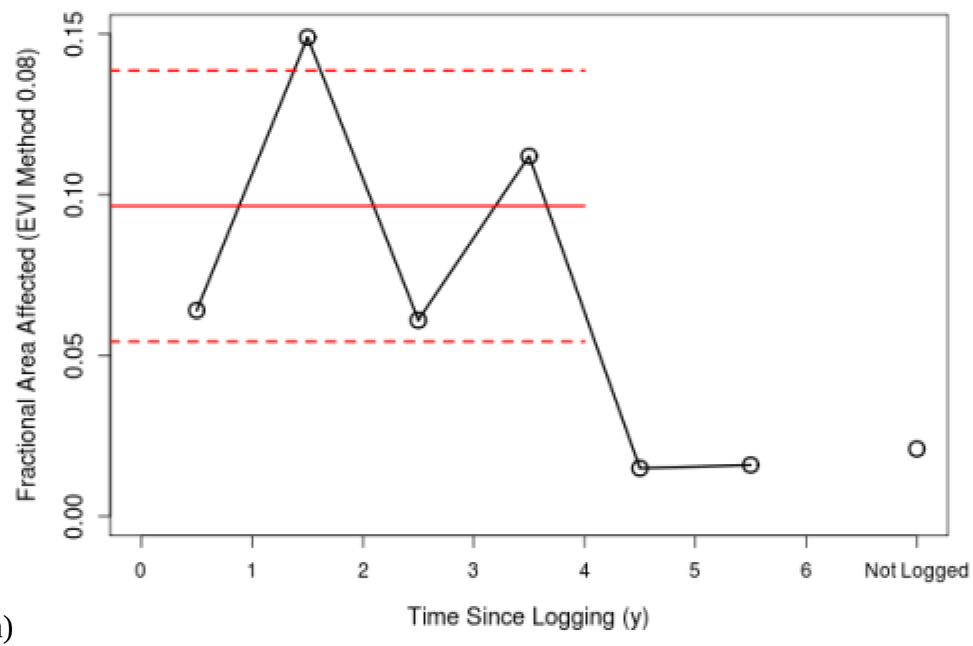
Wang et al. 2005 examined the utility of using several similar indices of greenness (e.g. EVI, NDVI, MSAVI) for mapping degradation. While the group chose to focus on the use of MSAVI because of the results of a hypothetical model, their work demonstrates that simple vegetation indices can be used to map degradation in tropical forests, which we test here using EVI.

Step 3 Compilation of field data

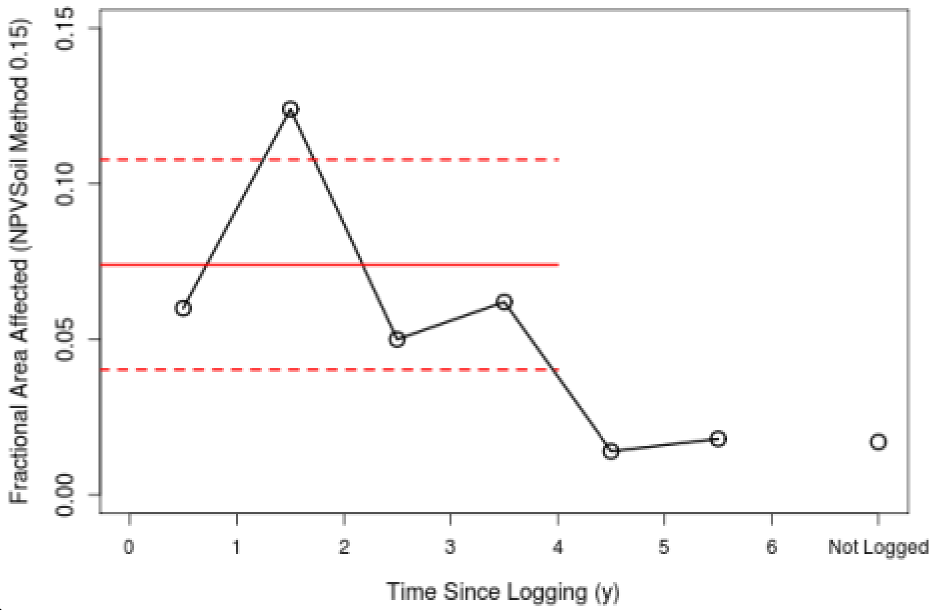
Based on data from GFC we have boundary information for blocks harvested each year from 2006 to 2011 (used also in the high-resolution analysis as described above). We also have identified the location of new roads and mining activity occurring between 2005 and 2011 and manually digitized these into a vector database. This database is used to group pixels in subsequent analyses.

Step 4 Degradation analysis

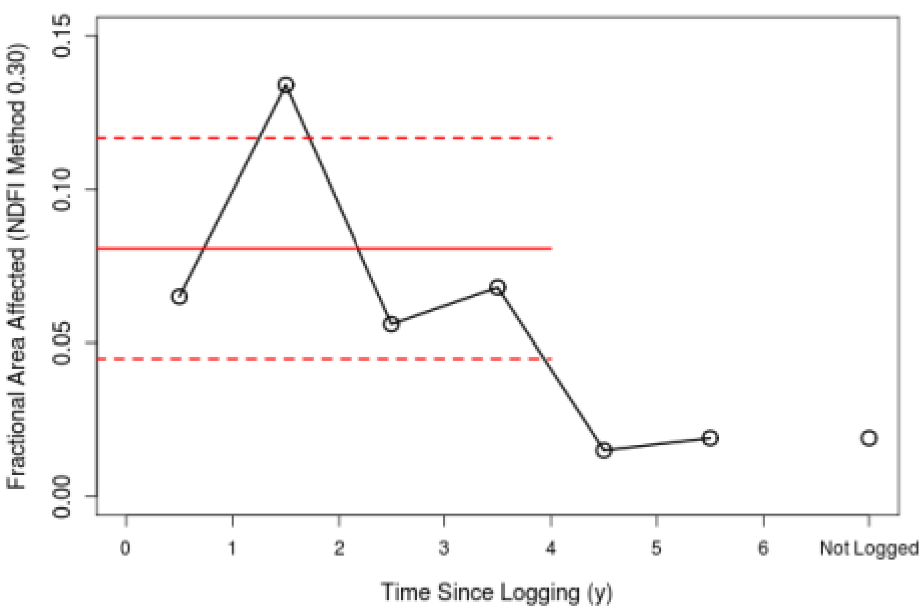
We compare three change metrics relative to pre-logging minus post-logging, derived from the Landsat data: (1) *EVI*, (2) the fraction of non-photosynthetic vegetation plus soil (*NPVSoil*), and (3) the Normalized Difference Fraction Index (*NDFI*). Our expectation is that logging or other forms of degradation will reduce the green canopy cover and expose more soil and NPV. We then estimate changes in *EVI*, *NPVSoil*, and *NDFI* in areas known to have been logged and examine these changes as a function of time since logging.



(a)


Fractional Area Affected (NPVSoil Method 0.15)
0.00
0.05
0.10
0.15
0
1
2
3
4
5
6
Not Logged
Time Since Logging (y)

(b)


Fractional Area Affected (NDFI Method 0.30)
0.00
0.05
0.10
0.15
0
1
2
3
4
5
6
Not Logged
Time Since Logging (y)

(c)

Figure 8: The EVI (a), NPVSoil (b), and NDFI (c) results show a significant difference between areas recently logged (2008-2011, represented by time since logging of 3.5, 2.5, 1.5, and 0.5 years respectively; mean of these four years (solid red line) and standard deviation of these years is dotted red line) and the areas logged in 2006 and 2007 (represented by "time since logging" of 5.5 and 4.5 years, respectively), as well as a biodiversity reserve known not to have been logged (Kuruduni).

This un-mixing approach for mapping degradation is targeted at identifying areas where there is a sharp increase in soil and NPV fractions following forest disturbance (due to opening of the forest canopy and increased gap fraction). It is clear that while the recovery of the lost carbon can take decades, the change in canopy gap fraction will be short lived (less than four years). Understanding this phenomenon will be important for the design of the Guyana MRV system.

The significant variation in the fraction of area affected from one logging plot to the next can be an effect of logging intensity as well as time since logging. In an attempt to quantify the effect of logging intensity, we examined five 1 km^2 blocks in the concession sampled, all logged in 2011. We compared the Landsat-based indices to the Maximum Allowable Cut from each block, assuming that the logging company extracted this amount.

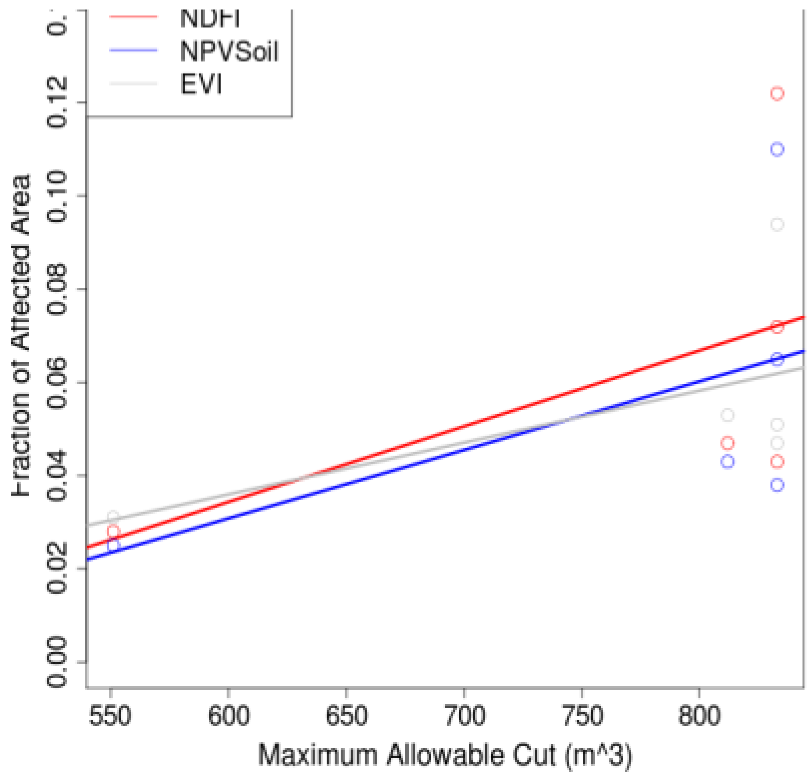


Figure 9. The effect of logging intensity (as estimated based on Maximum Allowable Cut) is not clear in all stands. While several blocks with high Maximum Allowable Cut have larger areas of forest degradation detected using this approach, several did not. This could be due to actual logging removals that are below the Maximum Allowable Cut or that some trees were logged after the Landsat image acquisition.

The variance explained (R^2) by the models ranges from 0.3 (NDFI and NPVSoil) to 0.35 (EVI). These results do not provide much evidence that Landsat is sensitive to intensity of logging. The unconvincing results could have many potential causes. It is important to note that four of the five blocks had nearly identical Maximum Allowable Cuts (MAC); the MAC is not a direct measure of canopy damage or carbon loss. We are not certain that all blocks were logged by late August of 2011. Access to precise dates of logging would greatly assist the interpretation of these data.

Task 3 Degradation analysis in buffers around new infrastructure

Location of new infrastructure from mining and roads has been derived from the deforestation analysis compiled by GFC and Pöyry, as well as from our own analysis of Landsat imagery. Based on the availability of cloud free optical data acquired before and after the new infrastructure, we selected a series of sites for mapping forest degradation, including nearly 10 kilometers of new roads and multiple mining sites. We selected sites where we have sufficient cloud free data to examine the impact. For each site, we processed the optical imagery as described in steps above to map changes in NDFI, NPVSoil, and EVI. We created buffers surrounding the new infrastructures at 100 meter increments out to 500 m, then a single 500 m increment between 500 and 1000 m from the infrastructure (Figure 10). Areas of logging concessions, roads, and mines are removed from the analysis. Based on the statistics of changes in NDFI, NPVSoil, and EVI fraction in 100-1000 meter buffers, we assess the indirect effect of new infrastructure on forest degradation in space and over time.

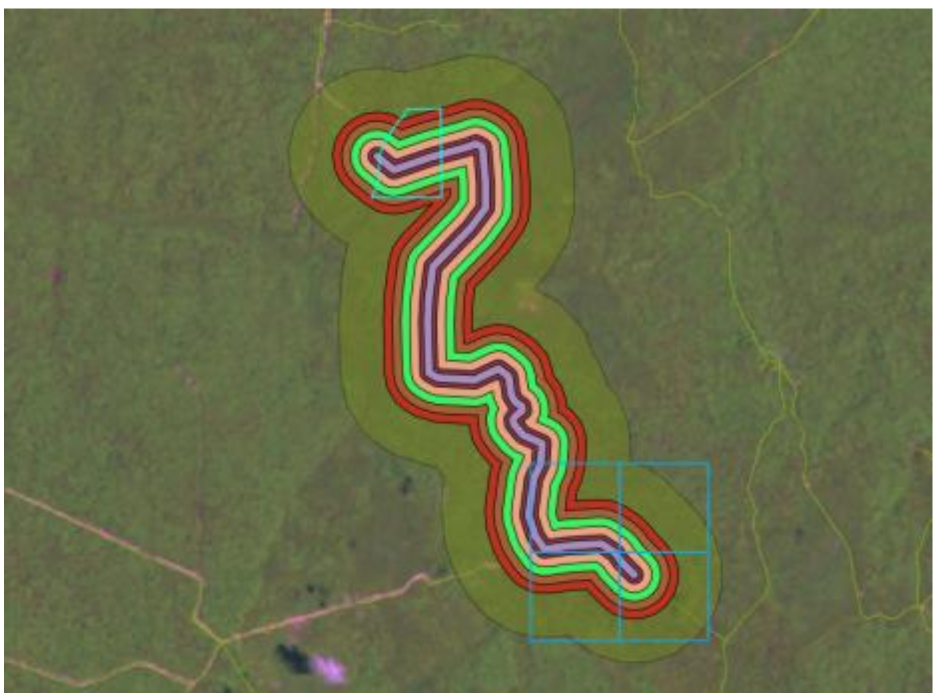
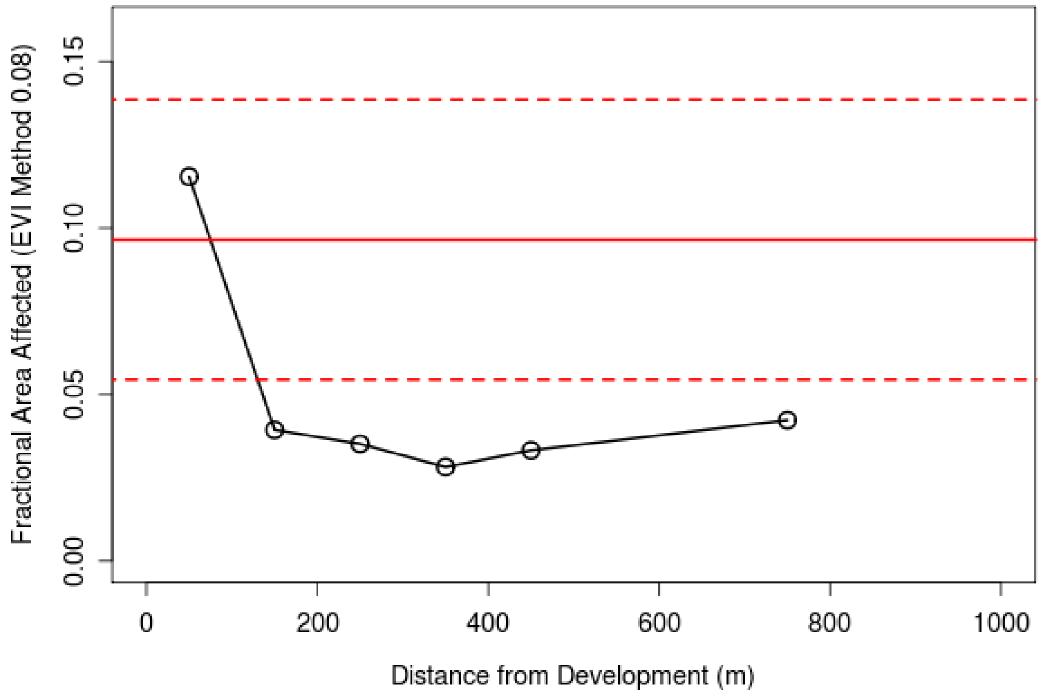
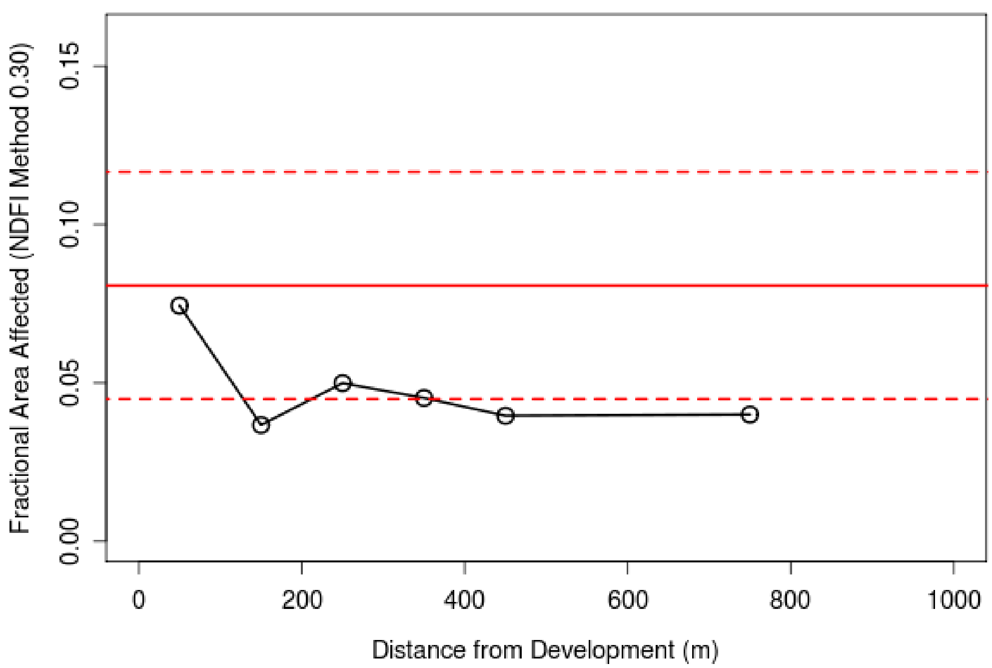


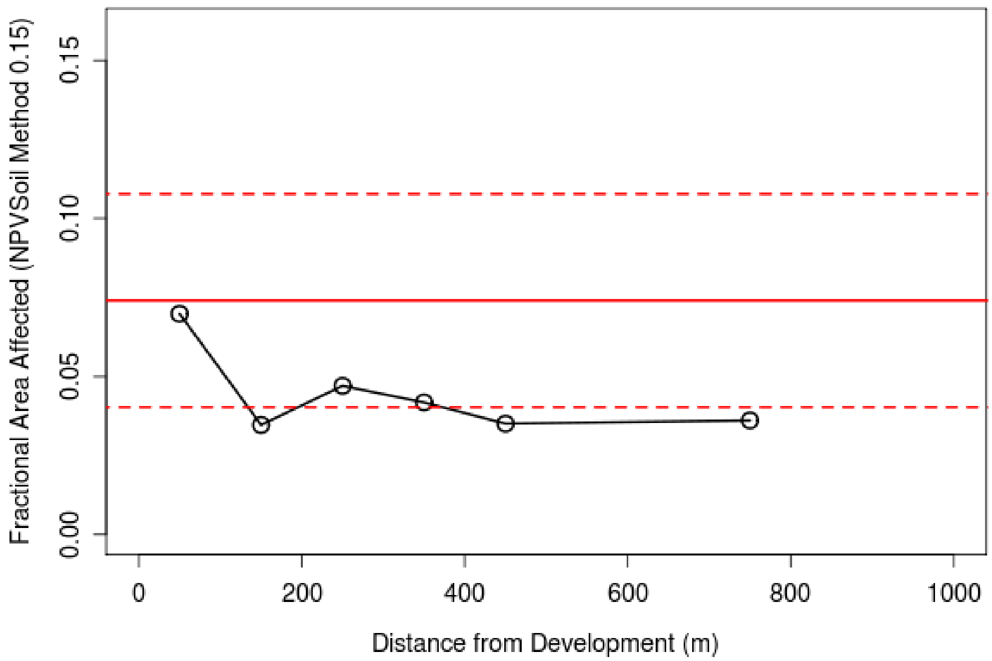
Figure 10. Illustration of buffers surrounding the new infrastructures (e.g. new road) at 100 meter increments out to 500 m, then at a final single 500 m increment between 500 and 1000 m from the infrastructure.



(a)



(b)



(c)

Figure 11: Landsat-derived fraction of area affected is a proxy for degradation and is a function of distance from the new infrastructure based on all three measures: (a) EVI; (b) NDFI; and (c) NPVSoil. Nearly all of the degradation associated with new infrastructure occurs within a 100 m buffer. Only the area within the 100 m buffer are similar to the mean (solid red line) and standard deviation (dashed red lines) of fractional area affected for logged areas within the last four years.

Table 1. The fraction of area affected based on distance from the new infrastructure using the EVI metric shows significant differences in the first 100 m compared to the other distances. A single standard deviation of the affected areas is represented by the range 0.054 to 0.139. By this measure of significance, only the first 100 m is affected by the new infrastructure in this analysis.

Distance (m)	Fraction Affected
0-100	0.115
100-200	0.039
200-300	0.035
300-400	0.028
400-500	0.033
500-1000	0.042

The results of this analysis show that nearly all of the degradation surrounding new infrastructure occurs in the first 100 m buffer (Figure 11 and Table 1). The buffer increments between 200 and 1000 m fall outside or nearly outside of the significance range derived from the logging analysis by years. While care was taken to mask out all new infrastructure (e.g. roads, logging decks, mines), it is possible that some of the degradation identified in the first 100 m buffer is directly from new infrastructure.

The fact that the radius of observable degradation seen in this analysis is limited to 100 meters is not surprising given that significant losses of trees in principle should only be associated with direct effects of installing new infrastructure. Indirect effects will be limited to subtle changes in forest structure and biogeochemistry that are likely caused by: (1) drying due to increased exposure; (2) altered turbulence and wind patterns; (3) invasion of gap species, out-competing low light species; and (4) temperature changes. All of these factors occur at close proximity to the gap edge and require actual penetration of altered light and moisture regimes into the canopy at distance. Indeed, many of these mechanisms could actually result in enhanced carbon storage (e.g. introduction of faster growing species in the buffer region). Therefore, viable mechanisms for removing carbon in the 10-50% range require large scale extraction of stems and crowns that we have demonstrated are visible in the remote sensing imagery. Furthermore, the signal of tree removal and associated gap formation is directly observable in satellite imagery due to the fundamentally different reflectance spectra associated with NPV and soil, versus green vegetation. While there are always uncertainties in image analysis associated with geolocation and atmospheric effects, the underlying principles of this analysis are straightforward, and similar to many other analyses we have performed in other areas. There is nothing strictly location-specific about the methodology we used because it relies almost entirely on the simple notion that vegetation appears differently in the visible and near infrared regions than non-vegetation, and as we have also shown, this applies to imagery with resolutions ranging from 0.5 to 30-meters. While additional field work will assist in improving the precision of our results, especially the actual carbon impacts, we feel the general conclusions in this section should have broad applicability across similar vegetation types.

Task 4: Comparison of high resolution optical data and Landsat for detecting logging

We conducted further analysis in the region of the concessions where we have high resolution and Landsat data before and after logging. We divided this 25 km2 area into 30 blocks of approximately 0.8 km2 regions. Four of these regions were logged in 2011 (#1, 2, 3, and 4), three in 2010 (#5, 6, and 7), four in 2009 (#11, 12, 13, and 14), and three in 2008 (#8, 9, and 10). The other sixteen regions were never officially logged (#15 through 30). We masked out cloud and cloud shadow, as well as roads and logging decks (Figure 12).

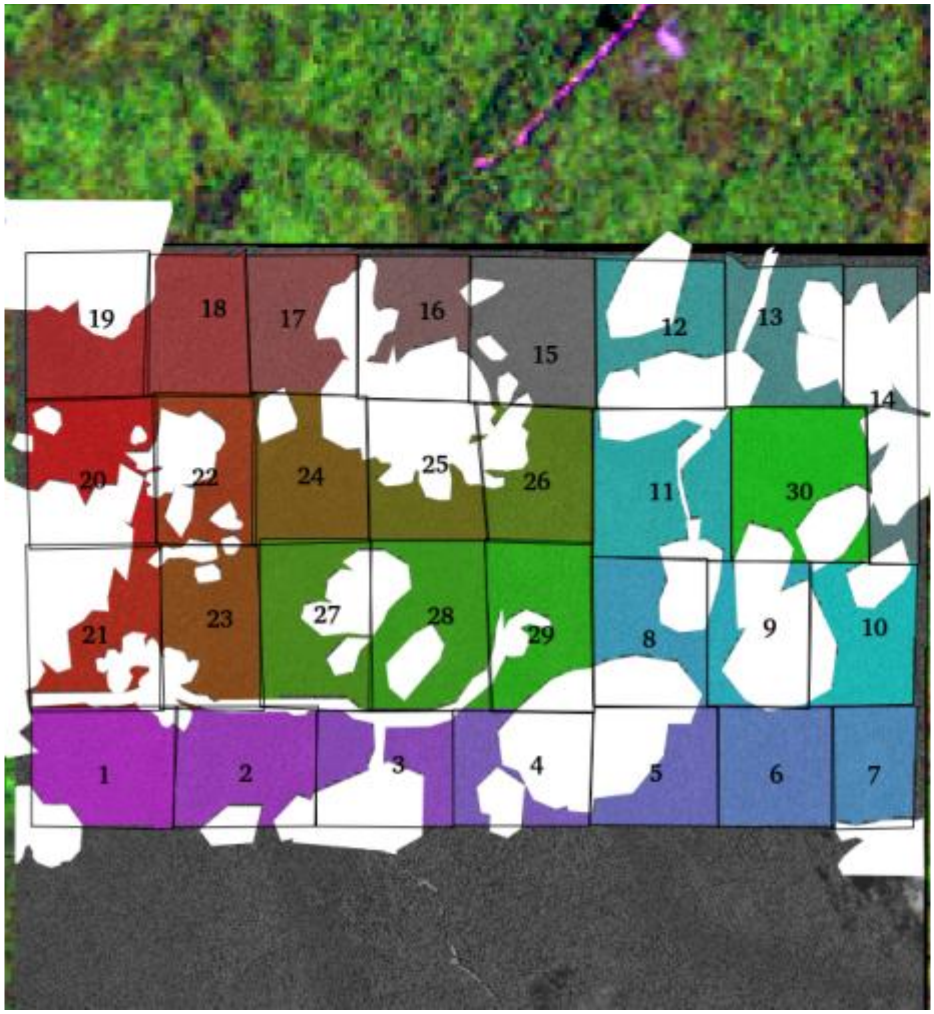
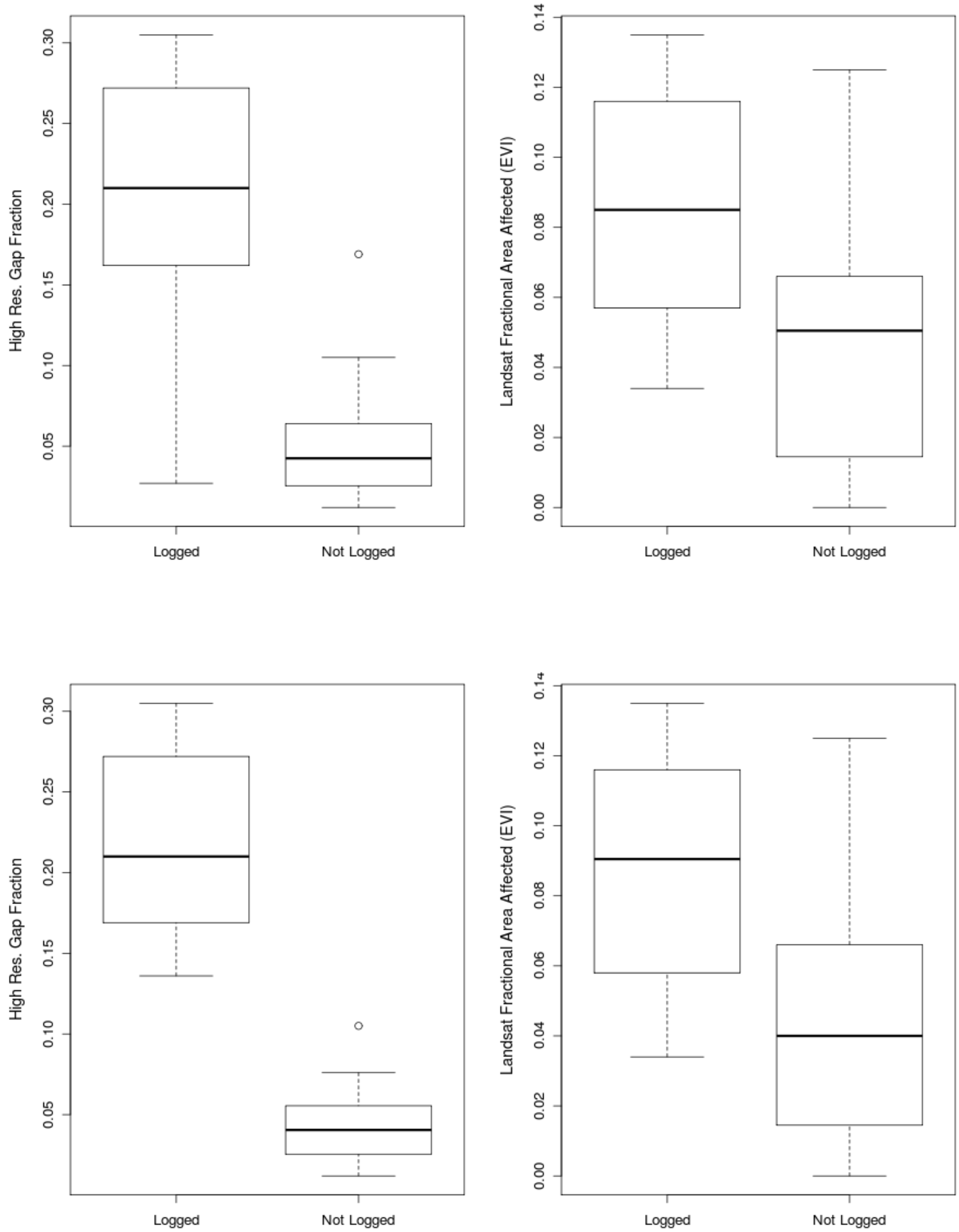


Figure 12: Concession study area with recent logging divided into 30 analysis regions. White areas represent clouds, cloud shadow and direct infrastructure (e.g. roads). These areas were omitted from the analysis.

For the high resolution analysis, we summarized the fraction of 50 m blocks within each analysis region that experienced a fractional gap increase of 0.015 or more. For the Landsat analysis, we counted the fraction of Landsat pixels that experienced a significant drop in EVI pre- to post-logging. The results show that regions marked as having been logged are significantly different than those not logged, in both the high resolution and Landsat. However, the separability between logged and not logged blocks is much larger using the high-resolution data (Figure 13a and b).

We noted two outliers in the 30 regions. Region #1, scheduled to be logged in 2011, is one of these outliers and shares all of the characteristics of not logged regions. It is possible, even likely, that this region was not logged at the time of image acquisition. Also, Region #29 is an outlier having been marked as not logged but showing characteristics of a logged area. This region is adjacent to the road and logging decks and may have suffered significant degradation. If we exchange the labels for these two regions (from logged to unlogged and vice versa), the separability between logged and not logged areas improves for both the Landsat and the high-resolution analysis (Figure 13 c and d).


High Res. Gap Fraction
0.05
0.10
0.15
0.20
0.25
0.30
Logged
Not Logged
Landsat Fractional Area Affected (EVI)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
Logged
Not Logged
High Res. Gap Fraction
0.05
0.10
0.15
0.20
0.25
0.30
Logged
Not Logged
Landsat Fractional Area Affected (EVI)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
Logged
Not Logged

Appendix 7

Figure 13. The high resolution analysis (a) shows significant differences between logged and not logged regions. These differences are significant enough for reliable detection. The Landsat analysis (b) also shows differences between the logged and not logged regions within this area, but the results show that detection based on these data are less reliable. For both the high resolution analysis (c) and the Landsat analysis (d), the separation between logged/not logged blocks increases when regions #1 and #29 are swapped (under the assumption that they were initially assigned to the wrong group).

Take Home Messages

1. In the Landsat analysis, we identified "loss of EVI" as the strongest indicator of logging and degradation, while "loss of NDFI" and "increase of NPV + soil" perform nearly as well.
2. Based on our Landsat analysis, nearly all of the degradation associated with new infrastructure occurs within a 100 m buffer and is similar in magnitude to the logging in the concessions sampled. Outside of the 100 m buffer, degradation appears less significant and similar to areas logged more than four years ago or never logged.
3. High resolution optical data outperform Landsat in identification of logged areas. High resolution data could be used to reliably identify logging and significant degradation for many years following the activity.
4. Textural methods and a crown delineation algorithm did not perform as well as a simple threshold analysis to estimate degree of gaps in the image.
5. A comprehensive study of degradation is limited by the lack of cloud-free imagery.

Recommendations

We advise that the degradation analyses presented in this report should be extended in a number of ways, both to improve the accuracy of the results but also to aid in quantification of uncertainty. First, the shadow fraction estimates derived from high-resolution imagery could be improved by including information on sun-sensor geometries available within the imagery metadata. We expect that differences in observation conditions influence the results and the degree of influence could be estimated and reduced with additional scenes and a simple model of shadow area. Second, a wall-to-wall study of degradation could be performed using Landsat data for continuity. This study would be limited by clouds and the large temporal gaps between imagery, but could be of value to GFC.

We also recommend applying the methods described in this report using other data sources (e.g. SPOT and RapidEye). RapidEye in particular, with its intermediate (5-meter) resolution and enhanced spectral coverage, offers the potential for execution of both direct pixel-level gap analysis (Task 1), as well as unmixing-based and EVI-based approaches (Task 2). An initial direct comparison between RapidEye and the other data types (using their associated respective analyses) using coincident data would quantify the potential improvements available using RapidEye and guide subsequent work, which could employ either approach, or some currently unimplemented hybrid of the two approaches. The cost of RapidEye data is about 10-20 times less ($US1 per sq. km) than the more detailed high resolution imagery.

Despite the associated challenges we would recommend the development of a sampling strategy using high-resolution data (including RapidEye) to be used within a comprehensive system for providing annual estimates of forest degradation. Given the difficulty in getting low cloud cover imagery, a sampling scheme would benefit from stratification using currently available spatial maps of deforestation and degradation pressures with the country, which are available and separated into 3 threat levels/regions. In any case, an effective and reasonable MRV system will need to rely on a multi-sensor approach with the use of high-resolution data in a sampling mode, combined with more spatially extensive and readily available lower resolution imagery.

We also recommend that the degradation analyses demonstrated in this report using high resolution optical and Landsat data can be brought into an operational environment for efficiency and ease of use. This could be done in several ways. For example, software modules could be developed:(1) in IDL for integration into the ENVI environment; (2) in Python for integration into an ArcGIS 10 environment; or (3) in Python and C for deployment within a custom application on the desktop or over the web.

Finally, to the extent possible, we recommend that additional work utilize field-based information that is more directly comparable and/or complementary with the remote sensing data. In this study, we relied heavily on pre-harvest inventory data, which has utility, but also introduces uncertainties with respect to actual removals. Having maps of all tree removals (location and estimate of volume and gap sizes) within logging blocks would be required for detailed statistical calibration and validation of the quantitative approaches described in this document. In addition, having an estimate of when the logging occurred at a given location would enhance the ability to understand the influence of time since disturbance (i.e., regrowth) on our ability to (a) detect disturbance, and (b) assess carbon losses from degradation. The thematic focus of applicable field data also relates to the possible scope of the image analyses. For example, the detectability of dieback of trees due to mining tailings in Guyana could be investigated.

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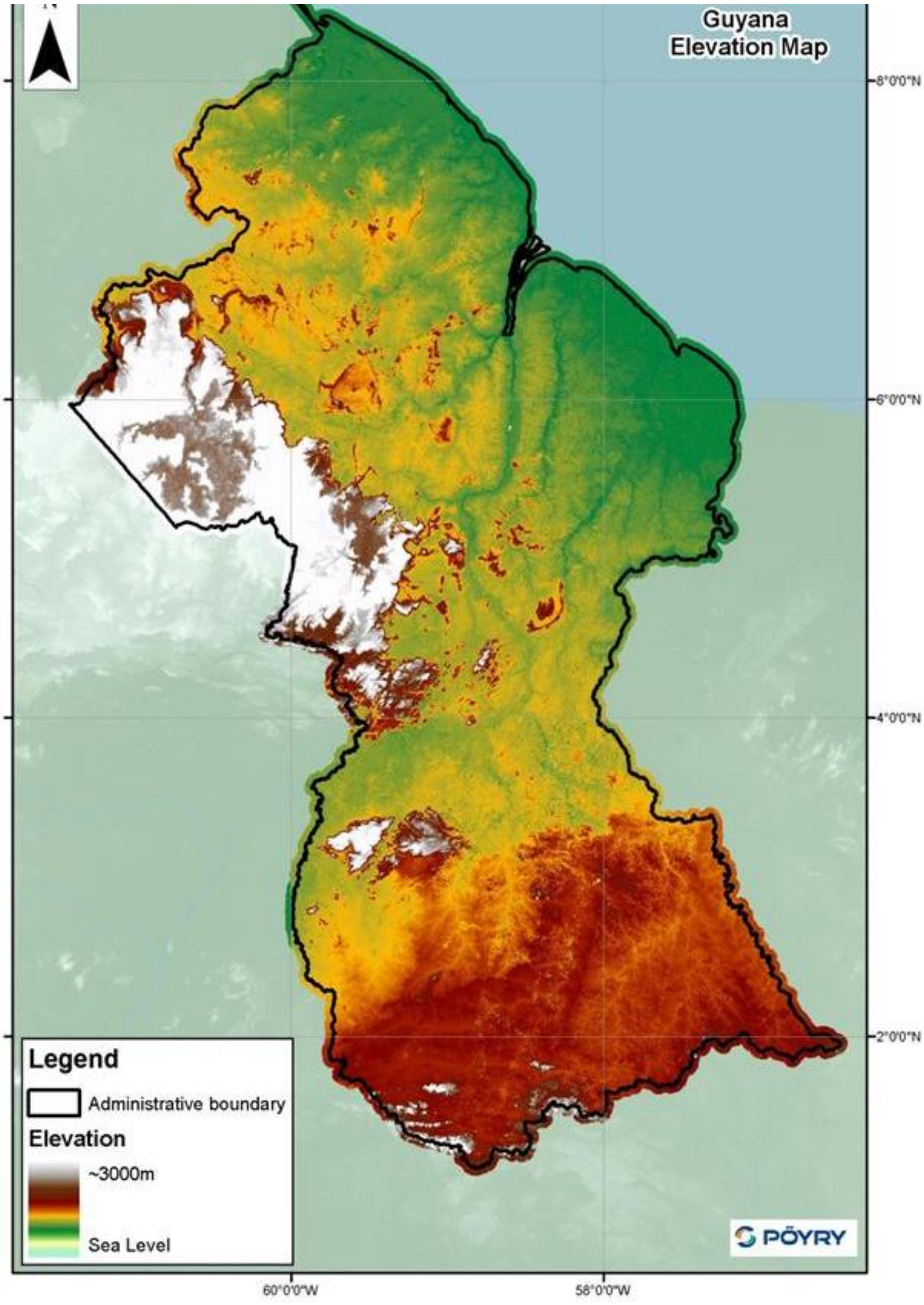
Appendix 8

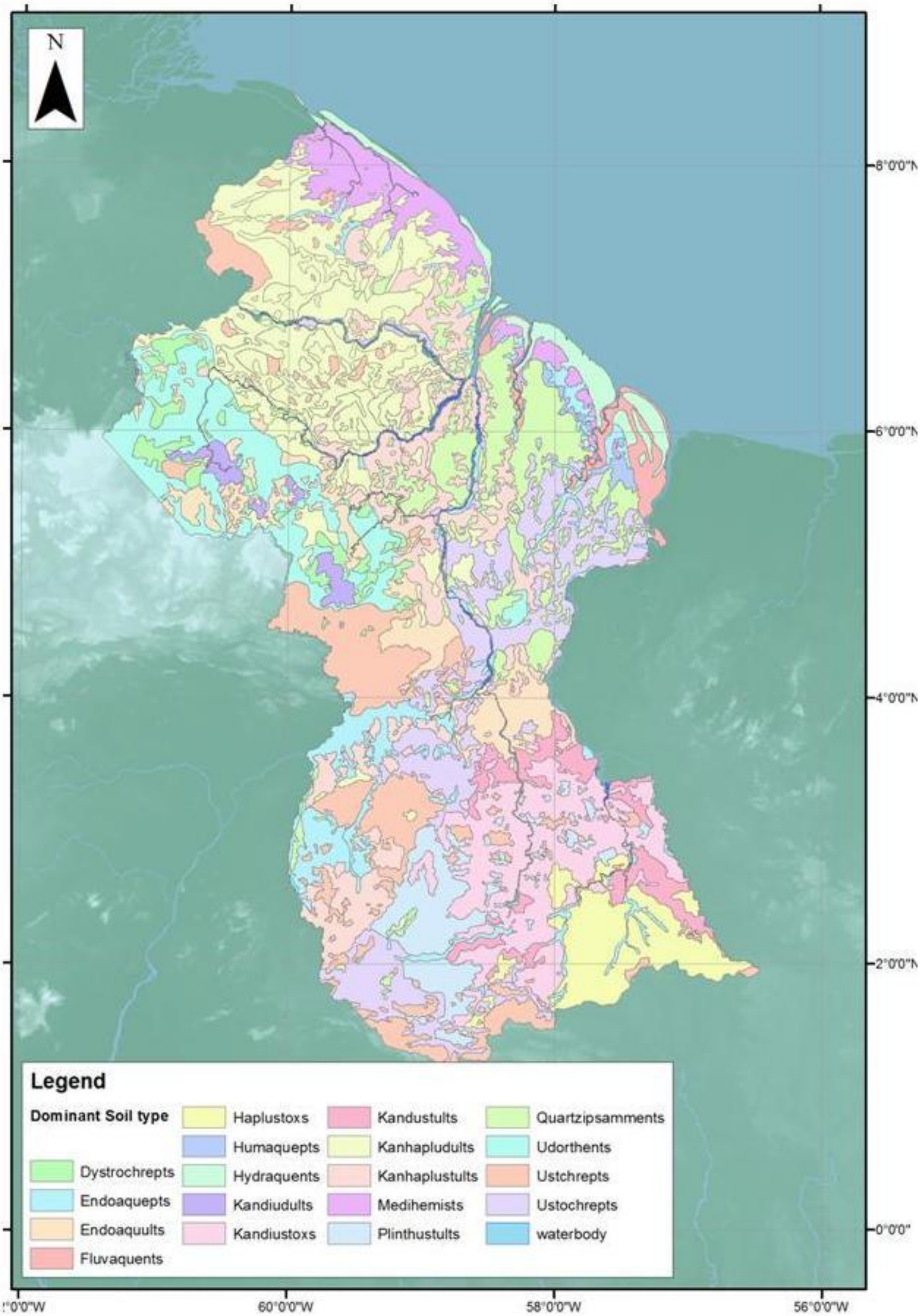
National Datasets

Some of the following maps are reproduced from the GFC / Pöyry Year 1 report and where appropriate updated for the year 2 analysis. They provide an overview of existing datasets held by GFC.

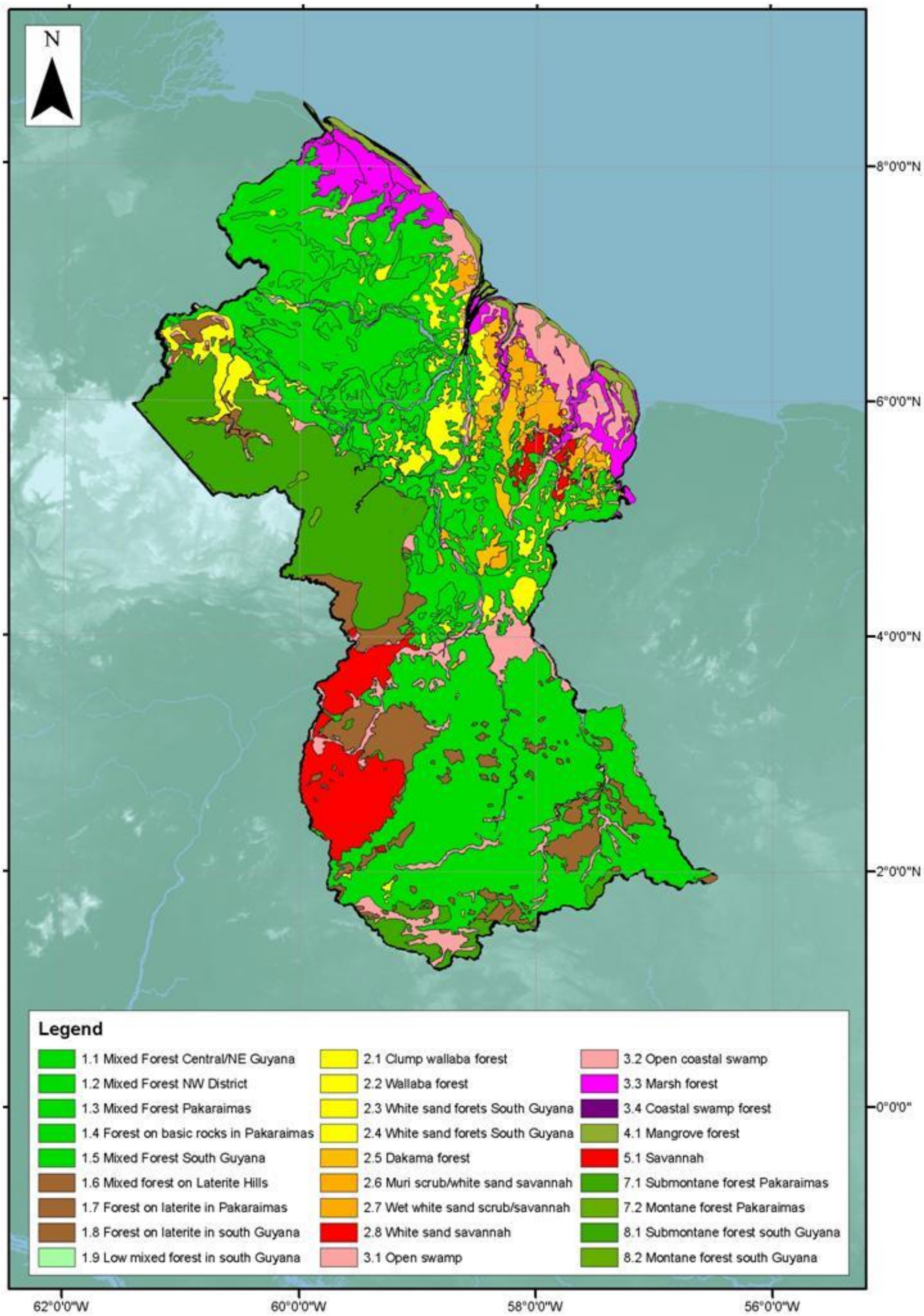
Guyana Digital Elevation Map



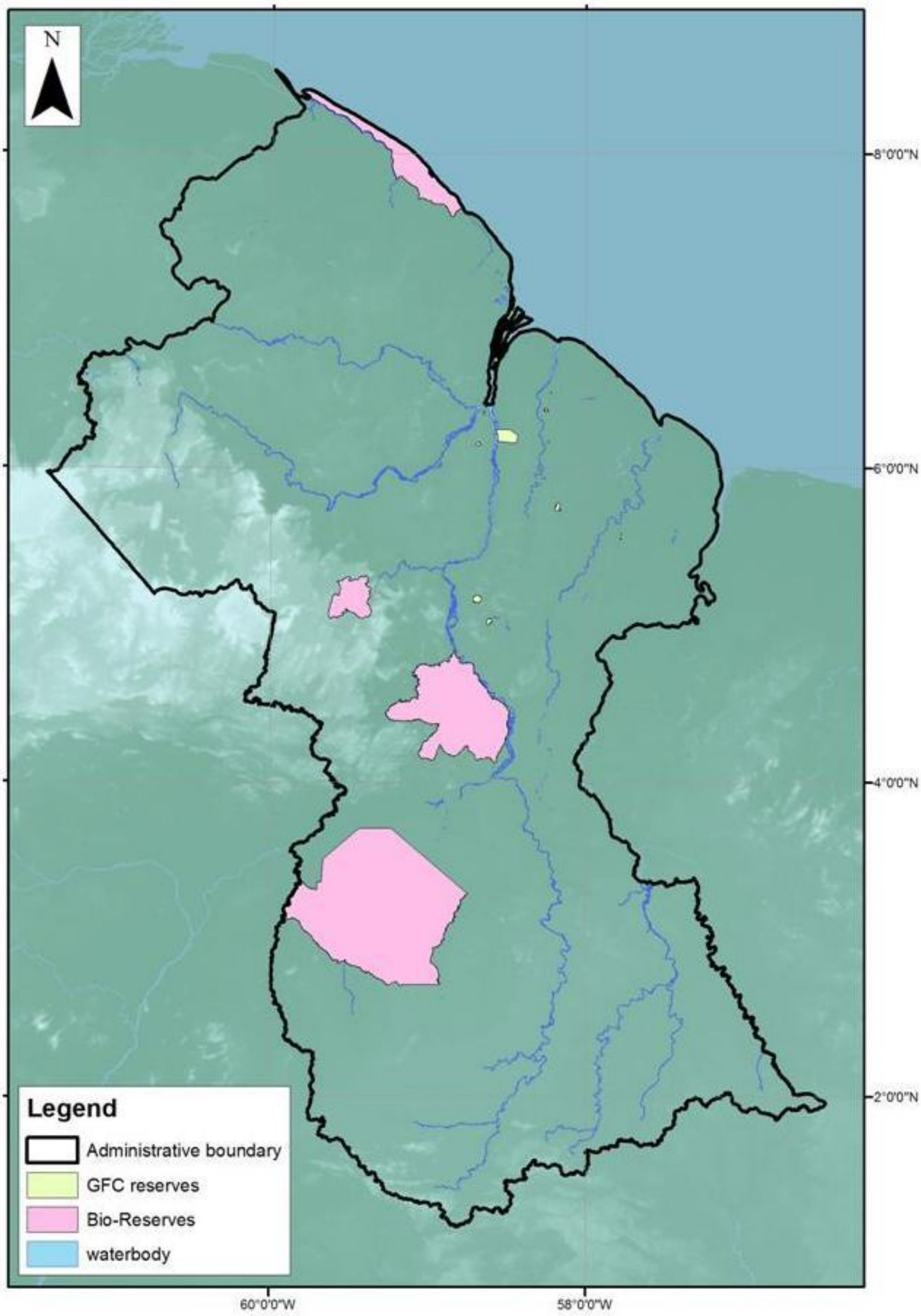
Guyana Soil Types Map



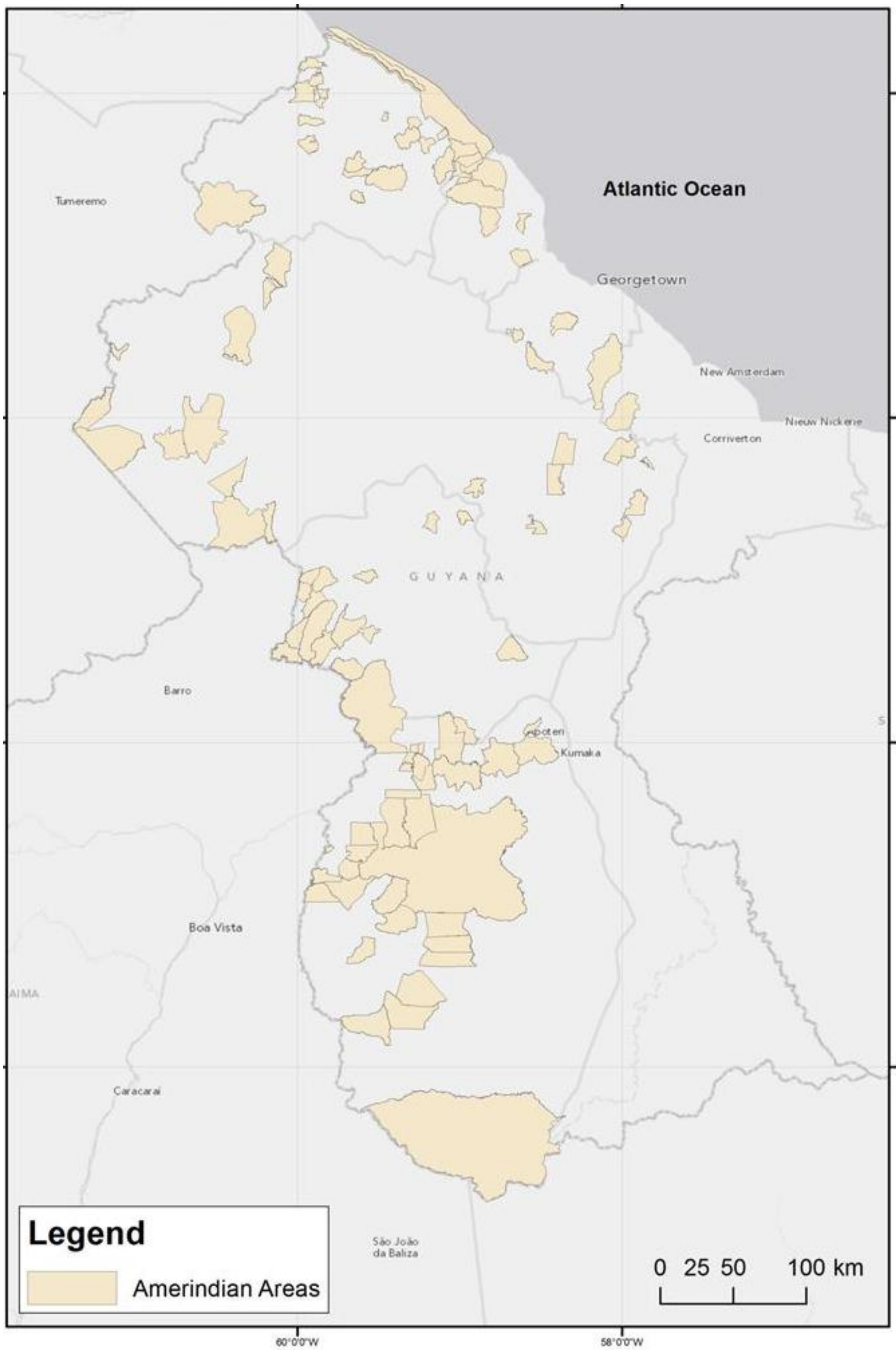
Guyana Vegetation Map



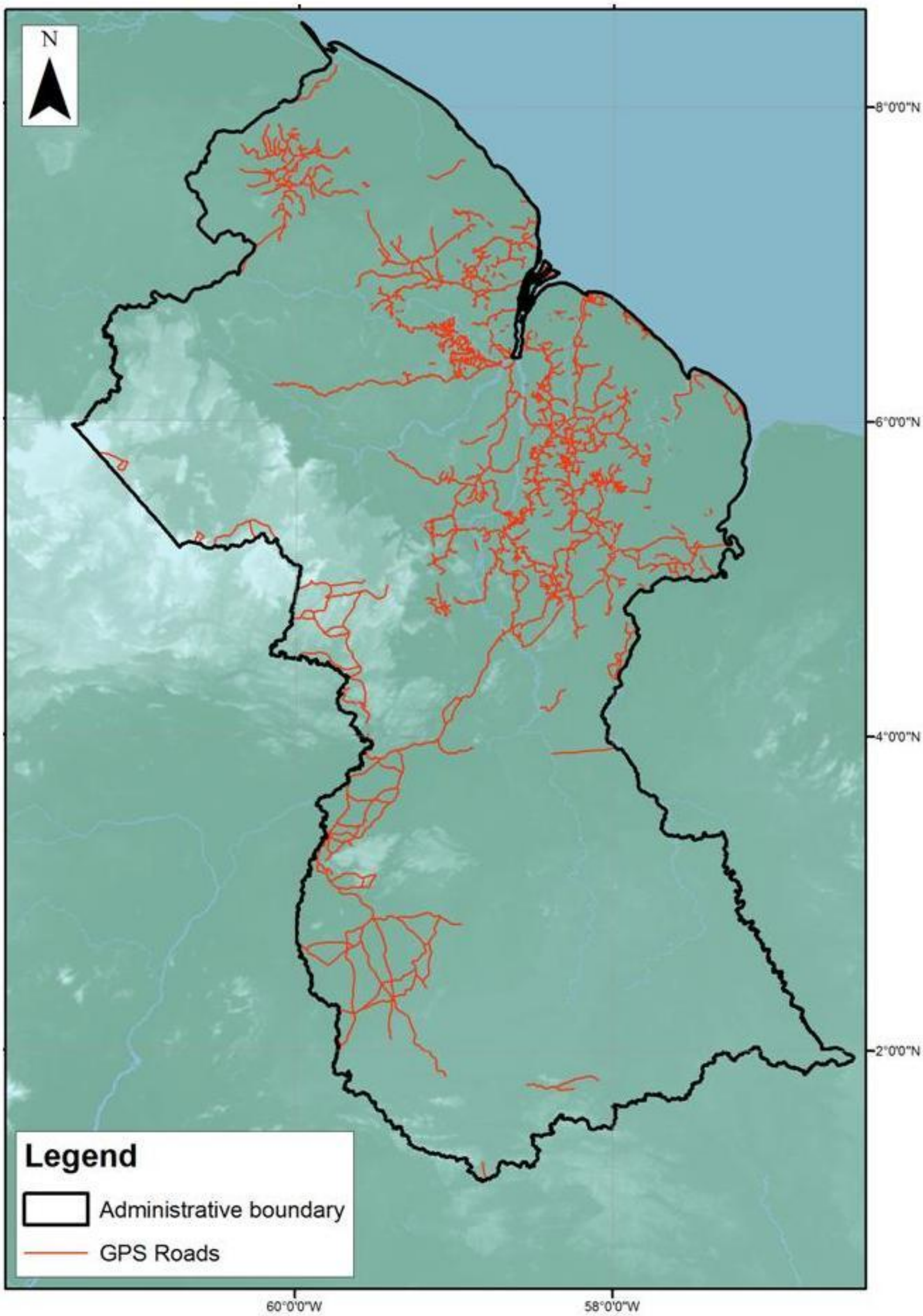
Guyana Forest Reserves



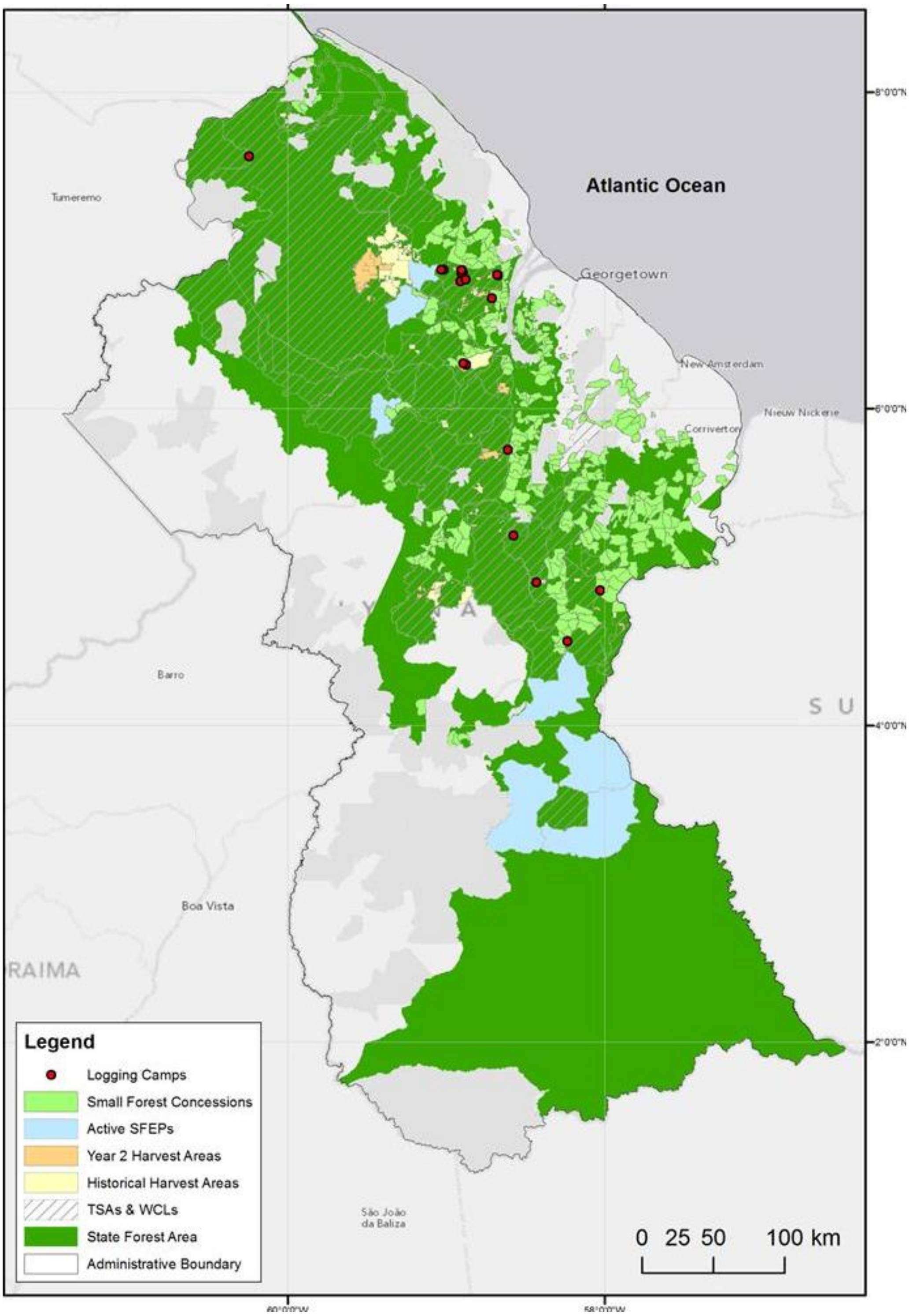
Amerindian Areas –Year 2 Update



GPS Roads Layer



Managed Forest Areas – Year 2 Update



July 2012

Appendix 9

Standard Operating Procedures for Guyana's MRVS Interim Measures

Indufor Asia-Pacific - New Zealand

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Jeff Pickering,
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In collaboration with:

Haimwant Persaud: Guyana Forestry Commission, Guyana
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July 2012

Standard Operating Procedures for Forest Change Assessment: A Guide for Remote Sensing Processing & GIS Mapping

BACKGROUND

The Guyana Forestry Commission (GFC) is engaged in a series of projects aimed at supporting the REDD+ programme, aimed at improving aspects of sustainable forest management, forest conservation, and forest enhancement.

The GFC has taken an active role is devising a framework for developing capacities for monitoring, reporting and verification (MRV) of carbon stock changes. An MRV System (MRVS) spanning from 2010 to 2013 is being implemented that will culminate in a system capable of monitoring and reporting annual land-use and carbon stock changes at the national level.

12.1 About This Guide

The mapping guide provides technical advice on how to pre-process satellite images and examples of how to map forest change, identify the drivers of change in forest land cover. The guide covers the following topics:

- a general description of Guyana's forest
- definitions of deforestation, degradation and forest change
- Land use changes recorded in the MRVS
- Image pre-processing
- GIS Mapping Process
- Illustrated Mapping Guide
- QA/QC relevant to the process

12.2 Forest land

Land classified as forest follows the definition as outlined in the Marrakech Accords (UNFCCC, 2001). Under this agreement forest is defined as: a minimum area of land of 0.05-1.0 hectares (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.

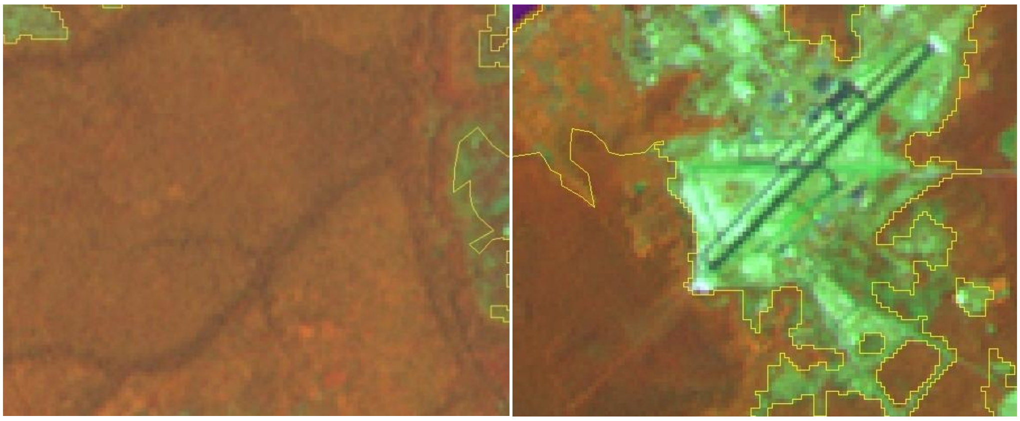
In accordance with the Marrakech Accords, Guyana has elected to classify land as forest if it meets the following criteria:

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

Medium resolution satellite images were used to calculate the forest area in accordance with Guyana's national definition of forest as at 1990[53]. The total forested area at this point in time is estimated as 18.3947 million hectares (ha) (with an indicative accuracy of ~97%), of which 14.8 million ha is administered by the State.

[53]Table 2 of the JCN requires that Forest area in Guyana be defined in accordance with the Marrakech Accords. The national definition of forest for Guyana was discussed at the level of the MRVS Technical and Steering Committee.

Figure 1: Mapped forest/non-Forest Boundaries at 1990



A benchmark map of the forest as at 30 September 2009 has been compiled from the 1990 forest map and mapping of subsequent forest changes from a time series of Landsat TM and ETM+ and other spatial datasets. This map is used as the basis for reporting subsequent forest change. The first reporting period (termed Year 1) is set from 1October 2009 to 30 September2010 and second reporting period termed Year 2 spanning from October 1 2010 to December 31 2011

12.3 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 forest code of practice would not be considered deforested as they have the ability to regain elected crown cover threshold.

The five anthropogenic change drivers that lead to deforestation, identified in previous work and by the initial workshop at which the MRVS Road map was developed, include:

- Forestry (clearance activities such as roads and log landings)
- Mining (ground excavation associated with small and large scale mining)
- Infrastructure such as roads (included are forestry and mining roads)
- Agricultural conversion
- Fire (all considered anthropogenic and depending on intensity and frequency can lead to deforestation)

12.4 Degradation

There is still some debate internationally over the definition of 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:

- Selective and illegal harvesting of timber (not reported spatially in the current MRVS)
- Shifting cultivation (not reported spatially in the current MRVS)
- Fire
- Around mining sites and road infrastructure

For the benchmark reporting period and the interim phase of the MRVS certain changes such as forest degradation or shifting cultivation and changes associated with forests under SFM are not required to be reported. However, for completeness it is important that historical changes are monitored to ensure that the drivers of change and transition of the change through time (i.e. regeneration or continued degradation) are recorded[54]. All naturally occurring disturbances, such as erosion and wind damage are also identified to ensure that these events are differentiating from anthropogenic changes.

It is also important that areas of continued degradation are monitored to ensure that any expansion of these disturbances is captured and reported. The acquisition of repeat 5 m resolution satellite imagery allows this to monitored from 2011 onwards using the methodology outlined in section 7. This applies to degradation around new infrastructure which in the interim measures includes- roads, mines, pipelines or reservoirs.

12.5 Change

The term "*change"* is used here to refer to the transition of an area from one type of land use to another as a result of either human induced activity or a natural event. Only change for forest land use types (Table 1) is considered for the interim measure reporting.

The exact cause of change of a forest area can sometimes be difficult to discern from satellite imagery, particularly where there is an overlap between drivers e.g. identifying the driver for road construction where mining and forestry areas use the same access routes. A decision can usually be made from the spectral properties of the area of change in combination with other characteristics such as shape, location and context.

Table 1:GFC Schema for Land Use / cover Categories

Class	Land use Category	Land use/ cover type
Forest Land	Forest Land	Mixed forest
		Wallaba/Dakama/Muri Shrub Forest
		Swamp/Marsh forest
		Montane forest
		Mangrove
		Savannah >30% cover
		Plantations
Non forest	Grassland	Savannah <30% cover Grassland
	Cropland	Cropland
		Shifting Agriculture
	Wetland	Wetland open water
		Herbaceous wetland
	Settlements	Settlements
	Other land	Other land

54Lands that have been converted to another land use should be tracked under the appropriate sections for as long as carbon dynamics are influenced by the conversion and follow up dynamics. 20 years is consistent with IPCC Guidelines, but Tier 3 methods may use longer periods where appropriate to national circumstances.

13. LAND USE CHANGE ACTIVITIES RECORDED IN THE MRVS

The following table provides an overview of drivers and associated deforestation or degradation activities that are reported spatially in the GIS as part of the MRVS. Some activities are not yet accounted for 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 2: Summary of Activities &Drivers Captured in the GIS

Activity	Driver	Criteria	Ancillary Info Available	Accounted in MRVs	End Land Use Class
Forestry	SFM	Fall inside state forest area and is a registered concession	Annual harvest plans, GIS extent of concession, previously mapped layers, Satellite imagery	No	Degraded forest by type
	Infrastructure formed to access and extract timber from concessions including landings	Roads > 10m		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	Assess area within 100 m buffer around deforestation event – road or new infrastructure - revisit sites post 2011 to assess change	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
Fire	Deforestation	Deforestation sites > 1 ha	FIRMs fire points, spatial tends from preceding periods, Satellite imagery	Yes	Bareland or crop land
	Degradation	Deforestation sites		Yes	Degraded forest by type
Infrastructure	Deforestation	Roads >10 m	Existing road network . Satellite imagery	Yes	Settlements
	Degradation	Assess area within 100 m buffer around deforestation event – road or new infrastructure - revisit sites post 2011 to assess change	Existing deforestation sites, Satellite imagery	Yes	Degraded forest by type
Shifting Agriculture	Degradation	Assess historical patterns	Proximity to rural populations, water sources and Satellite imagery	No	Degraded forest by type
Afforestation	Afforestation	Monitor abandoned deforestation sites	Historical land use change, Satellite images	No	Afforestation forest or land cover by type

14. DATA STRUCTURE, OPERATORS AND TRAINING

All spatial data is stored on the Network Attached Storage (NAS) at GFC and builds on the archived and manipulated data output from the Year 1 analysis. The NAS is managed by the IT team at GFC and is routinely backed up and stored off site.

The Year 1 data report recommended a central repository for all spatial information for inter-agency use. In 2012 GFC is looking to upgrade to ArcGIS server and in November 2011 the FRIU staff undertook ESRI training on working with relational databases as part of the Low Carbon Development Strategy (LCDS) assistance program. The implementation of a central repository for geographic data will provide an industry standard method for usage and manipulation of spatial data.

The relevant datasets that will be used during the analysis have been documented and archived. This includes brief metadata about the dataset, its location on the network and anticipated update frequency. Several datasets are actively used and reside on GFC's Forest Resource Information Unit (FRIU) network drive. These datasets are copied into a working folder at the beginning of each year. Care has been taken not to disrupt the structure of FRIU datasets and also to avoid duplication of datasets.

GIS and remote sensing data and layers are stored on the dedicated NAS. Raw image datasets as provided by image providers are retained and have been catalogued using the analysis period they relate to, sensor, path and row, and processing information. New folders are created as these scenes are processed using ENVI image processing software and all associated files generated are also retained. All images are named using a common format that identifies the satellite, path and row, image date, provider, processing level (e.g. O = orthorectified) and any post-processing that has been done to register the imagery to a terrain corrected base mosaic.

The current processed datasets are held in a GeoDatabase, and the satellite images are all full band stacks in either TIFF or IMG format.

GFC has recruited a number of staff recently, and now has eight GIS operators, a GIS manager and one remote sensing specialist. All desktop computers are running the latest version of ArcGIS (10) as provided by ESRI under the LCDS assistance program. Two copies of ENVI 4.7 have also been installed to enable image processing. Both are dongle versions and include maintenance contracts. The FRIU holds customised toolbars for automated processing imagery in ENVI and ArcGIS, where possible.

14.1 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.

Table 4-1 provides a summary of the various spatial datasets. The Ministry of Public Works is overseeing the development of the Amaila Hydropower Project. This planned hydroelectric project includes road construction and site clearance.

These datasets will be incorporated into the Year 2 analysis to assist in the detection of land use change events.

Table 3: Agency Datasets Held at GFC

Agency	Role	Data Held
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 lease information. Reconnaissance areas, large and medium scale mining areas including dredge locations.

Guyana Lands and Survey Commission (GL&SC)	Management of land titling and surveying of land	Land tenure, settlement extents and country boundary
Central Housing & Planning Authority	Management of Housing & Communities	Existing and planned housing information that are located in forested areas.

14.2 Guyana Forestry Commission

The GFC is responsible for advising the subject Minister on issues relating to forest policy, forestry laws and regulations. The Commission is also responsible for the administration and management of all State Forest land. The work of the Commission is guided by a National Forest Plan (2011) that has been developed to address the National Forest Policy (2011).

The Commission develops and monitors standards for forest sector operations, develops and implements forest protection and conservation strategies, oversees forest research and provides support and guidance to forest education and training.

The Forest Resource Information Unit (FRIU) holds a range of operational spatial data that are used to assist in the management of forest resources. A summary of the spatial layers is provided in Table 4-2.

14.3 Guyana Geology Mines Commission

The main functions of GGMC are to:

- Promote mineral development
- Provide technical assistance and advice in mining, mineral processing, mineral utilisation and marketing of mineral resources
- Conduct mineral exploration
- Research the areas of exploration, mining, and utilisation of minerals and mineral products.

The GGMC also has a role in the enforcement of the conditions of Mining Licences, Mining Permits, Mining Concessions, Prospecting Licences (for Large Scale Operations), Prospecting Permits (for Medium and Small Scale operations) and Quarry Licences. It is responsible for the collection of rentals, fees, charges, and levies payable under the Mining Act.

The GIS section at GGMC routinely collects information using field GPS units. The spatial layer developed holds information on the location of dredge sites and the person licensed to operate the dredge. The intention is to update this dataset quarterly.

GGMC also holds a spatial layer that defines the location of large and medium scale mining concessions. Recently GGMC also provided the reconnaissance areas. This information has been used to update the 2011 Intact Forest Landscape Map and qualifies as an exclusion area as defined by the Intact Forest Landscape Definition.

14.4 Guyana Lands & Surveys Commission

The Guyana Lands and Surveys Commission (GL&SC) remit includes the provision of land policy recommendations and draft land use plans to ensure orderly and efficient utilization of public land resources; advise on land surveying matters, and effective and efficient land administration.

- GL&SC also has a GIS unit that creates and provides geographic information. Several base datasets held by GL&SC have been identified as particularly useful. These include;
    - The extent of larger settlements in particular, Georgetown.
    - The location of registered agricultural leases.
    - Historical aerial photography not held by GFC
- Datasets from GGMC and GL&SC were consolidated into the GIS and used to assist with identification of areas undergoing change.

The following section provides details of image and GIS datasets considered relevant for the continued monitoring and mapping of temporal forest change in Guyana.

15. MONITORING DATASETS - SATELLITE IMAGERY

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

Presently, reporting satisfies interim measures outlined in Section10. This requires that changes in forest land to other land uses be reported relative to the benchmark map. Currently changes occurring between lands defined as non-forest are not reported. Changes from non-forest to forest however, are being reported. The basic premise is that eventually changes in the six IPCC categories will be reporting for the LULUCF sector once the MRVS is fully operational.

For the period post 30 September 2009 additional measures include reporting forest change and degradation relative to the benchmark map. For the Year 2 assessment a remote sensing method has been adopted rather than applying a generic 500 m buffer to newly detected infrastructure sites in the GIS. The method to be used, as outlined in the JCN, allows for this approach.

To ensure consistency, all imagery was geo-referenced to a base mosaic image which was generated from data provided in MrSid format by the Global Land Cover Facility (GLCF). The GLCF holds a global set of regional images which are divided into tiles and overlap each other seamlessly at their edges. This ensures consistency between images of a similar type, and also between different image types and resolutions.

The following table provides a summary of the image datasets used for the Year 2 for both the monitoring and accuracy assessment. A detailed scene listing is provided in Appendix 2

Table 4:Year 2 Imagery Datasets

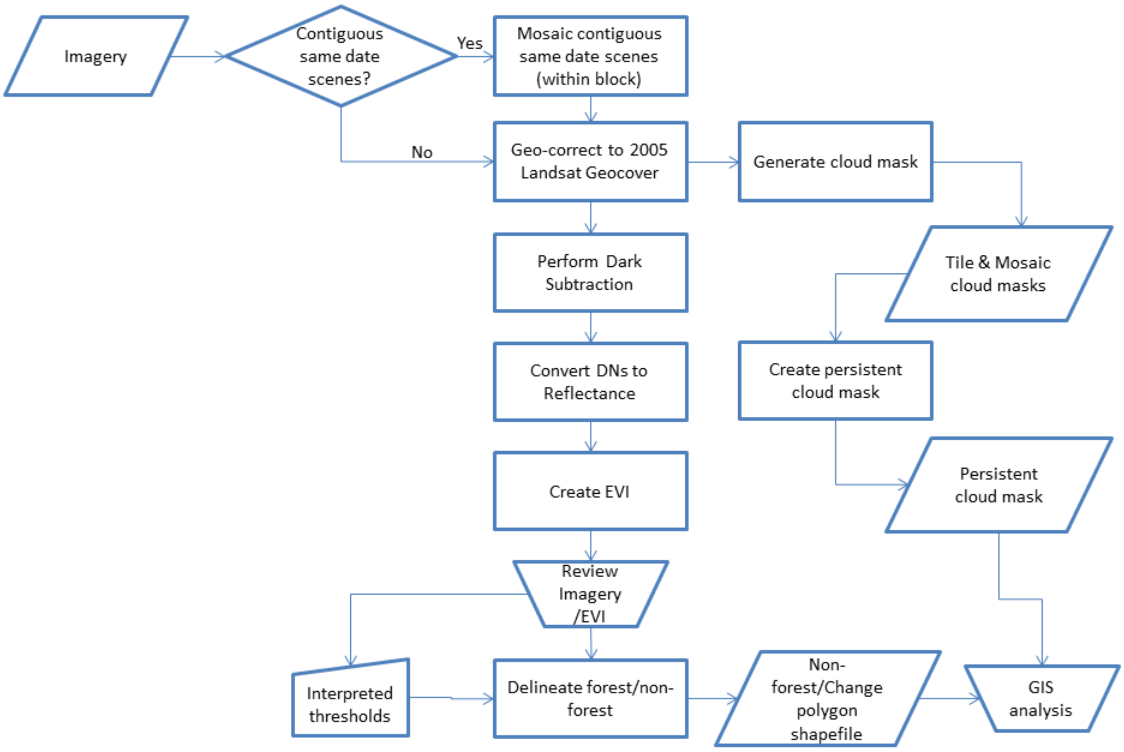
Application	Satellite	Spectral Bands[55]	Resolution (m)	Image Extent (km)	No. Scenes	Temporal Coverage	Image Cover
Land use & Forest Change Mapping	RapidEye	VNIR	5	25 x 25	385	Aug-Dec 2011	56%
	Landsat 5 & 7	VNIR & SWIR	30	185 x 185	35	Aug-Dec 2011	Full
	DMC	VNIR	22 & 32	660 x 4100	10	Aug - Dec 2010	Partial
	IRS	VNIR & SWIR	23.5	142 x142	5	Nov-Dec 2011	Partial
	MODIS	VNIR	250	~2000	2	Dec 2011	Full
	ASAR RADAR	HH & HV	5-15	~70 - 70	113	Jan- Nov 2011	Full

15.1 Image Pre-processing

The image processing follows the process documented below and automated to produce the EVI and persistent cloud mask. All data is to be tied to the Landsat Geo-cover dataset and ground control points retained.Once the EVI is produced direct interpretation and manual editing of the change area is conducted. The following pre-processing steps are undertaken in ENVI using the customised toolbar.A brief description of each step is provided as follows with the stepwise process explained in further detail.

[55]Bands used for the analysis

Image Processing Flow diagram



15.2 Image Mosaic

Contiguous image tiles acquired at the same date and time are mosaicked into a single multi-band file. Scenes without contiguous image tiles acquired at the same date and time were always processed as a single tile.

Step1 Mosaic contiguous RE tiles from the same swath (date).

- raw_mosaics directory

15.3 Image Geo-correction

All satellite images are to be geo-referenced to the 2005 Landsat Geocoverbase map. Accurate geo-referencing is important to ensure that changes detected in future time periods are valid and not simply artefacts caused by inaccurate co-registration. Mis-matches should be less than one Geocover pixel (<14.25 m). All GCPs are to be recorded and saved.

- Warped/1_Warped/IMG_TIFF
- warped/1_warped/GCPs

15.4 EVI Generation

The following three processing steps have been automated using an ENVI custom batch processing tool (Figure 2). Create a text file with a list of RapidEye files to process. After each filename include the scene's sun elevation angle (from image metadata file). Run the *RapidEye DRE batch processing* tool supplying the files to process text when prompted.

Figure 2: Custom ENVI Batch processing menu

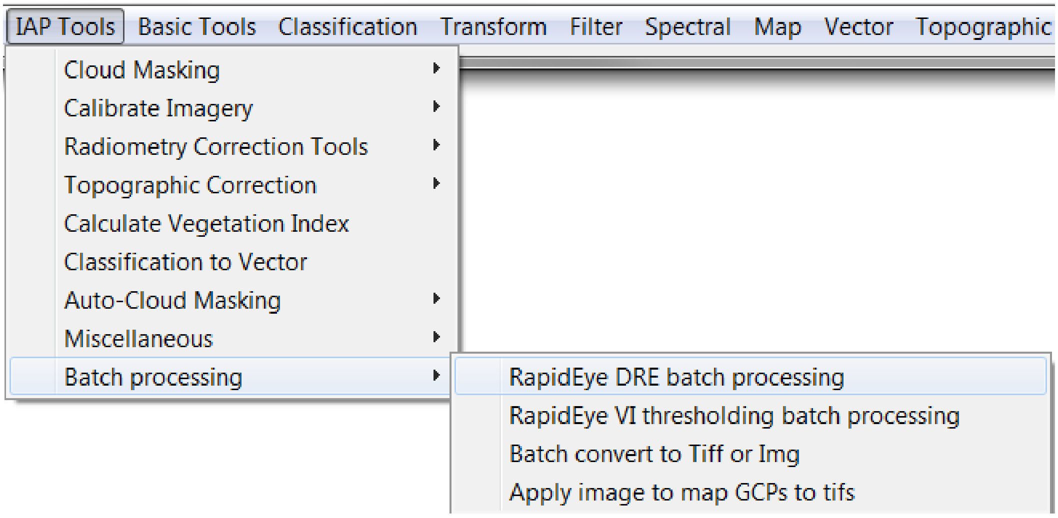
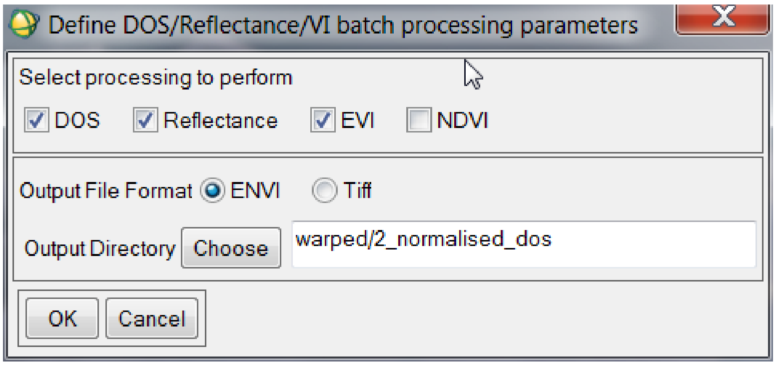


Figure 3: DRE batch processing parameters



15.5 Dark Object Subtraction - Radiometric Normalisation

Radiometric normalisation is a recommended image processing practise to ensure the radiometric values within images obtained over different time periods and by different sensors are calibrated to common reference values.

The Dark Object Subtraction (DOS) subtraction radiometric normalisation method implemented in ENVI was chosen. For each scene the band minimum Digital Number (DN) values are used.

- warped/2_normalised_dos directory

15.6 Convert to reflectance

Convert each normalised dos mosaic to reflectance value using the mean sun elevation from all input tiles. Sun elevation is in the metadata file with the raw image (open in MS Word or WordPad) and search for ‘illumination elevation angle”.

- warped/3_normalised_dos_reflectance directory

15.7 Perform EVI on reflectance

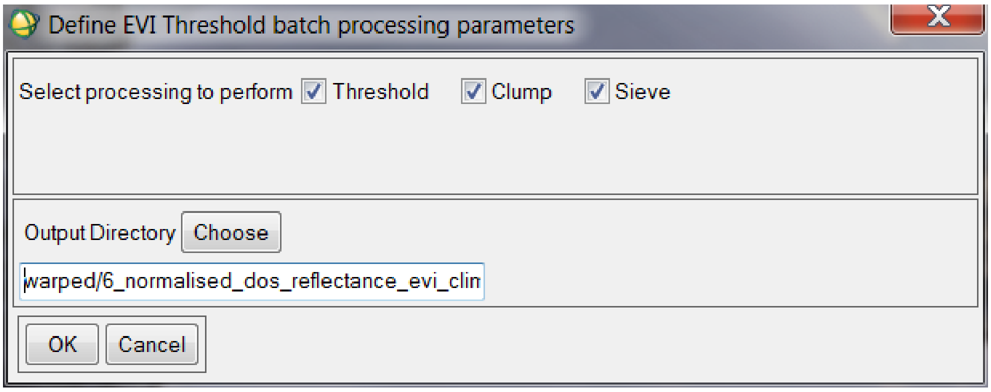
Save as ENVI raster file.

- warped/4_normalised_dos_reflectance_evi directory

15.8 Delineate non-forest regions

The following three steps have been automated using an ENVI custom batch processing tool tool (Figure 4). Create a text file with a list of EVI files to process. After each filename include the minimum and maximum EVI data range that defines the forest/non-forest boundary. This requires a review of each EVI file to identify the threshold limits. Run the *RapidEye VI_threshold_batch processing* tool supplying the files to process text when prompted (Figure 4).

Figure 4: VI thresholding batch processing parameters



15.9 Density slice the EVI to find forest/non forest boundary

It is important to note that the range of EVI values used is not uniform here, It has ranged between .37 - .45 depending on the parameters of mosaic normalisation. Generate Class Image ENVI raster that shows this. You can import to ArcMap temporarily and use the overflight photos to determine where the forest/non-forest boundary is.

- warped/5_ normalised_dos_reflectance_evi_climg

Apply a 'Clump' filter to the result.

Clump adjacent like classes to remove speckle and holes using a 3x3 kernel.

Apply a 'Sieve' filter to the result.

Sieve isolated pixels groups of less than 6 pixels

Vectorize non-forest polygons.

Review the classified image to see if it looks appropriate. Export the Non-forest class using the ENVI raster to vector conversion for analysis in ArcMap.

- warped/6_ normalised_dos_reflectance_evi_climg_filtered

Open the shapefile in ArcMap, run the vector pre-process model giving the input vector, input clip extent and output shapefile name. The model will explode all features. Calculate areas and delete any areas under 1 hectare. Run Fill-Donut-Holes tool in IAPtools toolbox with minimum size of 10 000 m^2, then clip the output to the border of the relevant RapidEye tile to avoid overlap with adjacent vectors.

15.10 Persistent Cloud Mask Generation

The generation of a persistent cloud mask enables the targeting and revisit of persistently cloudy areas. This process involves defining a cloud mask for each scene or mosaic based on a selected a threshold value. At the analysis block level, all the clouds masks are composited into a single persistent cloud mask. Coincident pixels that are cloudy or contain no data in all time periods are defined as persistent cloud.

Use the custom *Generate auto-cloud* masking tool in ENVI to first generated the cloud individual cloud mask for an analysis block (Figures 5 to 6). Use the *Combine selected cloud masks* to combine all cloud masks, identify persistently cloudy pixels (or pixels with no data) and generate binary tif image.

Figure 5: ENVI custom tools menu for persistent cloud masking

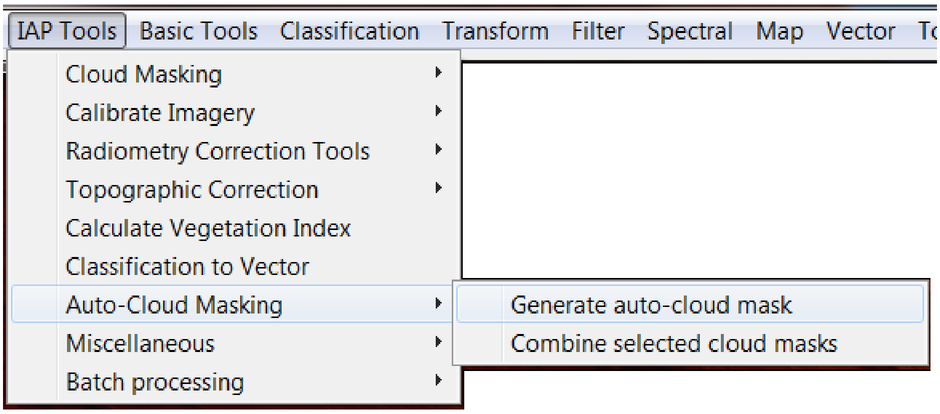
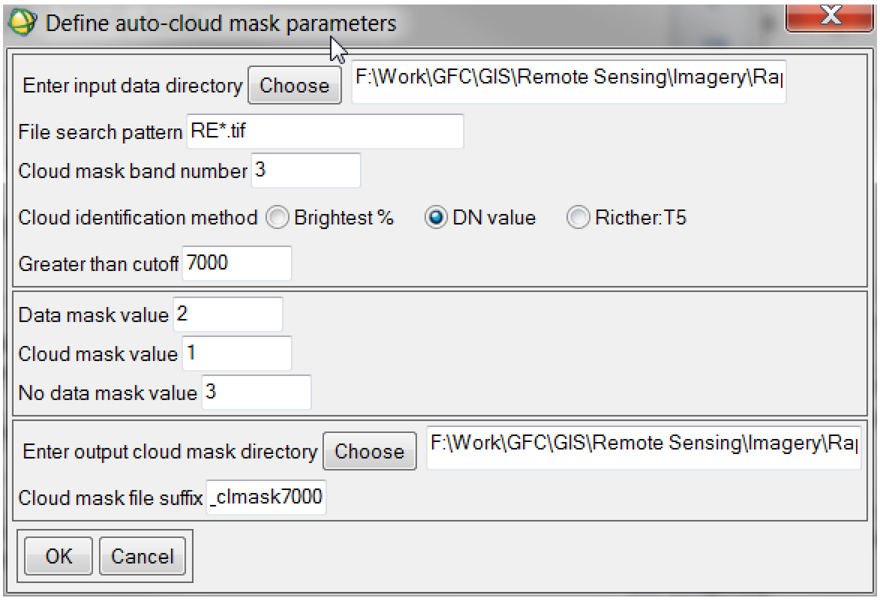


Figure 6: ENVI custom automated cloud mask generation



A list of all imagery once it has been processed is to be compiled using the following naming conventions.

Image Stack Name	Image name in the following format: Satellite (2-3), Path (4), Row (1-3) _ Image Date (YYMMDD)_Image Provider (U= USGS, R=RapidEye, D=DMC, MO=Modis, GF= Geo Fct,)_Processing level (1-2, O=Orthorectified, W=Warped)
Mapping Stream	The mapping stream that the imagery is for.
Data Provider	The name of the data provider.

16. GIS MAPPING PROCESS

In keeping with the methodology applied in previous assessments Guyana has been divided into a series of regularly spaced grids.The mapping process involved a systematic review of 24 x 24km grid tiles at a resolution of 1:15,000 over the RapidEye coverage region and a scale of 1:24,000 over the Landsat coverage region.

If cloud is present on the RapidEye then Landsat images over that location are also assessed. The tile size was chosen to align with the footprint of a single RapidEye tile and the different mapping scales were used to best align with the differences in image resolution. The RapidEye tiles were then subset to a 1km x 1km grid. The process involves a systematic tile-based manual change detection analysis in ArcMap.

It involves editing the EVI vector outputs from the change detection process as required to delineate Year 2 change events. Change is attributed with pre and post change event image evidence, driver of change event, and resultant land use class. The input process is standardised through the use of a customised GIS tool bar which provides a series of pre-set selections that are saved to a shapefile.

16.1 GFC GIS Change Detection Toolbar

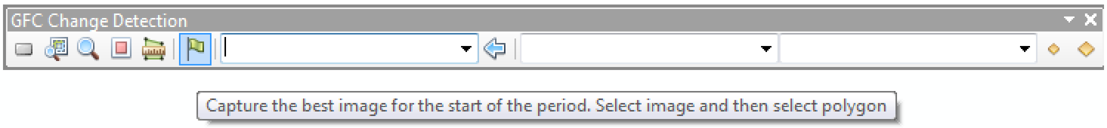
The intention of the toolbar is to track land use change by documenting the satelliteimages used, the period the change occurred, the driver of the change and the end land use. It also tracks the user and allows flags to be set to review inputs as required.

The following steps document the usage of the customised 'GFC Change Detection' VBAtoolbar for populating the fields of the 'new_LUC_change' shapefile.

The mapping decision tree should be consulted to determine the driver and land use class selection.

Capture Start Source image.

Highlight the name of the most recent image evidence in the Table of Contents that shows the polygon area as forested. Click the green flag button to capture the name of that image. This is input to the 'StartSrc' field upon field population.

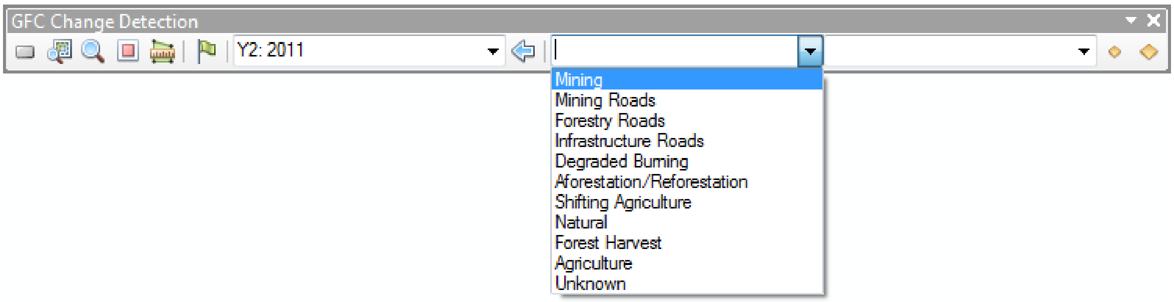


Period Selection

Select 'Y2: 2011' For year 2 change event. This is input to the 'Period' field upon field population.

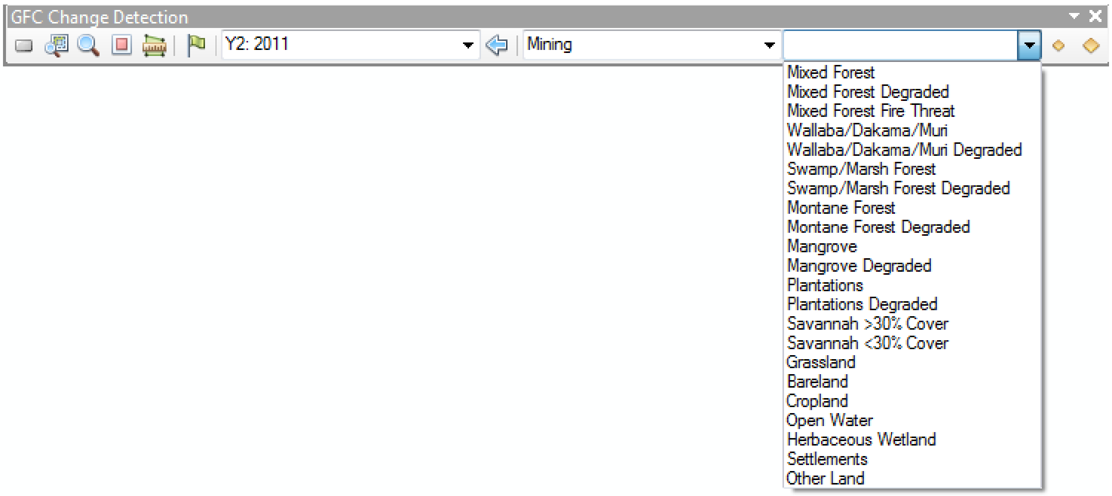
Driver Selection

Using the mapping decision tree select the appropriate driver of the change event. This is input to the 'Y2Driver' field upon field population



Land Use Class Selection

Using the mapping decision tree select the appropriate end state land use class that has resulted from the change event. This is input to the 'Y2EndLUC field' upon field population.



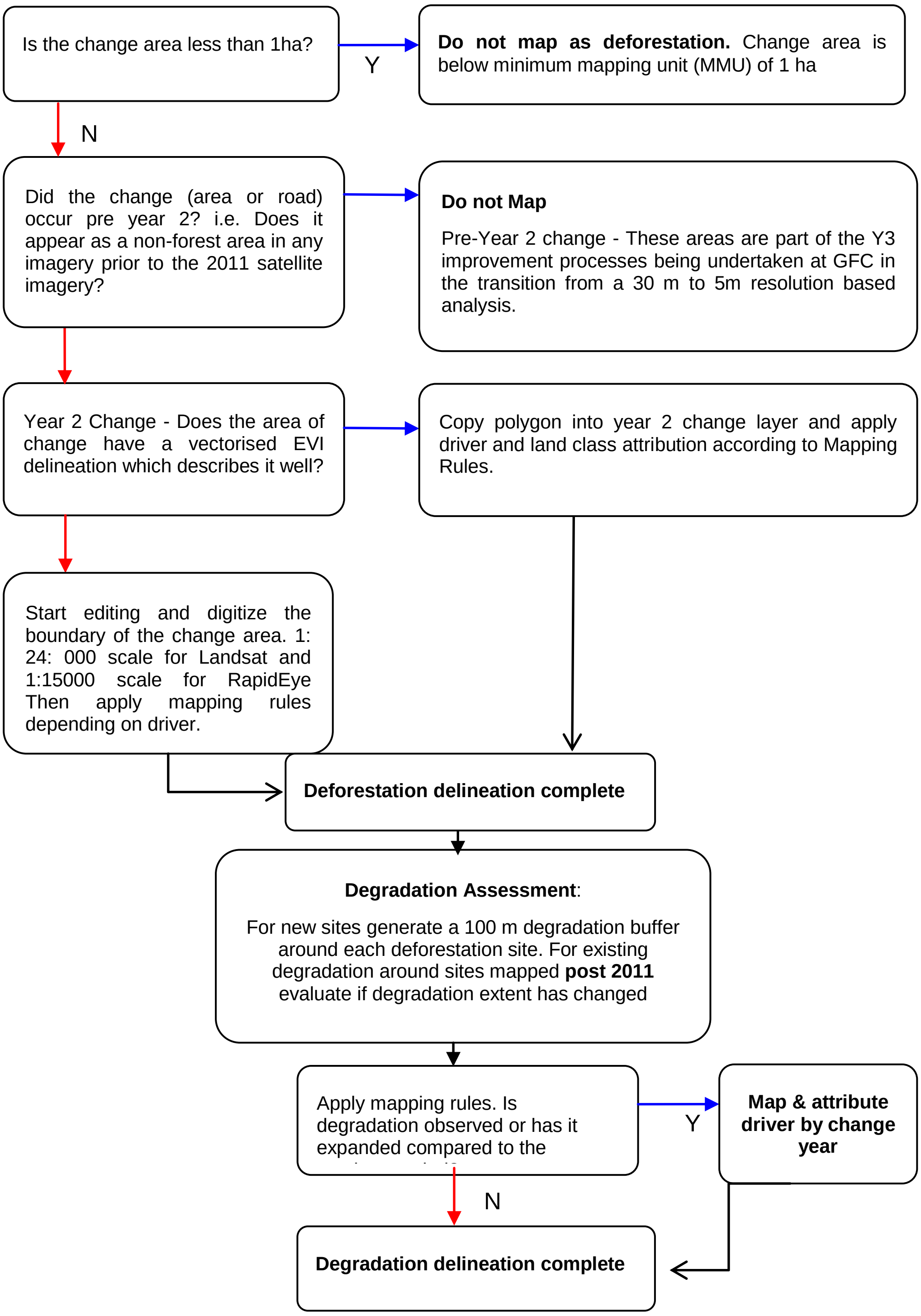
Field Population

Once clicking the gold diamond shaped field population button, the period, driver and land use class information in your toolbar will be populated into the 'new_LUC_change' shapefile.

The driver is evidence based operator determined using the geometry and spectral properties of landcover, as well as reference base datasets and land use context.

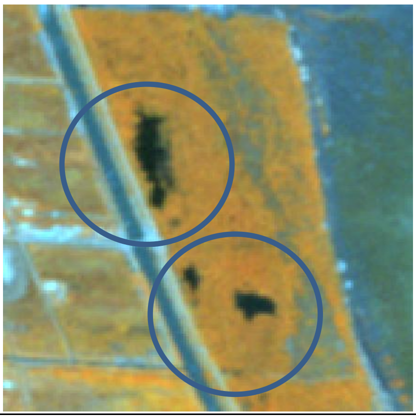
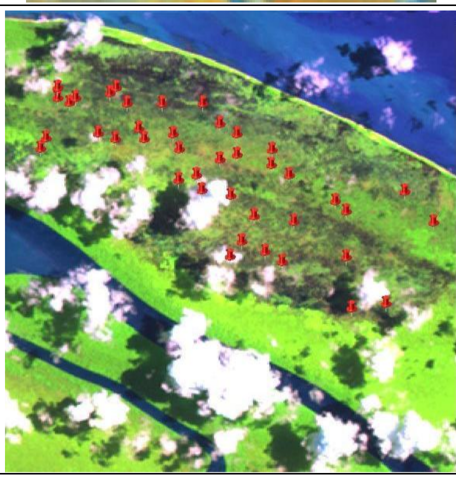
The decision tree that shows the process followed when mapping deforestation and degradation delineation is outlined as follows. This is process is supported by reviewing the mapping interpretation guide.

Figure 7: Mapping Decision Tree



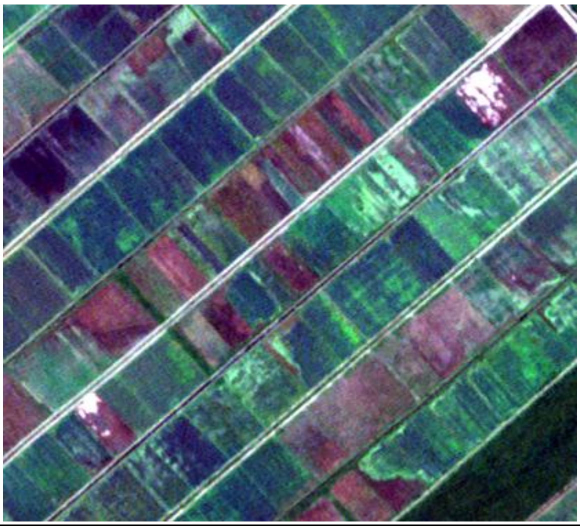
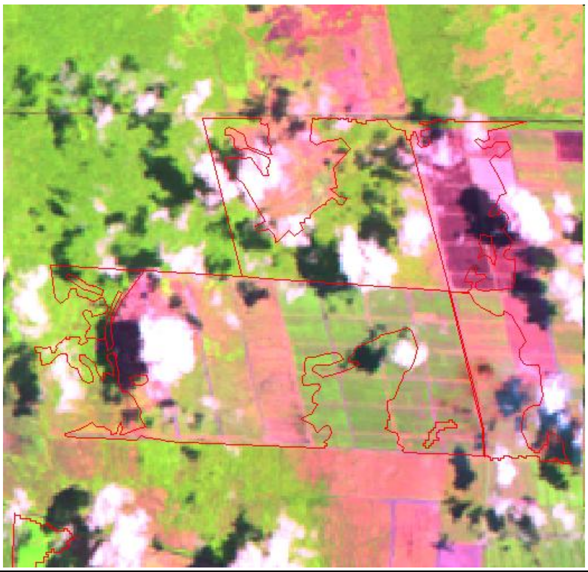
17. MAPPING GUIDE: DEFORESTATION EVENTS

Fire – Biomass burning

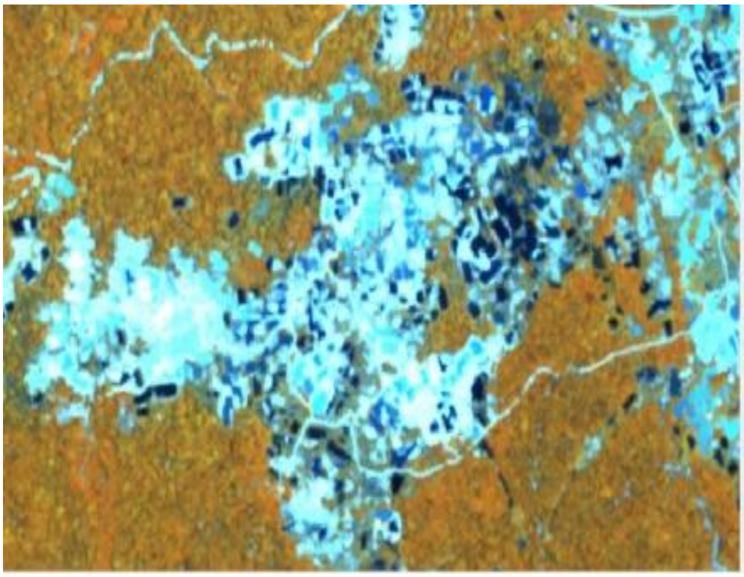
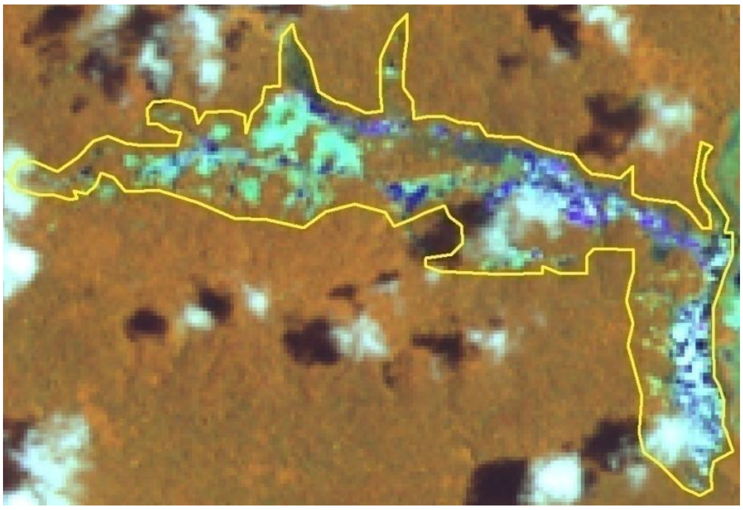
Description	Fires (biomass burning) are assumed to be human-induced. If the event has occurred recently, the burnt areas will show a strong response in near infrared band due to a decrease in actively photosynthesising vegetation. In Guyana areas most at risk include the coastal zone and savannah or white sands regions. Often burning is associated with land clearance. If vegetation still remains then it is identified as degradation rather than deforestation
Geometry	Irregular shaped, sometimes rectangular in 'fields'
Spectral properties	Often appears black in the imagery
Reference Data	Fire Information for Resource Management System (FIRMS) provides information about historic and present day fire locations. The MODIS product is only effective in cloud-free conditions. Successful detection of burnt areas depends on the intensity and the scale of the fire[56].
Mapping Rule	Digitize a single polygon around the spatial extent of the change area
Driver	Degraded Burning
Fire as detected from RapidEye	
Fire as detected from Landsat – FIRMs fire points overlaid	

[56]MODIS routinely detects both flaming and smouldering fires 1000 m² (1 ha) in size. Under very good observing conditions (e.g. near nadir, little or no smoke, relatively homogeneous land surface) flaming fires one tenth this size can be detected. Under pristine (and extremely rare) observation conditions even smaller flaming fires 50 m² can be detected".

17.1 Agriculture

Description	This category includes arable and tillage land, and agro-forestry systems. Cropland is identified as permanent fields, mainly sugar cane fields, but also other crops or mixed agricultural land, where the agricultural component is dominant. Forest areas converted to agriculture are generally found adjacent to existing established farmland, in proximity to settlements and along the coastal fringe. They take the form of regular rectangular blocks, 5 or more hectares in size. Each block has its own distinctive spectral signature. The Guyana Lands and Surveys Commission (GL&SC) layer of registered agricultural leases provide an additional reference source for identification of agricultural land.
Geometry	Regular shaped 'fields', can be irregular shaped
Spectral Properties	Can be very diverse in spectral signature due to vegetation type.
Reference Data	GL&SC agriculture lease boundaries (Not held for private lands)
Mapping Rule	Digitize a single polygon around the spatial extent of the change area
Driver	Agriculture
Land use Class	Cropland
Cropland as detected from RapidEye	
Cropland as detected from Landsat	

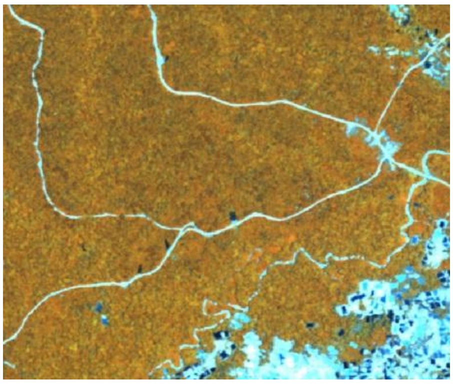
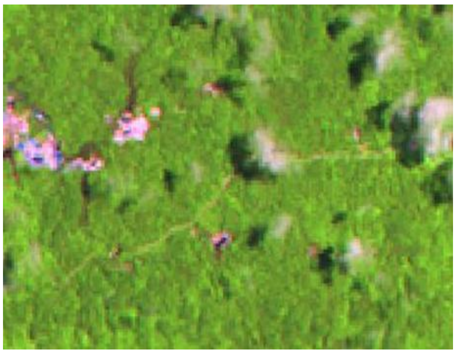
17.2 Mining

Description	Mining activity produces forest clearings with very variable shapes and sizes and with sharp boundaries The clearings often occur in linear clusters along streams or near water bodies and in remote areas with limited road infrastructure. Areas cleared by mining activity have a distinctive spectral response. The association of sand, mud, rock and pools of water is identified by pink or grey and blue colours in false colour composites (bands 4,5,3)..
Geometry	Irregular shaped areas
Spectral Properties	Characterised by water pools and bareland
Reference Data	GGMC Mining shapefiles and dredge sites point shapefile
Mapping Rule	Digitise or edit EVI delineation of mining area
Driver	Mining
Land use Class	Bareland
Mining as detected from RapidEye	
Mining as detected from Landsat	

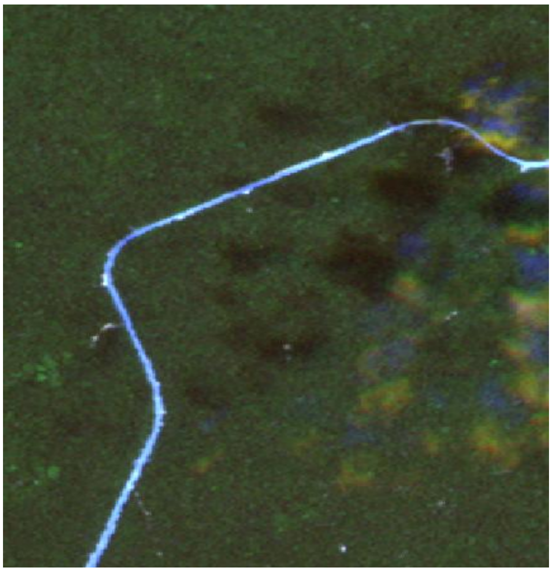
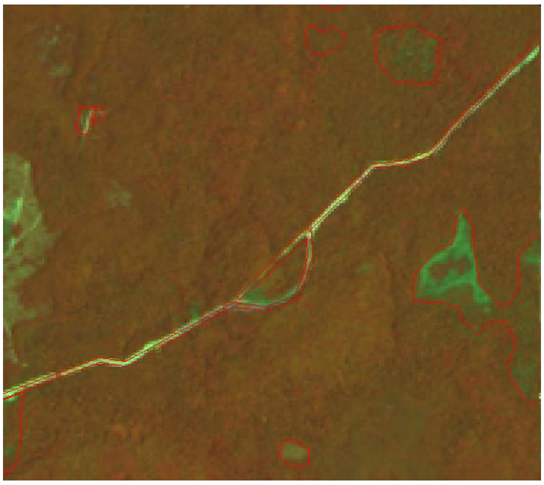
17.3 Infrastructure

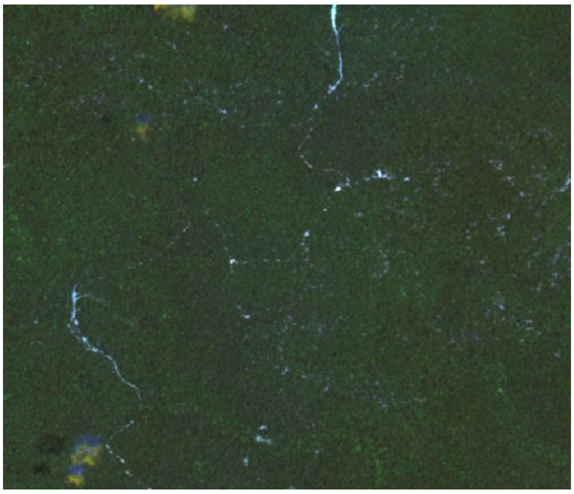
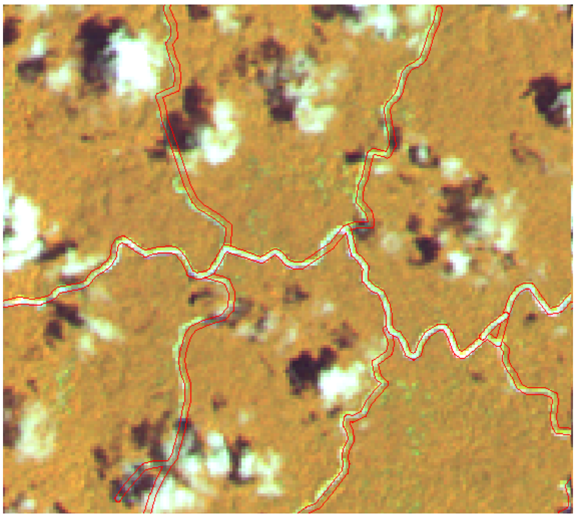
Infrastructure related to the activity can be identified on satellite imagery. In this assessment period all infrastructure development is related to road construction. It is likely that in future periods additional activities will be identified. Road clearings have a characteristic linearity and can be traced to the existing roading network. Bare soil associated with the construction of unpaved roads is evident in Landsat imagery if the gap in the forest canopy is wider than one pixel (~30 m). For the year 2 assessment roads > 10 m as identified from the RapidEye are mapped.

GFC has split the drivers for infrastructure into three classes. The attribution is determined by assessing whether the infrastructure is associated with sustainable forest management (SFM) areas (i.e. forest roads), mining areas (i.e. mining roads) or provides a link to major towns and settlements (infrastructure roads). Roads leading to both forest and mining areas are classed as forest roads to the SFM areas and then mining roads thereafter. The following examples describe the characteristics of each class.

Description	**Mining infrastructure**
Geometry	Linear features, easily picked out. map if >10 m (~2pixels), 20 m (2-4 pixels) or 30 m (4-6 pixels) wide but normally are 10-20 m. Accessing or leading to mining sites.
Spectral Properties	Appearing as bareland or 'white' depending on the soil type
Reference Data	GPS roads shapefile, Year 1 analysis Mining roads.
Mapping Rule	Trace from the imagery as linear features and converted to areas by applying a buffer on either side of the features. 10m (or up to 2 RapidEye pixels) 20m (or up to 4 RapidEye pixels) 30m (or up to 6 RapidEye pixels) Where appropriate edit the buffer.
Driver	Mining (by infrastructure type)
Land use class	Settlements
Mining Infrastructure as detected from RapidEye (band combination 5,4,3)	
Mining Infrastructure as detected from Landsat	

17.4 Infrastructure

Description	Infrastructure (in this period all roads)
Geometry	Linear features, easily picked out. map if >10 m (~2pixels),20 m (2-4 pixels) or 30 m (4-6 pixels) wide but normally are 30 m and alot straighter than other road types. Access or transport routes between inhabited areas and small villages.
Spectral Properties	Appearing as bareland or 'white'
Reference Data	GPS roads shapefile, Year 1 analysis Infrastructure roads, settlements point shapefile.
Mapping Rule	Trace from the imagery as linear features and converted to areas by applying a buffer on either side of the features. 10m (or up to 2 RapidEye pixels) 20m (or up to 4 RapidEye pixels) 30m (or up to 6 RapidEye pixels) Where appropriate edit the buffer.
Driver	Infrastructure (by infrastructure type)
Land use class	Settlements
Infrastructure as detected from RapidEye	
Infrastructure as detected from Landsat	

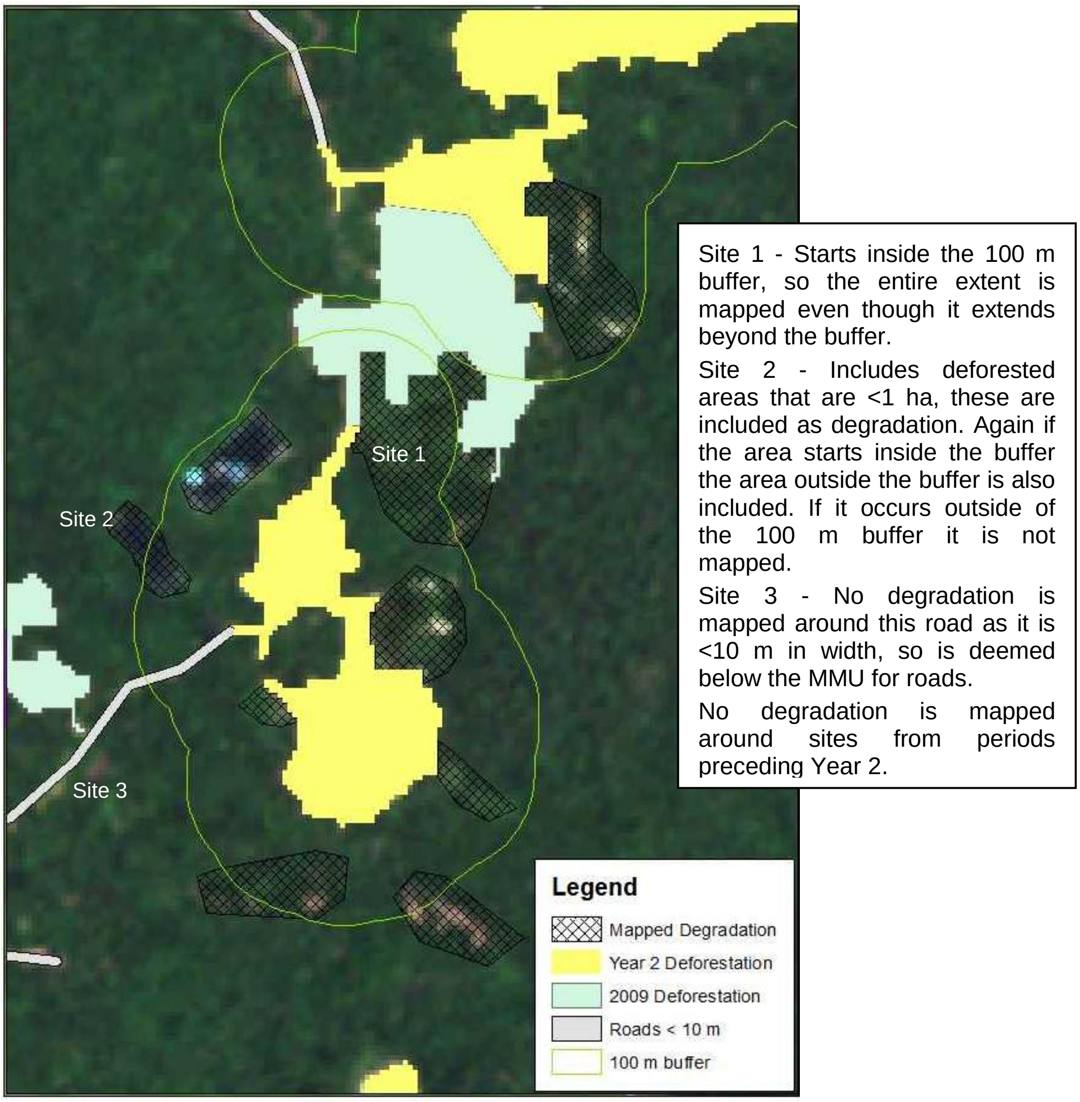
Description	**Forestry infrastructure**
Geometry	Linear feature, easily picked out. Map if>10 m (~2pixels),20m (2-4 pixels) or 30m (4-6 pixels) wide but normally are 10-20m. Often road networks surrounded by areas of forest harvest, complex road networks with no evidence of mining nearby are normally forestry roads. Skid Sites are often visible adjacent to roads.
Spectral Properties	Appearing as bareland or 'white' depending on the soil type
Reference Data	GPS roads Shapefile, Year 1 analysis Forestry Roads, Harvest Areas 2011
Mapping Rule	Trace from the imagery as linear features and converted to areas by applying a buffer on either side of the features. 10m (or up to 2 RapidEye pixels) 20m (or up to 4 RapidEye pixels) 30m (or up to 6 RapidEye pixels) Where appropriate edit the buffer.
Driver	Forestry (by infrastructure type)
Land use Class	Settlements
Forestry Infrastructure as detected from RapidEye	
Forestry Infrastructure as detected from Landsat	

18. DEGRADATION EVENTS

An important aspect of the Year 2 assessment was the quantification of the extent of degradation caused by new infrastructure developments such as road construction and mining through remote sensing and field observations.

The following example shows an area with change from different periods. Mapping is only conducted on Year 2 areas. It is therefore important that these areas are positively identified from previous periods.

Figure 8: Example Change Mapping

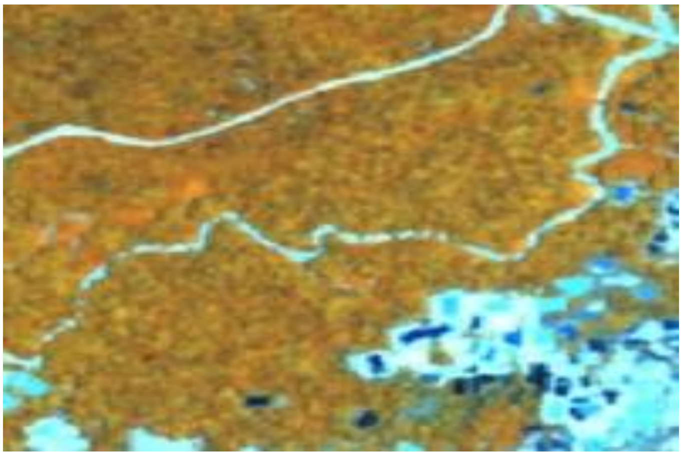
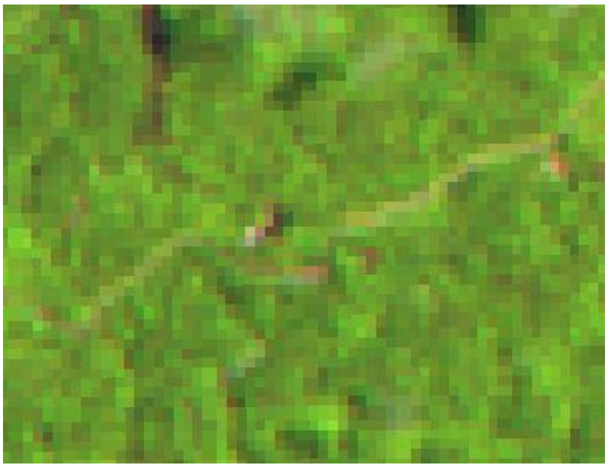


The yellow area is a Year 2 deforestation event. Around the event is a 100 m buffer (green). Degraded areas (hatched) are mapped. These include canopy gaps where the ground is visible (blue). The degradation extent captures these areas by drawing around these pockets.

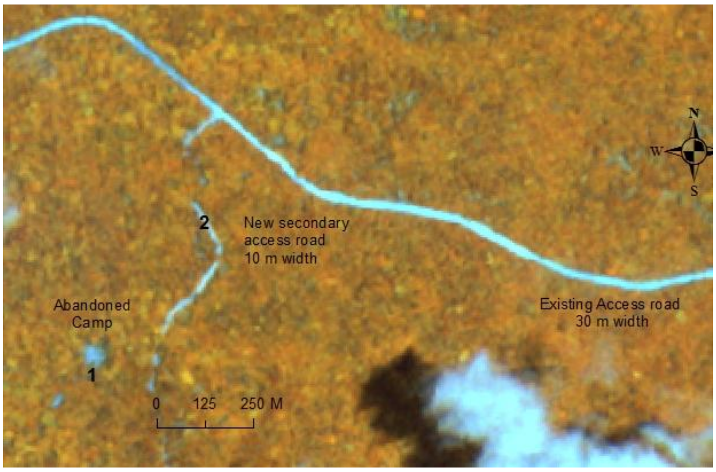
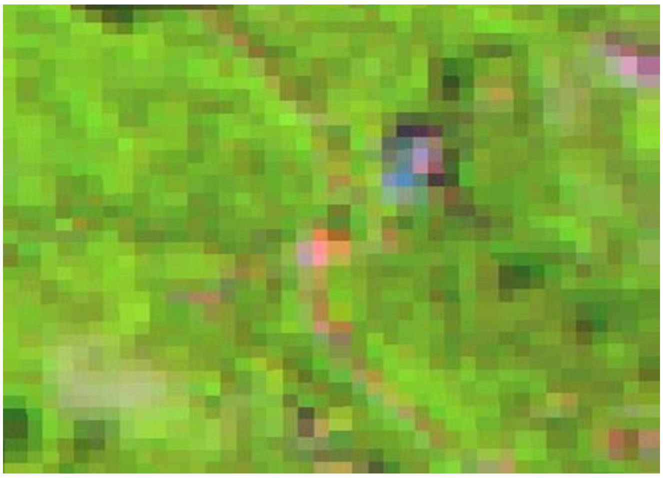
Mapping Expanding Degradation

Repeat coverage of RapidEye over the same locations allows for areas identified as Year 2 degradation to be revisited. This action considers the likelihood that prospecting may resume around recorded deforestation sites. This may result in an expansion of the degradation zone.

18.1 Degradation around New Infrastructure Roads

Description	Degradation around Y2 roads
Geometry	Patches of forest 'islands' within mining areas, or adjacent to mining areas are degraded forest, and a 'buffer' zone surrounding new roads and mining areas.
Spectral Properties	Degraded signature starting at edge of new infrastructure area (mining or roading) and continuing into the forest for a distance.
Reference Data	Adjacent to and buffering new infrastructure.
Mapping Rule	Digitise degradation around year 2 sites only and roads that lead to year 2 sites only if they exceed 10 m in width. Generate buffers around at 100 m either side of roads that are >10 m wide Inside these buffers digitise the extent of the degradation as identified by tonal changes or scattered canopy openings. This also includes deforested areas <1 ha (the current MMU). If degradation starts outside of the buffer do not map it. If degradation starts inside the buffer and extends beyond the buffer then map it. **Revisit** all degraded polygons resulting from new infrastructure mapped in Year 2. Compare the previously mapped extent. If the extent has increased then map and attribute as degradation belong to that period.
Driver	Mining, Forestry, Infrastructure
Land use class	Degraded by forest type
Degradation around Year 2 roads as detected from RapidEye	
Degradation around Y2 roads as detected from Landsat	

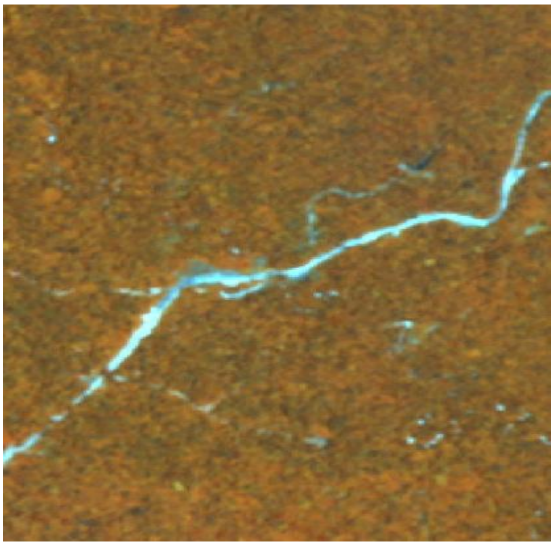
18.2 Degradation around New Infrastructure

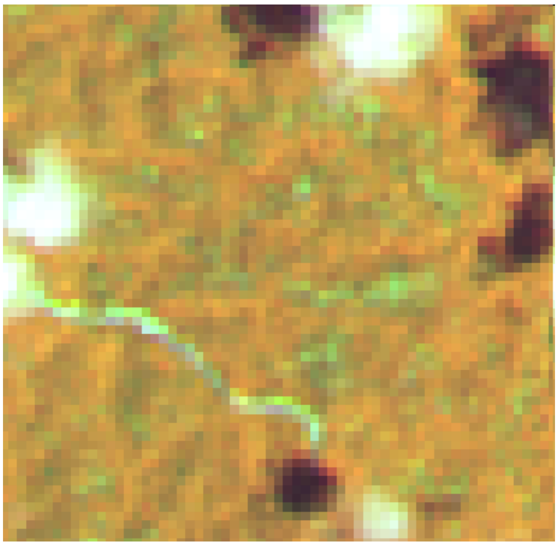
Description	Degradation around Y2 Infrastructure
Geometry	Patches of forest 'islands' around mining areas, or adjacent to mining areas are degraded forest, and a 'buffer' zone surrounding new roads and mining areas.
Spectral Properties	Degraded signature starting at edge of new infrastructure area (mining or roading) and continuing into the forest for a distance.
Reference Data	Adjacent to and buffering new infrastructure.
Mapping Rule	Digitise degradation around year 2 sites only Generate 100 m buffer around the site Inside these buffers digitise the extent of the degradation as identified by tonal changes or scattered canopy openings. This also includes deforested areas <1 ha (the current MMU). If degradation starts outside of the buffer do not map it. If degradation starts inside the buffer and extends beyond the buffer then map it. **Revisit** all degraded polygons resulting from new infrastructure mapped in Year 2. Compare the previously mapped extent. If the extent has increased then map and attribute as degradation belong to that period.
Driver	Mining, Forestry, Infrastructure
Land use class	Degraded by forest type
Degradation around Y2 roads as detected from RapidEye	
Degradation around Y2 roads as detected from Landsat	

19. LAND USE CHANGE TO BE FURTHER DEVELOPED AND REPORTED IN THE MRVS

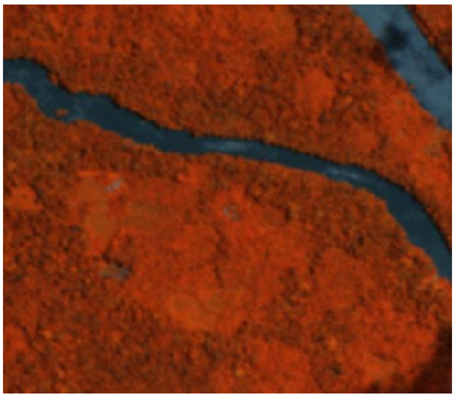
There are several land changes that have not entered the MRVS. Under the JCN changes in these areas are not currently reported. For completeness the general extent of these areas is mapped to ensure that they are not accounted for as measured land use change.

Forest Harvesting

Description	Degradation can be difficult to identify. Selective logging degrades the forest causing damage to nearby trees and soils and decreases the forest canopy. Forest burning may occur after a forest have been opened, further reducing the original canopy. The land cover shows a complex arrangement of dead vegetation, forest islands and bare soil. The spectral signature of the degraded areas is mixed on a pixel scale. When using Landsat imagery with band 4 5 3 combination, a mixture of white/red/pink pixels (soils), pale greed/yellow (dead vegetation, shrub) and red/brown (forest) is observed. Forest harvesting activity is also recognized by the presence of roading. The forestry roads typically define a dendritic pattern with short tracks radiating outwards into forest from a major road. Log landings are located along the major road and where the roads meet rivers. Log landings are identified from the typical spectral signature of soil.
Geometry	Patchy looking forest areas, normally with many forestry roads, may be difficult to spot, but small holes in the canopy can also be seen.
Spectral Properties	Noticeable change in signature between non harvested forest and harvested forest often 'browner' looking in 5,4,3. Watch out for band 4 of RapidEye which can be deceiving, use 3,2,1 to confirm. Band 4 can show natural variation as degradation.
Reference Data	SFM layer of approved harvesting plansshapefiles, including TSA's and WCL's, also Forest strata map which shows forest type.
Mapping Rule	Digitize a single polygon around the spatial extent of the impacted area (degradation).
Driver	Forest harvest
Land use class	Degraded by forest type
Harvesting as detected from RapidEye	

Harvesting as detected from Landsat	

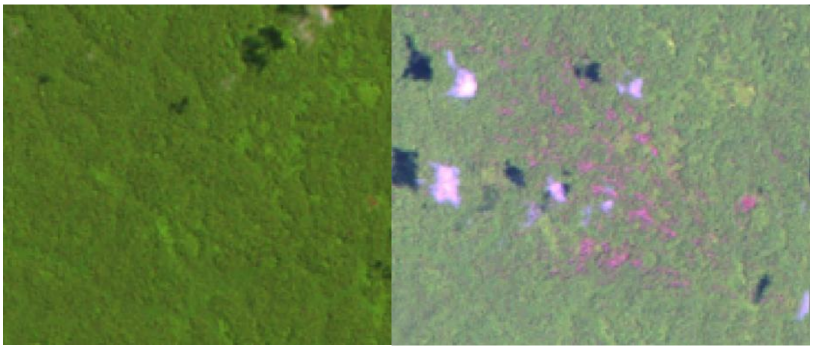
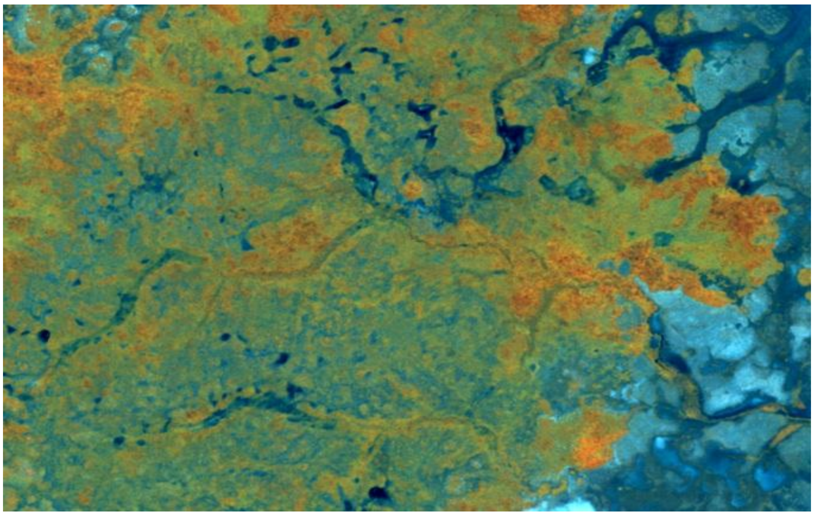
19.1 Shifting Agriculture

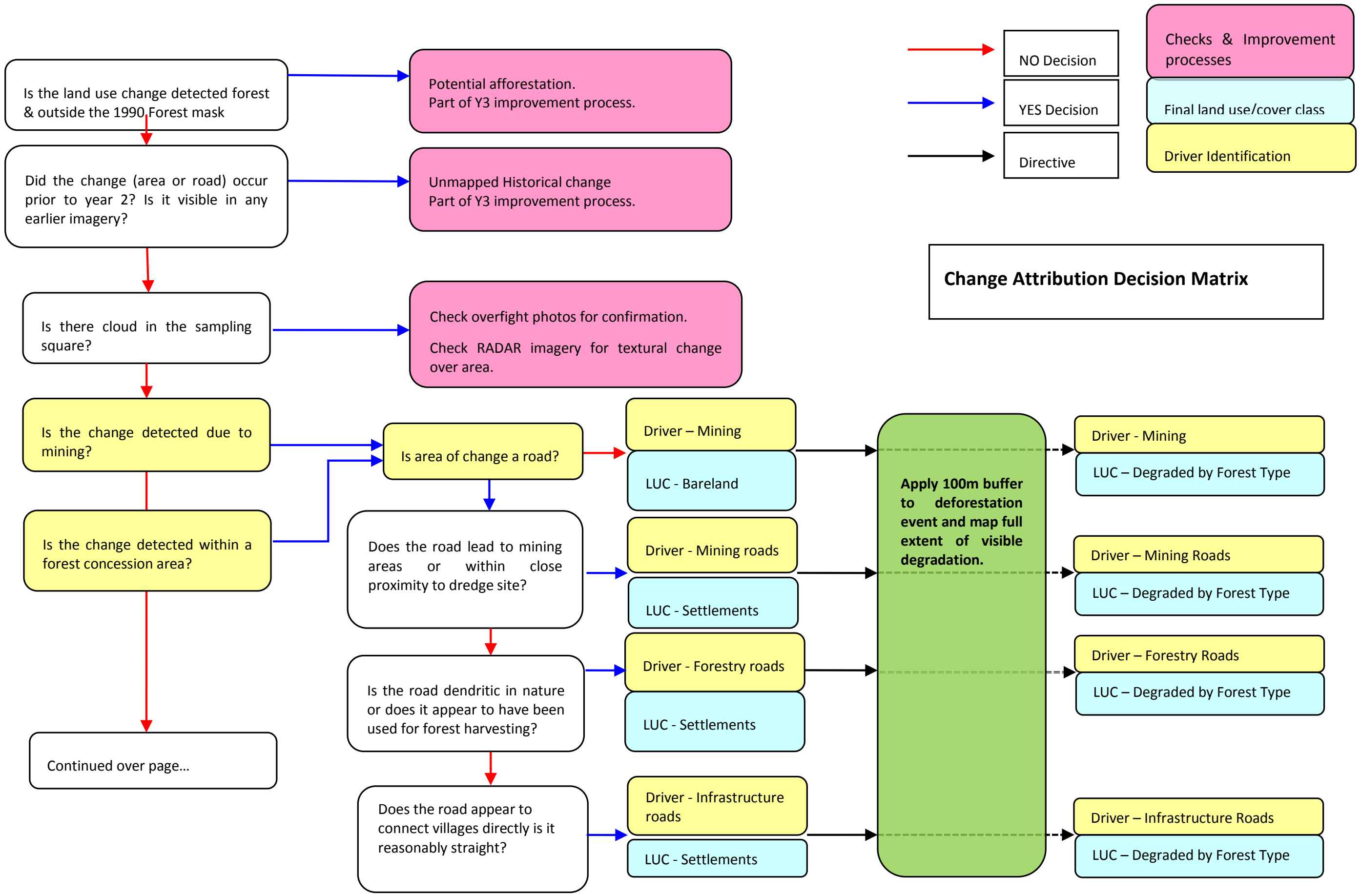
Description	Two types of shifting cultivation are recognized: pioneer and rotational. Pioneer shifting cultivation involves the cutting of primary forest and subsequent cropping and then abandonment. Rotational shifting cultivation involves revisiting areas on a rotational cycle. This agricultural activity is characterized by a disordered scattering of small forest clearings often in proximity to settlements and near rivers. Small patches of soil cover are interspersed with areas of cropland and grassland. The patches are amorphous to regular in shape and the transition to forest is usually gradual. The spectral response from bare soil typically appears beige to red and the cropland and grassland display as pale red/grey to pale green tones (Landsat 4, 5, 3 band combination). The extent of these areas is mapped by delineating the overall extent of the activity. Over time the coverage of these areas may extend or contract. The extent of any regeneration still remains to be quantified in the field.
Geometry	Patchy looking inhabited area with small scale agriculture areas in various states of use.
Spectral Properties	Diverse range of spectral signatures, from bareland to degraded forest within a small area.
Mapping Rule	Shifting agriculture - digitize a single polygon around the spatial extent of the impacted area (degradation). Pay special attention to ensure that shifting agriculture areas (forest degradation) are not confused with agriculture (deforestation).
Driver	Shifting Cultivation
Land use class	Cropland
Shifting cultivation as detected from RapidEye	
Shifting cultivation as detected from Landsat.	

19.2 Natural Events

Change from non-anthropogenic events such as flooding and wind damage is mostly observed outside of accessible, populated and managed areas. The degradation is identified from the presence of dispersed or clustered patches of dead vegetation in remote areas away from settlements and roads.

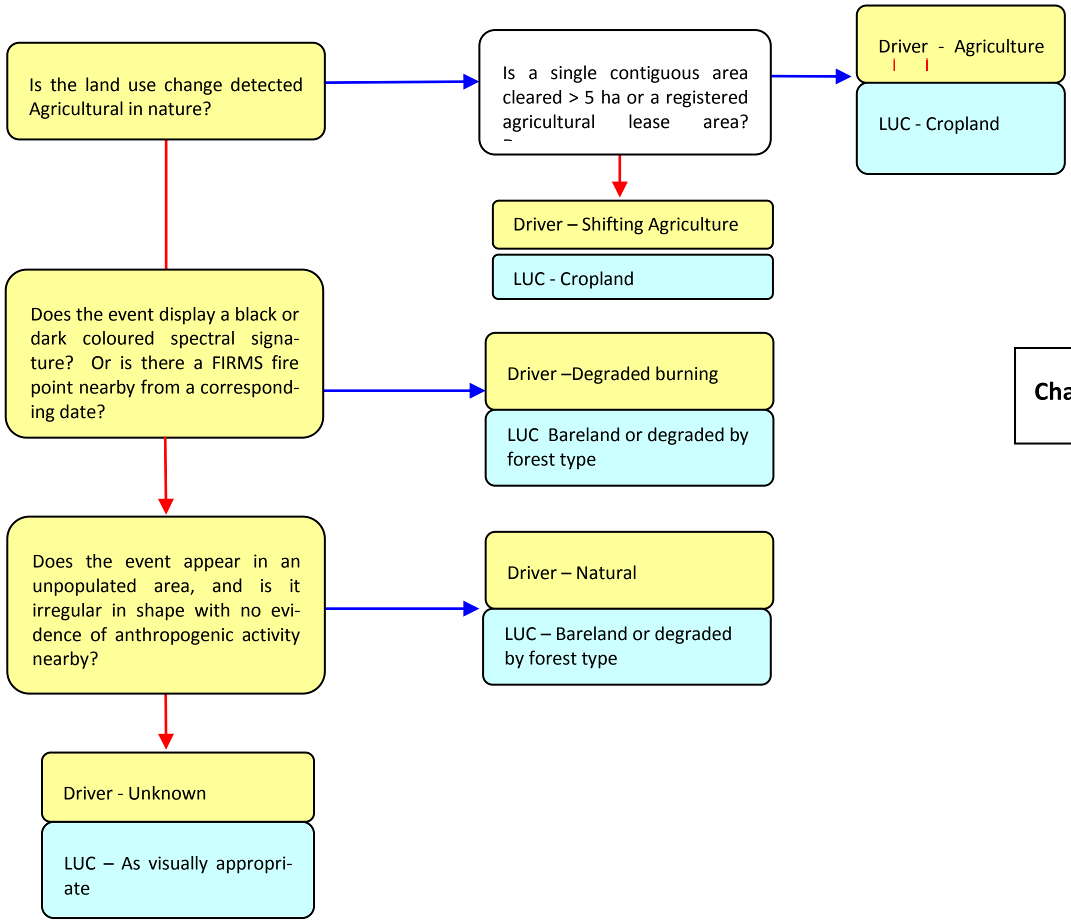
These areas are attributed with a land class of degraded forest by forest type or bareland as required.

Mapping Rule	digitize a single polygon around the spatial extent of the impacted area (if not forest change seek assistance)
Driver	Natural
Land use class	Degraded by forest type
Wind damage 1990 forested 2000 deforested 2005 forested	
Wetland	 Natural irregular shaped areas where there is no evidence of human activity - these can be wetlands which are occasionally inundated. Often the spectral signature can be quite different, but no deforestation has taken place. It is best to look at the 'texture' of the signature or uniformity of surrounding areas for evidence of deforestation.



Is the land use change detected forest & outside the 1990 Forest mask
Potential afforestation. Part of Y3 improvement process.
Did the change (area or road) occur prior to year 2? Is it visible in any earlier imagery?
Unmapped Historical change Part of Y3 improvement process.
Is there cloud in the sampling square?
Check overfight photos for confirmation.
Check RADAR imagery for textural change over area.
Is the change detected due to mining?
Is the change detected within a forest concession area?
Continued over page…
Is area of change a road?
Does the road lead to mining areas or within close proximity to dredge site?
Is the road dendritic in nature or does it appear to have been used for forest harvesting?
Does the road appear to connect villages directly is it reasonably straight?
Driver – Mining
LUC - Bareland
Driver - Mining roads
LUC - Settlements
Driver - Forestry roads
LUC - Settlements
Driver - Infrastructure roads
LUC - Settlements
Apply 100m buffer to deforestation event and map full extent of visible degradation.
Driver - Mining
LUC – Degraded by Forest Type
Driver – Mining Roads
LUC – Degraded by Forest Type
Driver – Forestry Roads
LUC – Degraded by Forest Type
Driver – Infrastructure Roads
LUC – Degraded by Forest Type
NO Decision
YES Decision
Directive
Checks & Improvement processes
Final land use/cover class
Driver Identification
Change Attribution Decision Matrix

Change Attribution Decision Matrix



20. QA/ QC PROCESSES

There are several Quality Assurance processes that are undertaken in developing the national change analysis results. The MRVS is currently not fully operational so further documentation and processes will be developed to ensure that the MRVS adheres to be best practice. The key elements of the process include;

- Development of the monitoring plan to ensure the provision of satellite data to cover the reporting period
- Task higher resolution satellite imagery to ensure better delineation of change and detection of degradation
- Facilitate data sharing between agencies through inter-agency training
- Inclusion of over-flights and capture of geo-referenced oblique photos to confirm vegetation types and change
- Upgrade of GPS units to assist with photographic documentation
- Development of routines to automate processing of remote sensing datasets
- Development of standardized toolbars to enable consistent attribution of change and documentation of drivers of change
- Development of training materials to assist with the attribution of change
- Review of appropriate peer- review documentation to ensure best practices are adopted in developing methods

20.1 QC Processes

- Review of operators change decisions
- Topology checks of spatial data to ensure area estimates are correct - i.e. removal of overlaps and duplication.
- Commissioning of an independent accuracy assessment to assess the accuracy of the forest change and degradation results
- Independent audit of Interim measures

July 2012

Standard Operating Procedures (GIS) for Reporting on MRVS Interim Measures

This SOP is divided into 3 sections in accordance with the analysis and subsequent reporting requirements of the interim measures. Table 2 is reproduced below and outlines these measures.

Table 2 Interim Measures

Measure Ref.	Reporting Measure	Indicator	Reporting Unit	Reference Measure	Year 1Period	Year 2 (01 Oct 2010 to 31 Dec, 2011) 15 months	Difference Y2 and Benchmarkand Y2 and Y1 for Indicators 2, 2b, & 5
1	Deforestation Indicator	Rate of conversion of forest area as compared to the agreed reference level.	*Rate of change (%)/yr^{-1}*	0.275%[57]	0.056%	0.054%	-0.002
2	Degradation Indicators	National area of Intact Forest Landscape (IFL). Change in IFL post Year 1, following consideration of exclusion areas.	*Million ha*	N/A	7.60 (refined to5.59)	5.59	0
2b		Determine the extent of degradation associated with new infrastructure such as mining, roads, settlements post the benchmark period.	*ha*	N/A	92 413[58]	5 460	-86 939
5	Emissions resulting from anthropogenic forest fires	Area of forest burnt each year should decrease compared to current amount.	*ha/yr^{-1}*	NA	1 706[59]	28	-1 678

The following sections describe the actions that pertain to generating the required outputs for the interim measures reporting. Some of the following sections can be found in the mapping guide SOP but are reproduced here to ensure the interim measures are all addressed in a specific and consolidated manner.

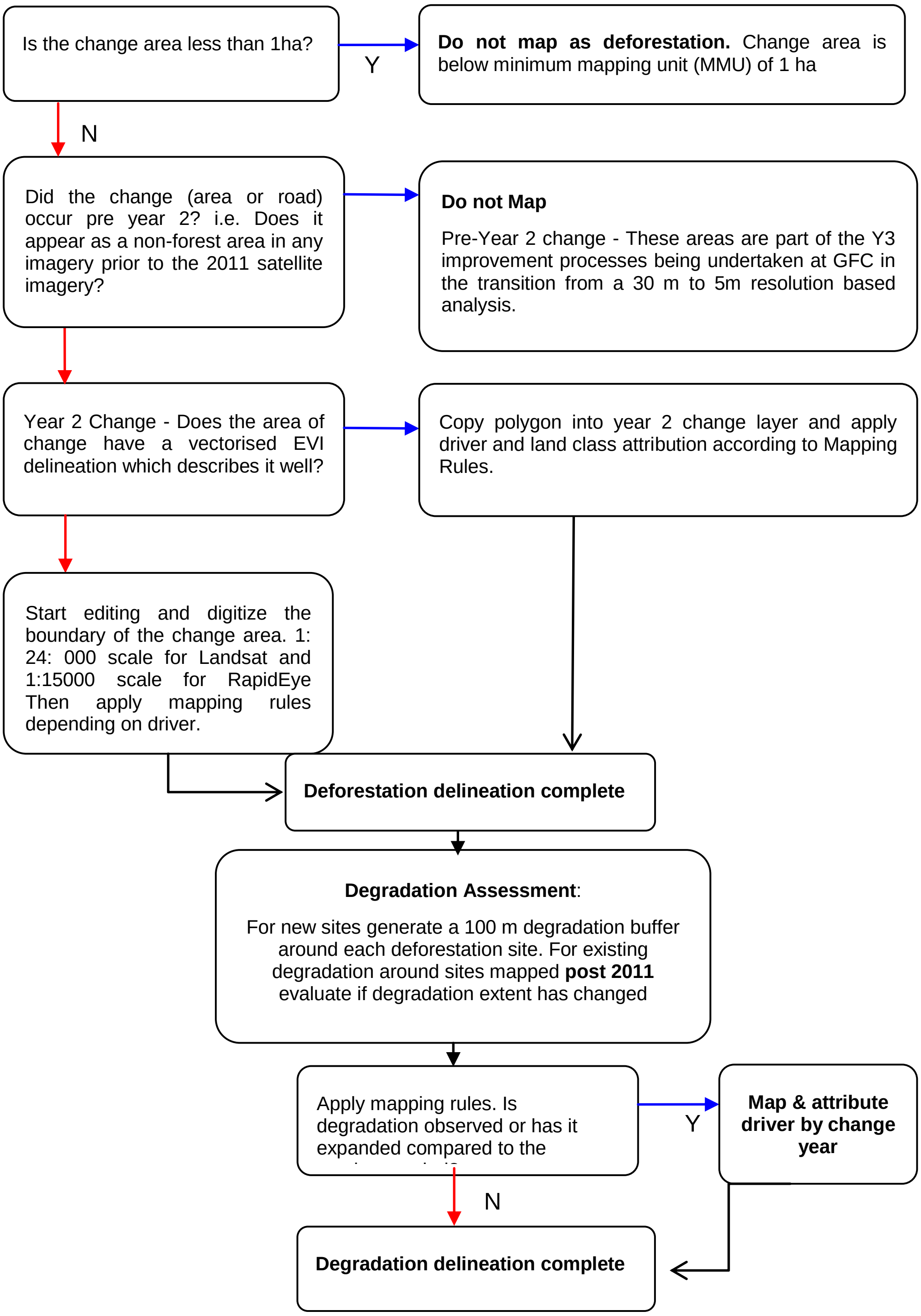
[57]JCN March 2011 Pages 6 and 11.

[58]This indicator as is required by the Joint Concept Note of the Agreement between Guyana and Norway, includes a buffering of 500 km on all sides of all **new (this is defined by all features that occur for the first time in the period under assessment - Year 1)** detected deforestation activities including road and infrastructure developments, forestry, and mining. This area does not necessarily reflect degradation of forest in a practical sense but it is a provision as required by the interim indicator of the Joint Concept Note. Degradation will be comprehensively informed when the full MRVS is operational. This is therefore a conservative way of measuring of degradation in the interim.

[59] Degradation from forest fires is taken from an average over the past 20 years.

1. DEFORESTATION INDICATOR – GIS PROCEDURE

Gross deforestation is one of the required REDD+ Interim Indicators. The following Standard Operation Procedures are applied in determining gross deforestation:



2. DEGRADATION INDICATORS – GIS PROCEDURE

These interim measures describe the generation of the two forest degradation indicators.

- The spatial representation of the Intact forest Landscape (IFL)
- The methodology employed for mapping degradation surrounding new infrastructure

Intact Forest Landscape

An intact forest landscape 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 500km² and a minimal width of 10km" (http://www.intactforests.org/concept.html).

Areas of human influence are not eligible and these include such areas as –

- Settlements (including a 1km buffer zone)
- Infrastructural developments (including a 1km buffer zone)
- Agriculture and timber production

The IFL is generated by removing all the required exclusions through running an ArcGIS based model. This model starts with the full extent of Guyana and works through the required exclusion areas and buffers of these exclusion areas to give two final outputs for manual intervention by operators. The required inputs as seen in blue in the model are also listed below –

- Guyana Non Forest Area
- Guyana Mining Concession polygon layer
- Settlements point layer
- Municipalities polygon layer
- Waterbodies polygon layer
- Agricultural Leases polygon layer
- Identified Mining Areas polygon layer
- Guyana Administrative boundary

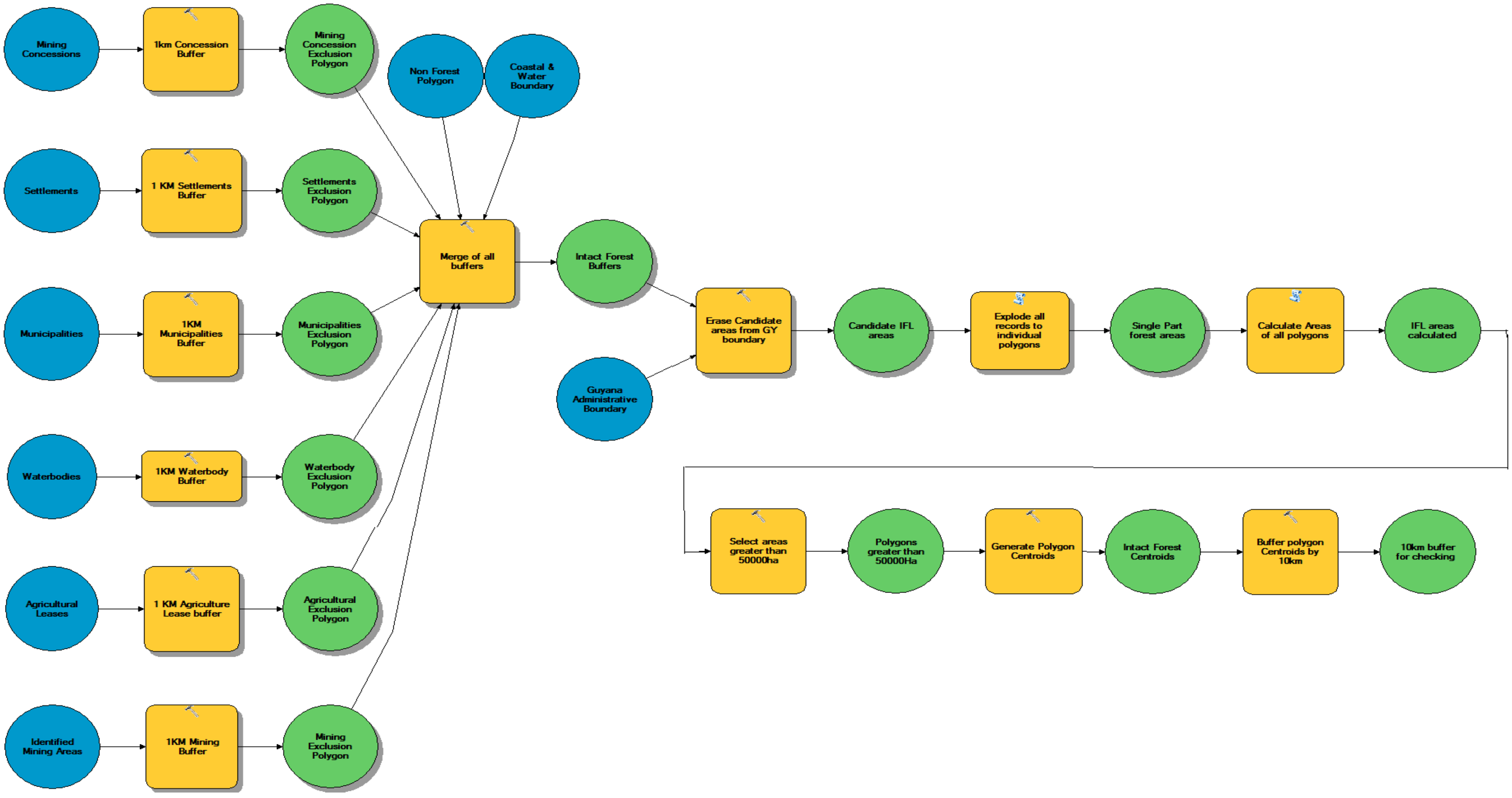
The model produces two outputs –

- The potential IFL polygons
- Buffer circles of 10km in diameter surrounding a centroid

The operator is now required to ensure that a 10km circle can fit completely inside the intact forest polygons, and if it cannot it should be deleted from the final analysis.

Figure 42 below shows the ArcGIS processing model used in generating the Intact Forest landscape.

Figure 42: Intact Forest Landscape Process Model – GIS Procedure



Forest Degradation as a Result of New Infrastructure

Determining the area of degraded forest as a result of new infrastructural development (from both roads and mining) has been undertaken through the spatial mapping of canopy damage using the 5m resolution RapidEye imagery. This methodology is guided by field transects taken perpendicular to Y2 infrastructure areas. The SOP for undertaking a field transect is described below.

The procedures which were applied were standardised and based on the procedures outlined below, and therefore, the determination by the team leader, provided for consistency in methods and accuracy of data collected.

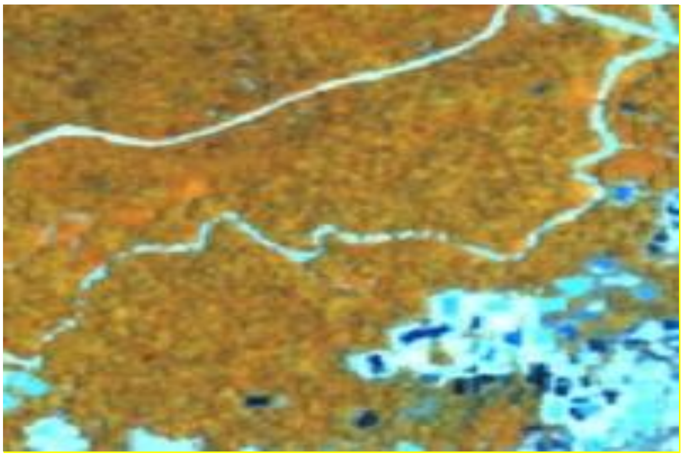
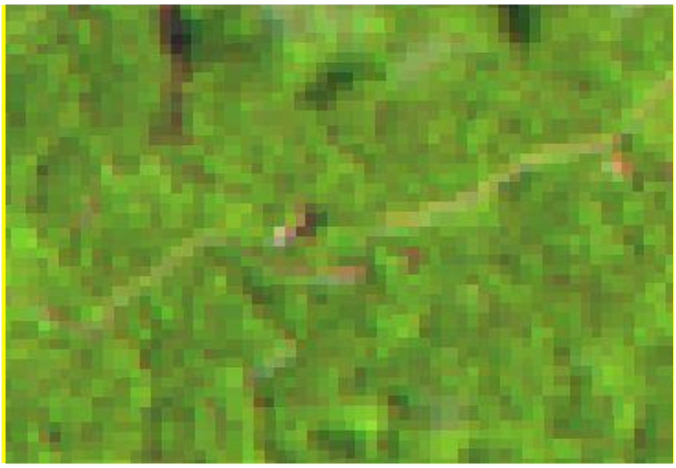
SOP MEASURMENT FOR FOREST DISTURBANCE SURROUNDING DEFORESTATION SITES

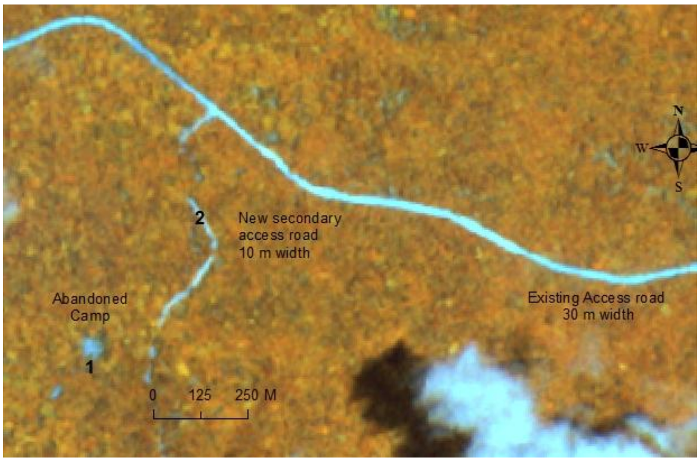
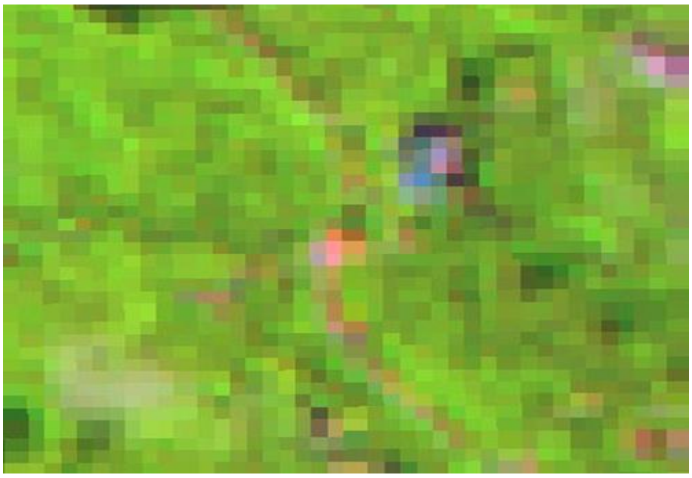
This Standard Operating Procedure (SOP) is used to estimate the disturbance to the forest associated with mining and road construction. The standard forestry methods for establishing and measuring the transect make reference to the existing SOP (GFC/WI) developed as part of the Forest Carbon Monitoring System (FCMS).

The SOP developed for measuring forest disturbance surround deforestation sites differs from the existing canopy-related SOP as itis measured over a transect and includes a quantitative assessment of damage to the forest canopy and floor. Elements of other SOP are relevant to this SOP. Modifications to these SOP's are noted where relevant. Aboveground biomass is estimated using the allometric equation for "tropical moist forests" developed by Chave et al. (2005).

1. Navigate to the start of the transect using a GPS (GFC/WI: SOP Global Positioning Systems)
2. Record the plot using the SOP for labeling plots
3. Establish the line transect on a predetermined compass bearing running perpendicular from the disturbance. All trees 10 m either side of the transect line are included in the plot (GFC/WI: SOP Establishment of Plots).
4. Record the dbh of all live and standing dead trees along the transect > 10 cm (GFC/WI: SOP Measurement of trees).
5. For standing trees use SOP Measurement of standing dead wood, however only measurements of dbh are recorded.
6. Record incidental damage as outline in SOP Measurement of trees - Incidental damage measurements. Only dbh measurements need to be recorded.
7. Record the location of the measured tree along the transect to the nearest metre.
8. Run the transect for a minimum of 100 m if the forest returns an undisturbed state, if not then continue measurement until this occur, unless field conditions prohibit measurement (i.e. swamp, or the transect encounters a deforestation event.
9. Record the quantitative canopy and forest floor scores at 10 m increments along the transect line as outlined below.
10. To calculate the biomass use the allometric equation developed by Chave et al 2005. Summarise the biomass at 10 m intervals.
11. Follow the SOP for Data Entry and add the tree measurements into the carbon stock calculator. This has been modified to cater for the additional canopy and forest floor scores.

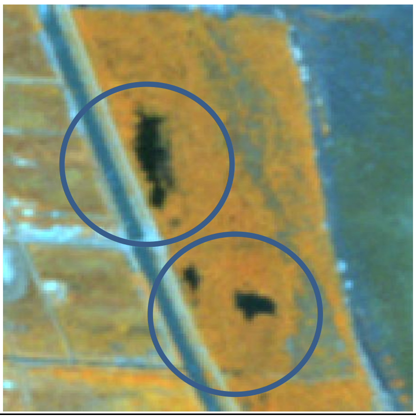
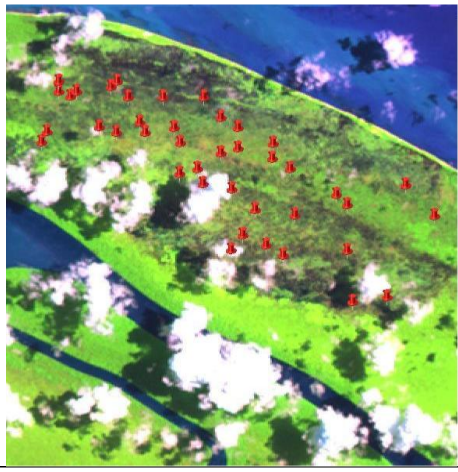
The methodology for undertaking this mapping is found in section 18 of the mapping guide SOP and is reproduced below. This mapping methodology follows on from field transects to create a spatial representation of degradation from new infrastructure.

Description	Degradation around Y2 roads
Geometry	Patches of forest 'islands' within mining areas, or adjacent to mining areas are degraded forest, and a 'buffer' zone surrounding new roads and mining areas.
Spectral Properties	Degraded signature starting at edge of new infrastructure area (mining or roading) and continuing into the forest for a distance.
Reference Data	Adjacent to and buffering new infrastructure.
Mapping Rule	Digitise degradation around year 2 sites only and roads that lead to year 2 sites only if they exceed 10 m in width. Generate buffers around at 100 m either side of roads that are >10 m wide Inside these buffers digitise the extent of the degradation as identified by tonal changes or scattered canopy openings. This also includes deforested areas <1 ha (the current MMU). If degradation starts outside of the buffer do not map it. If degradation starts inside the buffer and extends beyond the buffer then map it. **Revisit** all degraded polygons resulting from new infrastructure mapped in Year 2. Compare the previously mapped extent. If the extent has increased then map and attribute as degradation belong to that period.
Driver	Mining, Forestry, Infrastructure
Land use class	Degraded by forest type
Degradation around Year 2 roads as detected from RapidEye	
Degradation around Y2 roads as detected from Landsat	

Description	Degradation around Y2 Infrastructure
Geometry	Patches of forest 'islands' around mining areas, or adjacent to mining areas are degraded forest, and a 'buffer' zone surrounding new roads and mining areas.
Spectral Properties	Degraded signature starting at edge of new infrastructure area (mining or roading) and continuing into the forest for a distance.
Reference Data	Adjacent to and buffering new infrastructure.
Mapping Rule	Digitise degradation around year 2 sites only Generate 100 m buffer around the site Inside these buffers digitise the extent of the degradation as identified by tonal changes or scattered canopy openings. This also includes deforested areas <1 ha (the current MMU). If degradation starts outside of the buffer do not map it. If degradation starts inside the buffer and extends beyond the buffer then map it. **Revisit** all degraded polygons resulting from new infrastructure mapped in Year 2. Compare the previously mapped extent. If the extent has increased then map and attribute as degradation belong to that period.
Driver	Mining, Forestry, Infrastructure
Land use class	Degraded by forest type
Degradation around Y2 roads as detected from RapidEye	
Degradation around Y2 roads as detected from Landsat	

3. EMISSIONS RESULTING FROM ANTHROPOGENIC FOREST FIRES

Determining the spatial extent of deforestation due to fire damage is calculated through the mapping of fire driven change areas as outlined in the mapping guide. This is reproduced below. The reference data used is the MODIS FIRMS dataset, which is freely available.

Description	Fires (biomass burning) are assumed to be human-induced. If the event has occurred recently, the burnt areas will show a strong response in near infrared band due to a decrease in actively photosynthesising vegetation. In Guyana areas most at risk include the coastal zone and savannah or white sands regions. Often burning is associated with land clearance. If vegetation still remains then it is identified as degradation rather than deforestation
Geometry	Irregular shaped, sometimes rectangular in 'fields'
Spectral properties	Often appears black in the imagery
Reference Data	Fire Information for Resource Management System (FIRMS) provides information about historic and present day fire locations. The MODIS product is only effective in cloud-free conditions. Successful detection of burnt areas depends on the intensity and the scale of the fire[60].
Mapping Rule	Digitize a single polygon around the spatial extent of the change area
Driver	Degraded Burning
Fire as detected from RapidEye	
Fire as detected from Landsat – FIRMs fire points overlaid	

[60]MODIS routinely detects both flaming and smouldering fires 1000 m² (1 ha) in size. Under very good observing conditions (e.g. near nadir, little or no smoke, relatively homogeneous land surface) flaming fires one tenth this size can be detected. Under pristine (and extremely rare) observation conditions even smaller flaming fires 50 m² can be detected".

Appendix 10

Accuracy Assessment
University of Durham

Guyana Forestry Commission
Guyana REDD+ Monitoring Reporting and Verification System (MRVS)

Accuracy Assessment Report

May 2012

Professor Daniel Donoghue, Dr Niko Galiatsatos, Mr Abu Jamil Mahmood.
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EXECUTIVE SUMMARY

This report was commissioned by Indufor Asia Pacific Ltd for the Guyana Forestry Commission in support of a system to Monitor, Report and Verify (MRV) 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 2011-2012. 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 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 31 October 2010 to 31 Dec 2011 (Interim Measures Period – Year 2). High spatial resolution imagery combined with low altitude photography and field visits are used to assess the wall-to-wall mapping of Guyana undertaken by Indufor Asia Pacific Ltd (IAP) and Guyana Forestry Commission (GFC). In particular, imagery from the German RapidEye satellite constellation system, the Worldview-1 and -2 and Quickbird very high spatial resolution satellite data provided excellent sources for assessment of the Year 2 mapping period. A stratified sampling approach was adopted to help provide precise estimates of forest area. Two strata were selected according to "risk of deforestation", that is, land proximal to settlements, roads, logging concessions and known mining dredge sites, and other low risk land area. A 10 km by 10 km grid square was overlaid on the country and using available GIS data and grid squares containing any of the risk variables were tagged as high risk and the remainder as low risk. Interpretations of deforestation and degradation drivers were made from image interpretation of the highest available resolution satellite imagery.

For the Year 2 Forest–Non-forest map, the results show a correspondence(prevalence) between reference image interpretation and IAP/GFC mapping for all the 18,000 one-hectare plots sampled from both strata. The prevalence statistic is a good measure of overall correspondence between the map and reference data. For Year 2, the prevalence was 0.986 or 98.6% agreement.

This demonstrates a very high level of agreement between the MRV maps and the reference data.

Table 1-0: Comparison of Forest Change Estimates

Source	Forest Year 1 (ha)	Forest Year 2 (ha)	Benchmark Rate (%)	Year 1 Rate (%)	Year 2 Rate (%)
GFC/PöyryEstimate	18,388,190		0.021	0.056	-
GFC/ InduforGIS Map Estimate		18,378,301	0.021	0.056	0.054
Durham Sample-based Estimate		18,377,991	0.021		0.053

The estimate of Year 2 forest area for Guyana, based on the stratified sampling design is 6,808,790± 79,629 hectares for the High Risk stratum and 11,562,537± 59,337 hectares for the Low Risk stratum. The size of the sample is too small to estimate the area of Year 2 degradation with any certainty but the data suggests that the wall-to-wall mapping has overestimated the amount of degradation. Based on sampling, we estimate a Year 2 deforestation rate (15 months of change) of 0.053% compared with 0.054% derived by GFC and IAP. Dredge mining and road construction are the principal causes of deforestation and degradation. Parts of Guyana are subject to shifting cultivation that accounts for a small amount of degradation although many areas previously mapped as non-forest are in fact degraded forest or areas of regrowth.

TERMS OF REFERENCE

The objective of this section is to explain the methods used to

i) derive forest area and degradation estimates
ii) quantify the drivers for the types of change mapped, and
iii) derive the <u>deforestation rate</u> for year 2. This includes the results of REDD+ Interim Indicators as outlined in the Bid 1 MRVS report, and assessing their error margins/confidence bands.

Specifically, the objectives are targeted towards:

- Providing confidence and credibility in the estimates derived from the mapping exercise, nationally and at the international level;
- Providing a greater understanding of error patterns and to provide recommendations on how these may be used to inform a continuous improvement programme for future years;
- Providing the client with the resources needed to improve local ownership and capacity for the Guyana Forestry Commission and its partners to use and produce such data for themselves in future.

Specific areas of activity

1. To refine and enhance the methodology developed in 2010/11 to assess 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.[61] For the design component, reference data are identified, and relevant literature is cited to support the approach taken.
3. To report on REDD+ interim measures and national estimates (Gross Deforestation, Intact Forest Landscape, Extent of Degradation associated with new infrastructure, and report of the processes driving deforestation and degradation) 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), providing verification of the deforestation rate figure for Year 2 as a total and a breakdown by driver, assessing the error margins/confidence bands on deforestation area estimates.

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 and will have to entail field / over-flight verification. The error analysis 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 is used either from the ancillary map data (e.g. for concessions), and acquired high resolution image pairs for change reference.

[61] GOFC-GOLD Sourcebook Section 2.6.

1. AREA REPRESENTATION

The total land area for Guyana at the Benchmark period 2009[62] is reported in the Interim Measures Report to be 21.1 million hectares. This figure is based on GIS polygon data of Guyana’s National boundary and is used when calculating area based statistics. 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. For mapping, the GFC uses ArcGIS v.10 software although data were exported to Shapefiles for data analysis.

3.1 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 0.05-1.0 hectares (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 IAP/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 for 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 mapping was based on manual interpretation of Landsat TM and ETM+ imagery at approximately 1:24,000 using ArcGIS software. Mapping was conducted for GFC by Pöyry Consultants for the following epochs: 1990, 2000, 2005, 2009 and 2010 (See GFC/Pöyry Interim Measures Report, March 2011). The 2009 epoch represents the Benchmark period for the Interim Measures and for the MRVS.

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 Year 1 and to quantify the precision of the estimate of deforestation and forest degradation in Year 2. A second task is to estimate the processed (drivers) that are responsible for deforestation and degradation, estimation area and precision of estimates where possible.

[62] The precise area edited to account for coastal erosion between 1990 and 2010 is given as 21,128,606.0 ha.

4. SAMPLING DESIGN FOR VERIFYING YEAR 2 FOREST CHANGE AND FOREST DEGRADATION MAPPING

4.1 Maps to be validated

The accuracy assessment task is to assess the accuracy of a countrywide thematic land use map digitized from RapidEye, Landsat TM and ETM+ imagery. The map depicts **Forest / Non-Forest** area for Year 2 and includes a map class showing areas interpreted as **degraded forest**. The map contains map classes for deforestation attributed to all epochs of change mapped since 1990. The maps were interpreted with a minimum mapping unit (MMU) of 1 ha and digitized manually using ArcGIS software at 1:24,000 scale for Landsat TM and ETM+ scenes and 1:15,000 scale for RapidEye scenes.

The thematic accuracy of the maps was assessed using the following well established procedures:

1. Select the thematic criteria to be assessed and identify the data to be used for validation;
2. Determine the number of sample areas to be assessed;
3. Select the sample areas using an appropriate random or stratified sample;
4. Prepare a sampling grid and decision tree for thematic assessment;
5. Conduct sampling.

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.

Best efforts are made when making interpretations from Landsat TM and ETM+ data and so it is expected that mapping will be more generalized when compared with what can be seen in the higher spatial resolution RapidEye imagery.

Several factors potentially impact on the quality of forest mapping (GOFC GOLD, 2009), namely

- The spatial, spectral and temporal resolution of the imagery
- The radiometric and geometric pre-processing of the imagery
- The procedures used to interpret deforestation and degradation
- Cartographic and thematic standards (i.e. minimum mapping unit and land use definitions)
- The availability of field reference data for evaluation of the results.

It is clear that accepted approaches were used to minimize these sources of error following IPCC and GOFC-GOLD good practice guidelines as appropriate.

Mapping of 1990 and through the reference period (1990-2009) suffered from cloud cover, temporal specificity of image acquisition and uneven spatial distribution of high resolution reference imagery over Guyana. This situation improved in Year 1with the acquisition of RapidEye, Ikonos and DMC data in late 2010 and early 2011. Sample selection for Year 2 has improved since Year 1 because RapidEye imagery covers most areas at high risk of deforestation and forest degradation.

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).

4.2 Response Design

Table 1-1summarises the data available to validate the Year 2 (2010-2011) *Forest/non-Forest* and *forest degradation* map polygons and attribute labels. It also specifies the areas covered by the RapidEye and a selection of Very High Resolution (VHR) imagery used to validate the Year 2 mapping.

Table 1-1: Data sources used for Validation

Application	Dataset used	Provider	Sensor	Spectral Range	Date of Acquisition	Pixel size (m)	Area (ha)	% of Guyana
Forest Change	QuickBird-2	DigitalGlobe	QB-2	MS	09 Aug 11	2.7	3789	0.02
	WorldView-1	DigitalGlobe	WV-1	Pan	Aug-Oct 11	0.6	10165	0.05
	WorldView-2	DigitalGlobe	WV-2	MS	Aug-Sep 11	1.9	22000	0.1
	RapidEye	RapidEye	RapidEye constellation	MS	Aug-Dec 11	6.5	11832019	56.0
	Overflights (1km_buffered flight lines)	Durham University and Indufor	Digital Camera	Colour	2-3 Apr 12 and 3 Dec11	Variable	574646	2.7
Total for forest change (there are overlaps)							12442619	58.87

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, 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 2 deforestation was mapped by the IAP/GFC team from a combination of RapidEye, Landsat TM and ETM+ data while the accuracy assessment used a combination of data from RapidEye, WorldView-1, WorldView-2, Quickbird and aerial over flights. In addition, Landsat TM, ETM+ and DMC data were used to establish that observed deforestation could be correctly assigned to Year 2.

The 2010 (Year 1) Durham University Accuracy Assessment report concluded that RapidEye and IKONOS data were of sufficient spatial resolution to identify deforestation and the main drivers of deforestation. In particular, areas of agriculture could be distinguished from shifting cultivation and that infrastructural features such as mine dredges & camps and roads associated with mining and logging could be mapped with confidence.

The mapping and digitising was undertaken by a small team (4 persons) of GFC staff at GFC under the supervision of Indufor using a rules-based manual interpretation method. For consistency, the Accuracy assessment was also carried out in Durham by a small team (three persons) using the same rules-based approach. Any misinterpretation or labelling error is most likely to arise from human-error or interpretation using poor quality imagery or areas in partially obscured by cloud or cloud shadow.

For this reason the response design allows areas of obvious uncertainty to be coded as *Omitted*. It is helpful that the classification is binary in nature and the accuracy assessment team are not faced with the more complicated task of assessing forest or land cover type where spatial, spectral and radiometric resolution can be limiting factors (Khorram, 1999).

The Interim Measures for Year 2 includes an assessment of the mapping of areas of forest degradation. Degradation has been mapped alongside Year 2 deforestation using a rule-based approach as follows:

(1) the boundary of an infrastructural feature (e.g. mining area or road) is delineated

(2) a 100 m buffer is generated around the feature;

(3) the deforestation event is confirmed to be Year 2;

(4) ensure that any additional non-forest areas, surrounding the site are not included in the analysis. In accordance with the Year 2 mapping rules, areas less than 1 ha and / or roads less than 10 m in width are included as degraded areas. In sum, this process involved delineation and masking of all areas that met the criteria listed.

Table 1-2:Year 2 Deforestation/Degradation Assessment Exclusions

Reference	Criteria
1	Land use change that occurred prior to 2011
2	roads that exceed a 10 m width.
3	naturally occurring areas – i.e. water bodies
4	cloud and cloud shadow

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

LANDSAT

The two map products *to be validated* were derived from Landsat TM and Landsat ETM+ data. The selection criteria and image processing used to derive these data for the Year 2 analysis are documented in the report in Chapter 5. We note that the Landsat data were referenced to the Landsat GeoCover dataset which is a collection of high resolution satellite imagery provided in a standardized, orthorectified format(http://glcf.umd.edu/research/portal/geocover/).

Landsat will not be used for map accuracy assessment alone, but will be useful to help identify the period to which deforestation should be attributed to. The 2011 Landsat data is generally of good quality but the North of Guyana is cloud covered partially obscuring some areas.

RAPIDEYE

RapidEye is a constellation of five high-resolution visible and near infrared satellites. These acquire five-band multispectral imagery at 6.5 m nominal ground pixel size. These data were provided to GFC as a Level 3A orthorectified image product using a Landsat orthorectified mosaic for horizontal control and SRTM v4.1 for height control (total accuracy 30m CE90 at worst; February 2011 Product Guide; www.rapideye.de). The imagery was resampled by cubic convolution. The RapidEye data contain clouds for which an unusable data mask (udm) file was produced and delivered by RapidEye. This mask highlights the areas of unusable data within an image but it fails to detect small clouds, haze and cloud shadows. However the data are of good quality and remain useful for validation purposes.

WORLDVIEW-1

WorldView-1 was launched in September 2007, and the product acquired for the assessment exercise has 0.5m nominal nadir-looking spatial resolution at one panchromatic band (400-900 nm). It was rectified with the use of rational polynomial coefficients that were provided with the product that would nominally offer accuracy of 5m CE90 excluding terrain effects. In practice, it proved geometrically accurate enough for the validation purposes.

WORLDVIEW-2

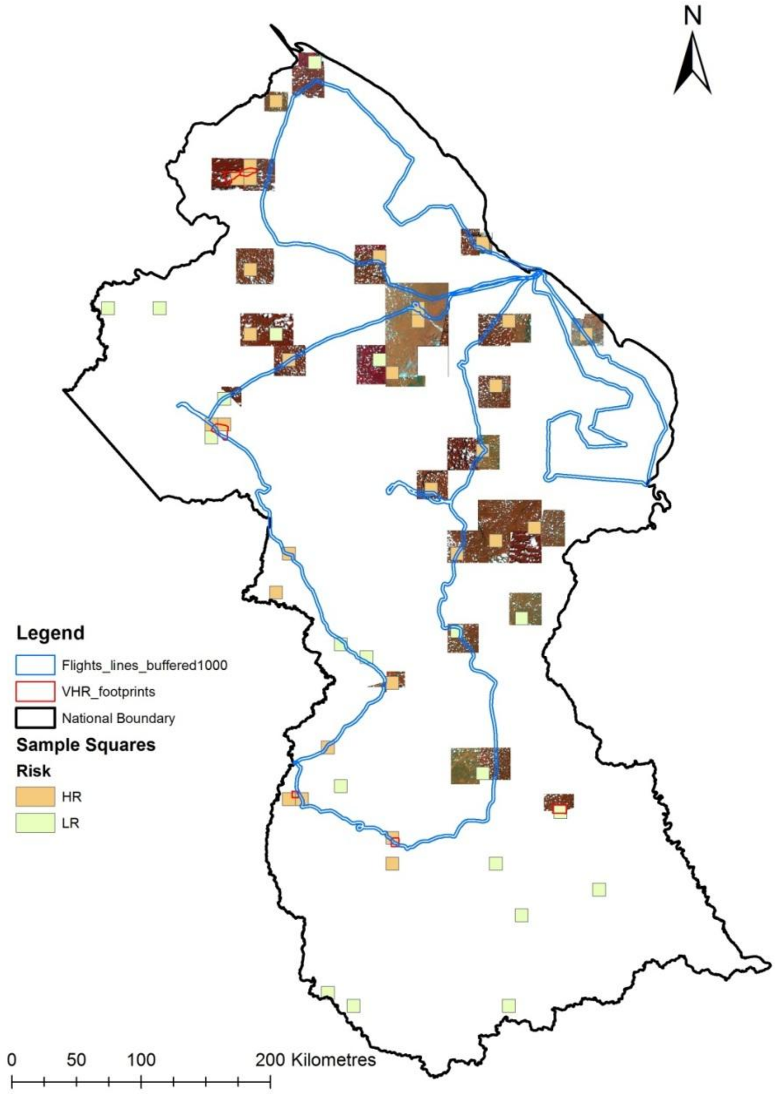
WorldView-2 was launched in October 2009, and the product acquired for the assessment exercise has 2.0m nominal nadir-looking spatial resolution at four bands (red, green, blue, and near-infrared). It was rectified with the use of rational polynomial coefficients that were provided with the product that would nominally offer accuracy of 5m CE90 excluding terrain effects. In practice, it proved geometrically accurate enough for the validation purposes.

QUICKBIRD-2

QuickBird-2 was launched in October 2001 and raised in orbit in April 2011 to extend the operational life of the mission. The product acquired for the assessment has 2.62m nominal nadir-looking spatial resolution with four spectral bands (red, green, blue, and near-infrared). It was rectified with the use of rational polynomial coefficients that were provided with the product. Typically this provides an accuracy of 23m CE90 excluding terrain effects. In practice, it proved geometrically accurate enough for the validation purposes.

The following map provides an overview of the image data used for the accuracy assessment.

Figure 43: High Resolution Data available for validation



RADAR

Several radar datasets exist over Guyana available via the Forest Carbon Tracking Portal(www.geo-fct.org) and include single and dual polarised (30 m resolution) ASAR scenes that provide partial coverage of Guyana. The spatial resolution, as well as the nature of the backscatter product, is not of sufficient quality to allow detailed interpretation of forest change and forest change drivers and so these RADAR data were not used in the verification process. However, in future it may be possible to use fine beam-mode RADAR products to assist with change detection analysis.

4.3 Additional Verification Datasets

Two over-flights were undertaken using a Cessna 206 high wing light aircraft to provide high resolution photography of the ground from at altitude of 1,000-1,500 ft, GPS tagged oblique pictures were taken from both sides of the aircraft using 5 megapixel digital cameras. We estimate that each photograph captured an image of one-km in depth therefore providing near total coverage of an area of 574,646 ha in total from two flights (see figure 3-4).

Figure 44: The Cessna 172 and Observation Team

Figure 45:Example over flight photography (TL: clearance for shifting agriculture and fire; TR secondary road almost invisible; BL forest types easily confused with non-forest; BR Year 2 mining camp / dredge)

4.4 Data Provided by Guyana Forestry Commission

The Forest Resource Information Unit (FRIU) holds a range of operational spatial data that were used to assist in the stratification into areas of high and low risk of deforestation. A summary of the spatial layers updated for Year 2 mapping is provided.

Table 1-3: GFC GIS Datasets

Data Group	Layer Name	Created/ Update freq	Description
Admin	guyana_boundary	Received March 2012	Updated country boundary for Guyana.
Hydro	Waterbodies (GFC)	Received March 2012	Waterbodies layer, digitised from geo-corrected Land-sat imagery. Layer integrated into the 1990 forest / non-forest map
Managed Forest Areas	State_Forest_2006	2006	Layer showing the extent of the state forest boundary.
	TSA_WCL_Merged	6 monthly	A merged layer showing all active Timber Sales Agreements (TSA) and Wood Cutting Leases (WCL) (large forest concessions)
	PropSFEP_Merged	6 monthly	A merged layer of all proposed State Forest Exploratory Permits
	activeSFEP_Merged	6 monthly	A merged layer of all active State Forest Exploratory Permits.
	activeSFPs_Merged	6 months	All active State Forest Permits (small forest concessions). Merged by Division – De-merara, Essequibo, Berbice, North West
	logging_Camps	NA	Point location of logging camp sites, based on the An-nual Operating plan.
	harvest_Areas	NA	Polygons showing extent of harvest activities (pre 2008, 2008 & 2009)
Roads	gps roads_dd	3-6 months	All GPS roads and trails as at August 2011.
Agricultur-al Leases	GFCAGleases	Upon titling	Agricultural leases that fall within the State Forest Es-tate (Administrative Regions: 1, 2, 3, 6, 7, 8 and 10)
Mining Areas	LRG_Scale-Aug2010_region, MED_Scale-Aug2010_region, Mining_dredges	Upon granting of mining per-mit/licence/clai m	Large and Medium scale mining areas including dredge locations. Received March 2012.

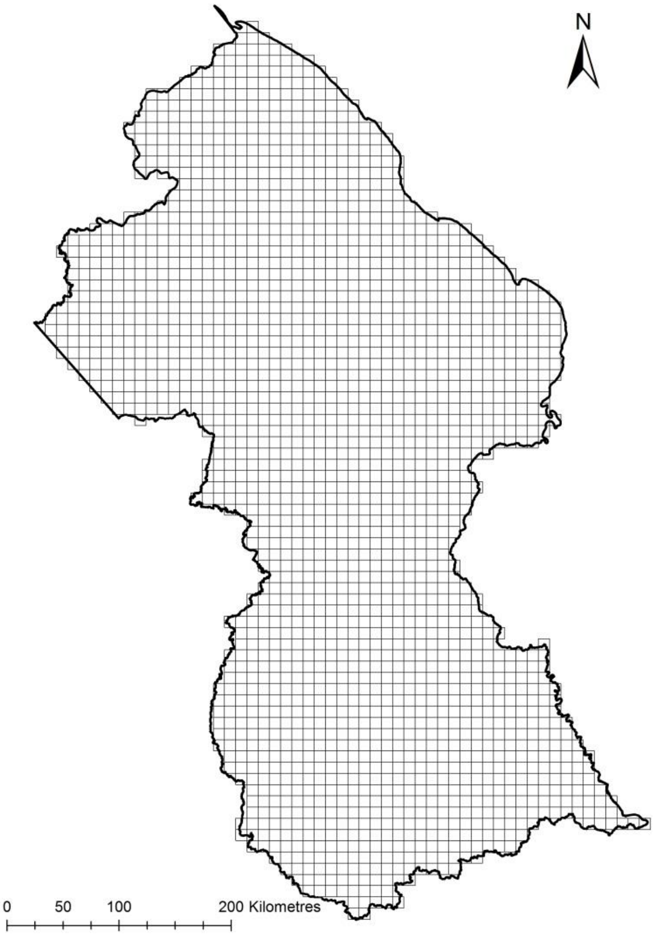
4.5 Sampling Design

The sampling design refers to the methods used to select the locations at which the reference data are obtained.

To assess the Year 2 deforestation map a two stage sampling strategy with stratification of the primary units was adopted. In the first stage, a square grid of 10km by 10km in size was created within the spatial extent of the country's national boundary[63]. This resulted in 2115 squares; note that only squares included within the national boundary are selected.

[63] According to the Interim Measures Report January 2011, the national boundary was defined by following information received from the GL&SC and with the aid of Landsat imagery.

Figure 46: A grid of 10km by 10km in size was created with the centroids within the national boundary of Guyana



As the area of the country is large, and deforestation is observed to be clustered around relatively small areas of human activity, it is efficient to adopt a stratified sampling framework 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, 2009b). Based on geographical data provided by GFC, grid squares were stratified according to factors closely associated with risk of deforestation. In particular, data about the location of logging camps, mining dredges, settlements, and the existing road network were used (see Table 2-4 and Figure 2-5). This way, all grid squares that satisfied the following criteria were selected.

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

OR

Intersect with at least one road.

This resulted in the classification of grid squares into two strata. The ones that satisfied the criteria (named “High Risk”) and the ones that did not satisfy the criteria (named “Low Risk”). This resulted in 850 “High Risk” squares and 1265 “Low Risk” squares.

Figure 47:Criteria for sampling stratification - left map Year 1 and right map Year 2:

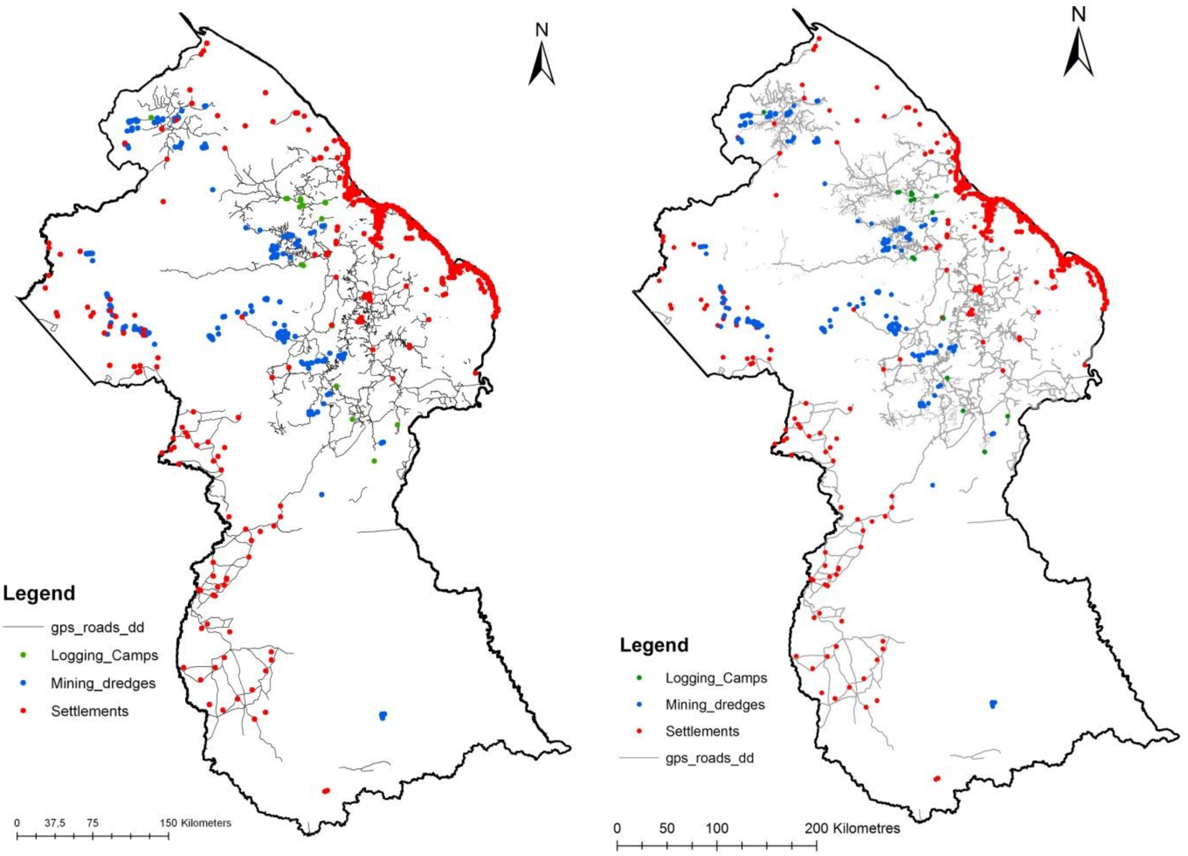


Figure 48shows an overlay in red colour of the deforestation data on the sampling stratification map. It demonstrates that about 84% of the deforestation for Year 2 falls within the "High Risk" stratum with the remaining 16% falling within the "Low Risk" squares. Note that the risk strata have changed between Year 1 and Year 2.

Figure 48 : Mapped deforestation from 1990 to Year 1 (left); deforestation mapped as Year 2 (right)

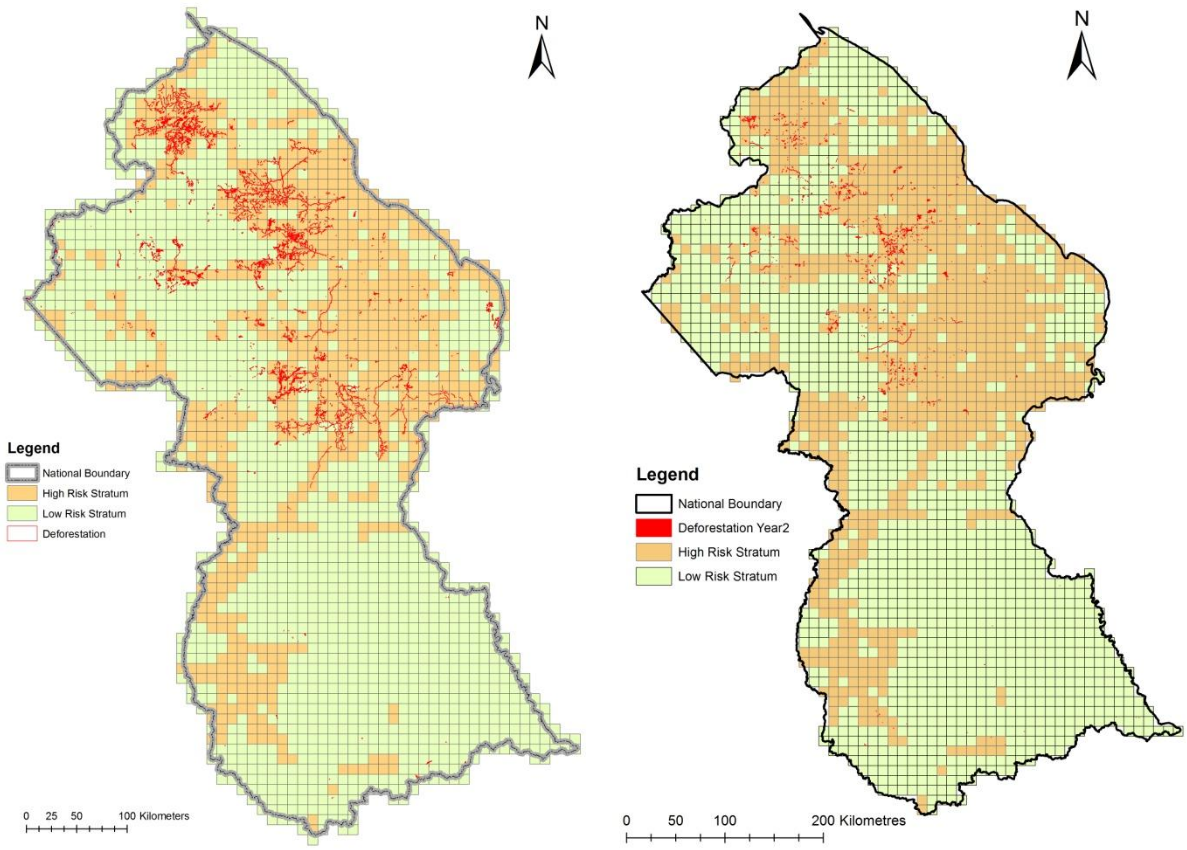


Table 2-4: Spatial data used to Assist with Stratification

Data Group	Layer Name	Created/Update freq	Description
Admin	guyana_boundary	Received March 2012	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	gps roads_dd	3-6 months	All GPS roads and trails as at August 2011.
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 a number of larger settlements from the place names point feature class.

The map in suggests that there is a low probability of sampling deforestation in the Low Risk stratum and so, in order not to under sample and miss deforestation events in this stratum, a weighting was applied when randomly selecting grid squares to analyse in detail. As the area ratio of High Risk to Low Risk is 40:60, we decided to randomly sample at a ratio 60:40. This resulted in 30 “High Risk” squares and 20 “Low Risk” squares.

Figure 49: High and Low risk strata (left) and random sampling of the High Risk (60%) Low Risk (40%) strata (right image).

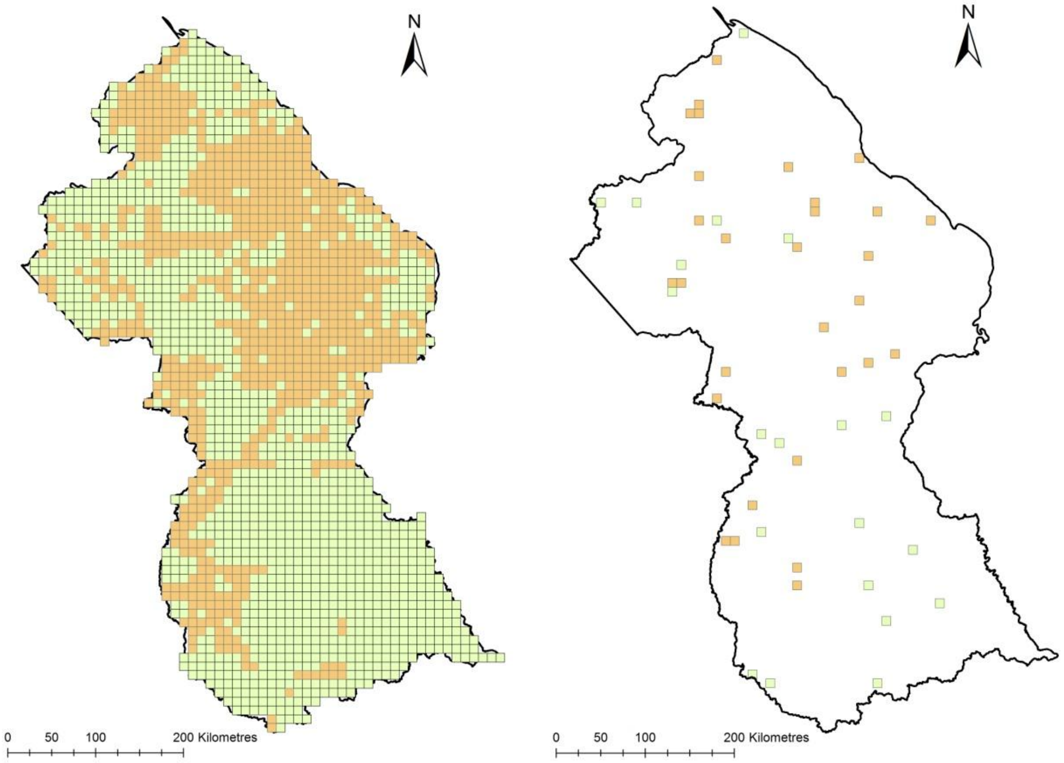


Table 1-4 Area represented by each stratum

Stratum	Total number of squares	Area (ha)	Percent of Guyana (%)
Total Grid	2115	21,150,000	100.1
High Risk	850	8,500,000	40.2
Low Risk	1265	12,650,000	59.8
HR 60% random	30	300,000	1.4
LR 40% random	20	200,000	1.0

Within each grid square, a systematic sample of points spaced at regular 500m intervals was created, yielding 361 points in each sample square. These points were then buffered to create a circular sampling area of one hectare in size corresponding to the minimum mapping unit (MMU). Each of the grid squares was assigned an ID according to its centre point location, and each of the sampling circles has an ID according to its respective centre point location. In total 18,050 one hectare sampling areas are available for accuracy assessment.

For each sample area, the land cover class (e.g. Forest or Non-Forest, Degradation or Non-Degradation) is determined for the Year 2 deforestation and degradation map. The assessment follows a systematic procedure where the GIS table for the samples is populated using the ArcGIS toolbar shown.

Specifically the tools used to interpret and validate the Year 2 map data included Landsat data, pre-2011 where appropriate high resolution imagery. We also had available land use maps and GIS data indicating mining, forestry and agricultural concessions.

For the Year 2 (2010/2011) map the interpretation proceeds as follows:

1. Is the area **mapped as forest in Year 2)**? If **yes**, then is it forest in the high resolution validation from 2011 imagery? If **yes**, then sample is classified as **Forest-Correct**. No driver label is needed and a confidence label on a 0-4 scale is given.
2. Is the area **mapped as non-forestin Year 2**? If **yes**, then is it non-forest in the in the high resolution validation from 2011 imagery? If **yes**, then the sample is classified as **NonForest-Correct**. No driver label is needed and a confidence label on a 0-4 scale is given.
3. Is the area **mapped as non-forest in Year 2**? Is the area seen in the high resolution validation from 2010 imagery as forest? If **no**, has it been interpreted as deforested at any epoch between 1990 and 2010 (GIS check)? If **no**, then sample is classified as **NonForest-Incorrect**. A **Driver label** is needed (e.g. Agriculture, Settlement, Road, Mining, Burning or River) and a **Confidence label** on a 0-4 scale is given.
4. Is the area **mapped as non-Degraded in Year 2**? Is the area seen in the high resolution validation from 2010 imagery as forest? If **yes**, then sample is classified as **non-Degraded-Correct** and a **Confidence label** on a 0-4 scale is given.
5. Is the area **mapped as Degraded in Year 2**? Is the area seen in the high resolution validation from 2011 imagery as forest? If **yes**, then sample is classified as **NonForest-Incorrect**. A **Driver label** is needed (e.g. Agriculture, Settlement, Road, Miningor-Burning) and a **Confidence label** on a 0-4 scale is given. If the degradation is not associated with any year 2 activity then the driver label will be given as **Non-year2 degradation**.
6. Is the area obscured from view by missing data or cloud or outside the national boundary (e.g. beyond coastline)? If so then mark as **Omitted** from analysis. This is normally because of cloud or cloud shadow.

When assessing the Year 2 map, any areas seen to be incorrect were labelled with the appropriate deforestation driver or marked as afforested. The approach to interpreting the correct driver relied on following the Mapping Rules that include identifying the cause of deforestation and also field and aerial survey experience.

The most important points to note are:

1. Areas of forest degradation that relate to Year 2 are estimated; degradation that was identified and interpreted as pre-year 2 are recorded as such, but not included in the area estimates.
2. Areas of shifting cultivation are generally small in size (under 5 ha) and are treated as degraded forest as these have the potential to return to canopy closed woodland.
3. Areas of infrastructure including settlements are classified as non-forest as are water bodies.
4. Areas cloud and shadow or missing data are labeled as *Omitted*.
5. Areas representing Year 3 change (post December 31 2012) were also omitted from the analysis as this change postdates the Year 2 reference imagery. These areas are labeled as Year 3 in the GIS database.

The rules for validating each point account for small discrepancies between the original mapping that was digitized at 1:24,000 scale from Landsat TM and ETM+, and the VHR data that can normally be interpreted at 15,000 scale. Minor discrepancies might include digitizing error due to map generalization and map-to-image mis-registration. These are distinct from factors that might explain misclassification or mislabeling in the mapping or indeed in the validation of the mapping. Misclassification can occur due to poor radiometric quality of imagery, spectral overlap among classes, scale / resolution of imagery and human error.

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. A toolbar was created by the Durham team so that both errors of omission and commission could be tagged; that is each label A, B, C, D in table 2-5 could be selected. For errors of omission, the interpreter could assign the correct land cover class and, if the area has been deforested in the 2010-11 period, make an assessment of the driver causing the change. The toolbar also included a confidence label on a 0-4 scale. This allows for uncertainties in interpretation to be removed from the estimation and validation process if required.

The two-stage sampling strategy with stratification of the primary units uses a large sample size that will allow for assessment of the true extent of false positives and negatives in accordance with the GOFC-GOLD (2006) recommendations. Note that the right hand side of the interpretation toolbar contains a dropdown database entry to represent the confidence or certainty of the interpretation. Uncertainty, in this case refers to doubt in the interpreters mind about the nature of the change observed not the classification between forest and non-forest. The uncertainty will refer to confidence in interpreting the driver for change and is recorded on a four interval percentage scale

Figure 50: Systematic sampling showing 361 one hectare sample points superposed on a false colour 5 m resolution Rapid Eye image with Worldview-2 superimposed in the lower half (left image). Zoomed in systematic sample grid showing the deforestation / degradation mapping layer added to the view frame (right image)

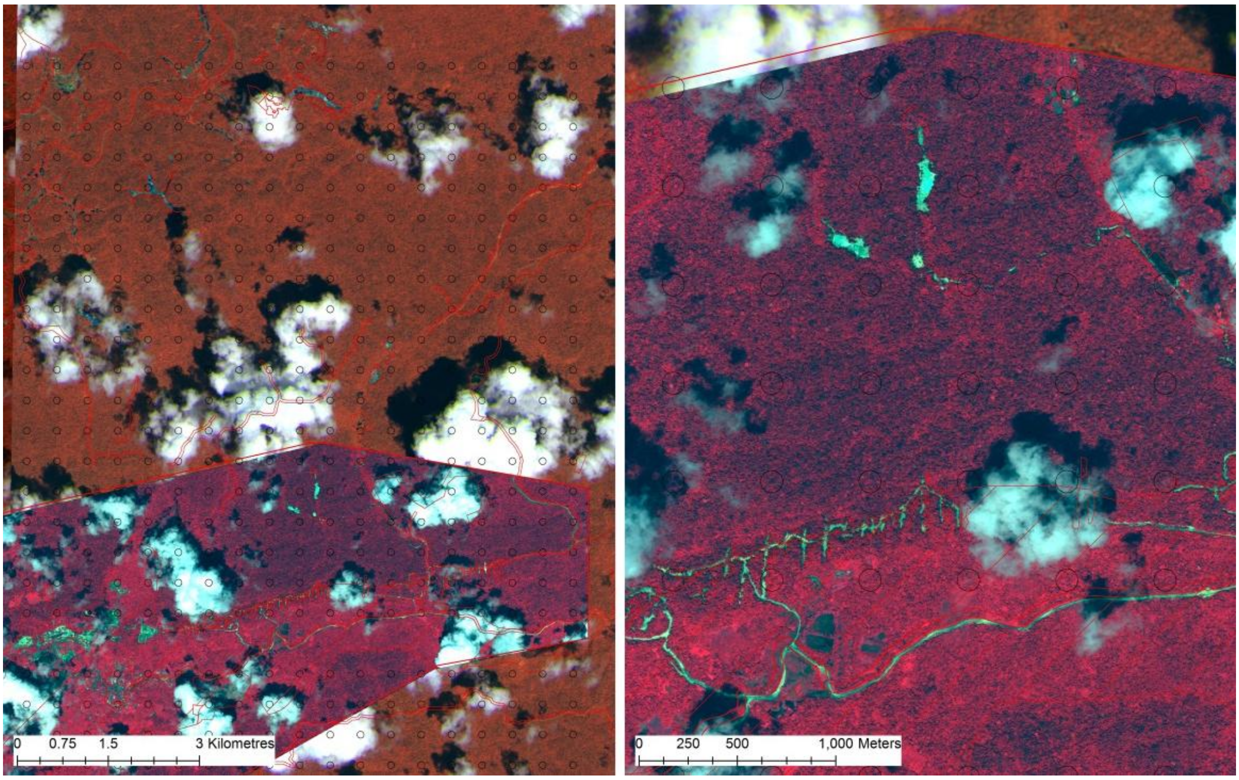
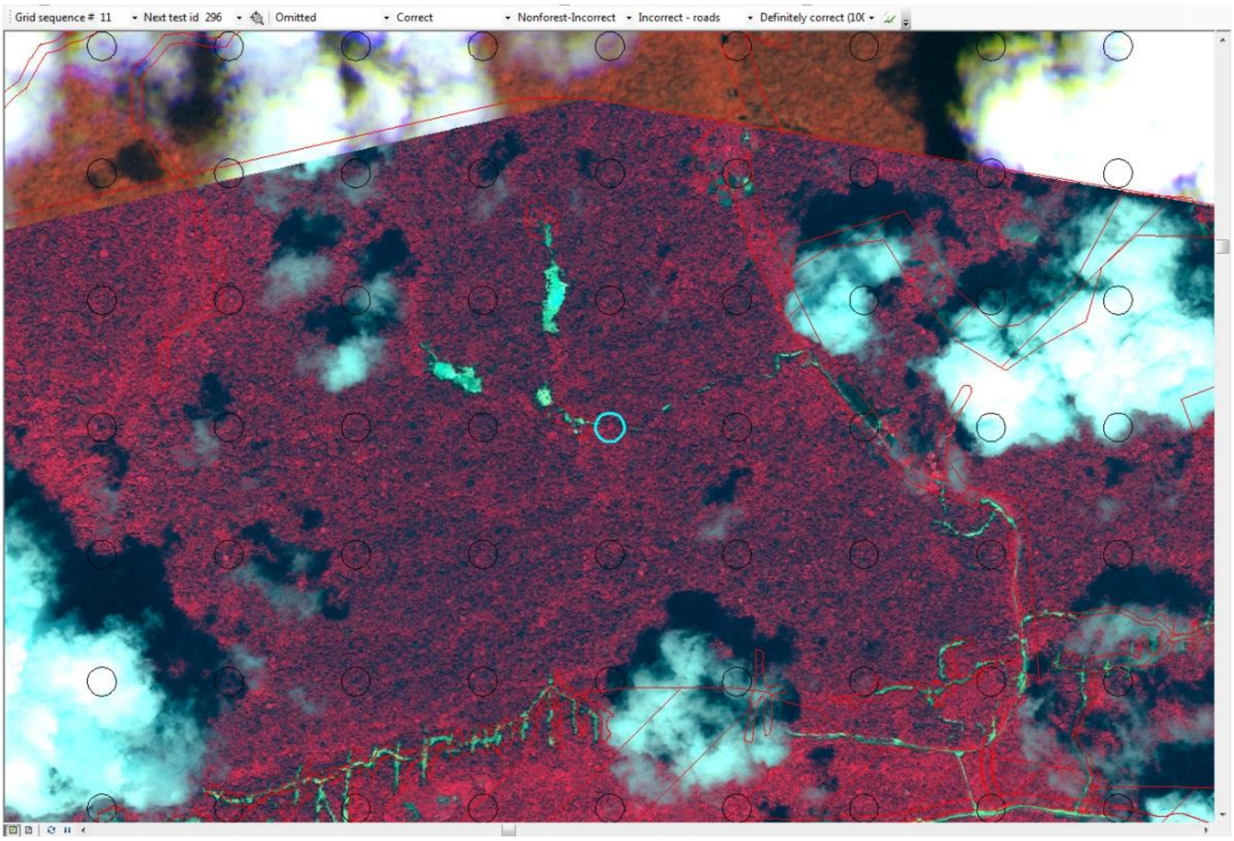


Figure 51: The ArcGIS Interpretation Toolbar as seen at the top of the Image



4.6 Analysis and Estimation

The analysis procedure, assisted by the toolbar provides the process to validate the points within each sample grid square. These data were recorded in a database, one for each stratum, and used to generate a cross tabulation between reference data and the maps. The structure of the tabulation, sometimes called a confusion or error matrix is shown. This matrix is widely used to quantifying the quality of the classification and characterizing the error (Foody, 2002; Story and Congalton 1986; Van Oort 2007). The labels assigned to sample points in the reference data are cross-tabulated against the mapped classes for each sampling frame.

Table 1-5: Structure of accuracy assessment matrix

		Reference Data			
Map	**Class**	**No change**	**Change**	**% of Total Area**	**User Accuracy**
	No change	A	B	X	
	Change	C	D	Y	
	Total	x’	y’	100	
Producer Accuracy					

Cells **a** and**d** represent map areas that have been validated as correct. Counts in cell **b** are false negatives and those in cell **c** false positives. Interpretation of these data assumes that the reference data are error free, that the sampling is unbiased and of sufficient size. Nevertheless, the confusion matrix provides a simple and convenient method to illustrate the nature of any disagreement between the map and the reference data.

The accuracy of a class is expressed in two ways, as a user's and producer's accuracies (Story and Congalton 1986; Van Oort, 2005). The user's accuracy indicates the probability that land classified into a given land cover class by the map is actually that class on the ground. It is also referred to as the error of commission as sample points that are incorrectly classified are commissioned into another class (i.e. forest misclassified as non-forest or the reverse).

The producer's accuracy provides a measure of accuracy of the classification scheme. The producer accuracy is also known as the error of omission because areas that have been incorrectly classified are "omitted" from the correct class. This accuracy indicates how well the sample points falling on a given land cover type are classified, i.e., it is the probability of how well the reference data fitted the map.

For a simple random sample the user's accuracy is calculated by dividing the number of correctly classified sample points in each class by the total number of sample points classified in each class (row total).The producer's accuracy value is calculated by dividing of the total number of correctly classified plots in each class by the total reference data plots in each class (column total).

Unlike a simple random sample, raw counts in a stratified sample cannot be directly used to make unbiased statistical estimates. For stratified random sampling, each cell must converted into an estimated joint probability (the proportion of total class counts per percentage class area) before the assessment statistics are derived.

4.7 Precision of Area Estimates for Year 2 Deforestation and Forest Degradation maps

The two-stage sampling with stratification of the primary units design optimises the probability of sampling deforestation and degradation in Year 2 when the area concerned represents only a tiny 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 intoducing 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 probabliity 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 VHR satellite imagery.

5. RESULTS

Results are organised into four sections. First, an assessment is made of the quality of the Year 2 deforestation and degradation mapping undertaken by IAP and GFC. This is based largely on interpretation of Landsat TM, ETM+ and RapidEye imagery.

Secondly, we assess the consistency of the interpretations made by the Durham validation team to ensure that the quality of the reference data is of a good standard. Thirdly, we present estimates of forest area and deforestation rate for Year 2 (2010-11) based on the two-stage sampling design with stratification of the primary units. Finally, we assess the Year 2 forest degradation data and the mechanisms responsible for that degradation.

5.1 Quality of Mapping

The prevalence statistic is a good measure of overall correspondence between the map and reference data. We found that for Year 2, prevalence was greater than 0.96 or 96% agreement, see**Table 1-6**. This is a very high figure, better than one would expect from automated classification of multispectral remotely sensed data, and is almost certainly explained by the manual process of interpretation and on-screen digitizing. We also note that the reference data used for the validation are not perfect, about 14% of the sample area could not be used because of missing reference data or because the ground was obscured by cloud or cloud shadow. Missing reference data were excluded from the analysis.

Table 1-6: Error matrix for the Forest-Non-forest Year 2 map.

Year 2 Forest-non Forest	Class	Reference Images			
		Forest	Non-forest	Total	User Accuracy
Year 2 Map	Forest	13592	327	13919	97.65%
	Non-forest	285	2561	2846	89.99%
	Total	13877	2888	16765	
Producer Accuracy		97.95%	88.68%		96.35%

2785 samples omitted due to cloud and cloud shadow

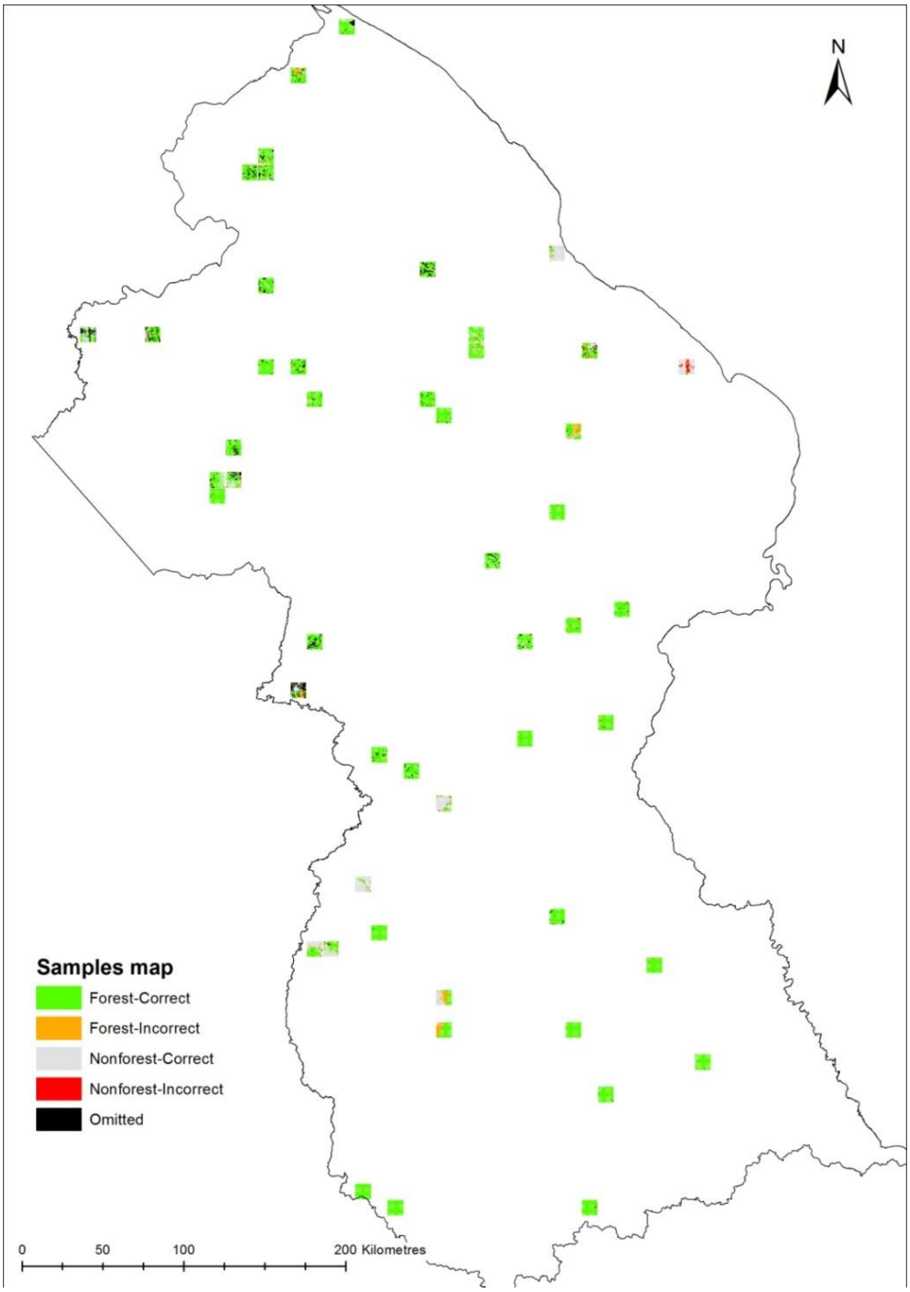
Table 1-6 is not weighted by strata and should only be used to note the correspondence between Map and Reference data. Note, however, that 327 of sample areas that were mapped as forest were found to be non-forest. While this is a small figure (2%) it warrants further analysis because it means that areas of deforestation are being missed by the wall-to-wall mapping and it is important to understand why this is happening. Equally interesting 285 samples mapped as non-forest were found to be forest covered. The majority of these incorrect forest and incorrect non-forest areas are attributable to areas where RapidEye data was not available to the IAP/GFC interpreters or that the data was cloud covered, despite repeat imagery being available for most areas. Table 1-7shows the stratum weighted error matrix in order to show the correspondence according to the stratified sampling design.

Table 1-7: Error matrix for the Forest-Nonforest Year 2 weighted according to the stratification.

Year 2 Forest-non Forest	Class	Reference Images			
		Forest	Non-forest	Total	User Accuracy
Year 2 Map	Forest	6742	134	6876	98.05%
	Non-forest	124	1066	1190	89.58%
	Total	6866	1200	8066	
Producer Accuracy		98.19%	88.83%		96.80%

The correspondence of 96.80% demonstrates close agreement between the Indufor/GFC mapping and the sample units assessed by the independent accuracy assessment. Figure 52uses the GIS to illustrate the spatial distribution of areas seen as non-forest in the reference imagery. Most of these could be tracked back to the deforestation events that preceded 1990 or that had occurred before the Interim Measures Year 2 period (Oct 2010 to Dec 2011). These errors due mainly to misclassification of agriculture, shifting agriculture and imprecise mapping of non-forest areas such as rivers and settlements were reported in Year 1 and will be corrected before the period of the Interim Measures expires.

Figure 52: Distribution of Errors in Year 2 Analysis Plotted by Sample grid Square



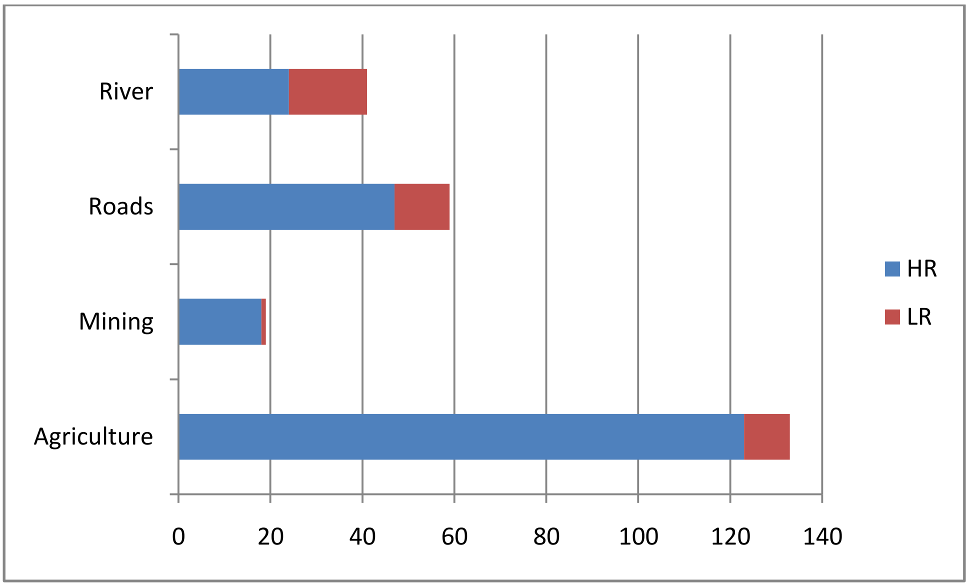
With regard to understanding the drivers for the deforestation observed, shows the breakdown of deforestation attributable to Year 2 and this clearly shows that mining and mining infrastructure is responsible for 95% of the deforestation.

Table 1-8: Deforestation Driver Summary (Year 2 only)

Driver	Year 2 Contribution (%)	Land use Change
Agriculture	04.76	Cropland
Mining Roads	19.05	Settlements
Mining	76.19	Bareland
Total	100.00	

Comparing these data to the breakdown of deforestation from 1990 up to and including Year 2, this shows a significant shift away from land clearance for agriculture to one dominated by mining and infrastructure such as roads.

Figure 53: Deforestation Driver Chart (all periods)



We examined a large number of 1 hectare samples containing roads and observed that roads crossing through our sample area never occupied more that 20% of the 1 ha area. We also noted that the IAP/GFC mapping team applied a 20 m buffer around roads when digitising. Therefore, we calculated that deforestation surrounding a road will never occupy more that 45% of the 1 hectare.

We have not scaled the number of Road-deforestation sample points accordingly and so the area estimate will overestimate the amount of deforestation due to roads in all cases. It does however provide a less biased estimate since Roads were identified in the mapping process if any part of the sample circle touched any part of a road. This validation rule was different from other mapping polygons where the interpretation of land cover was assessed at the location of the sample centroid. This rule was applied because of the narrow and linear shape of roads.

Table 1-9: Analysis of Forest Degradation

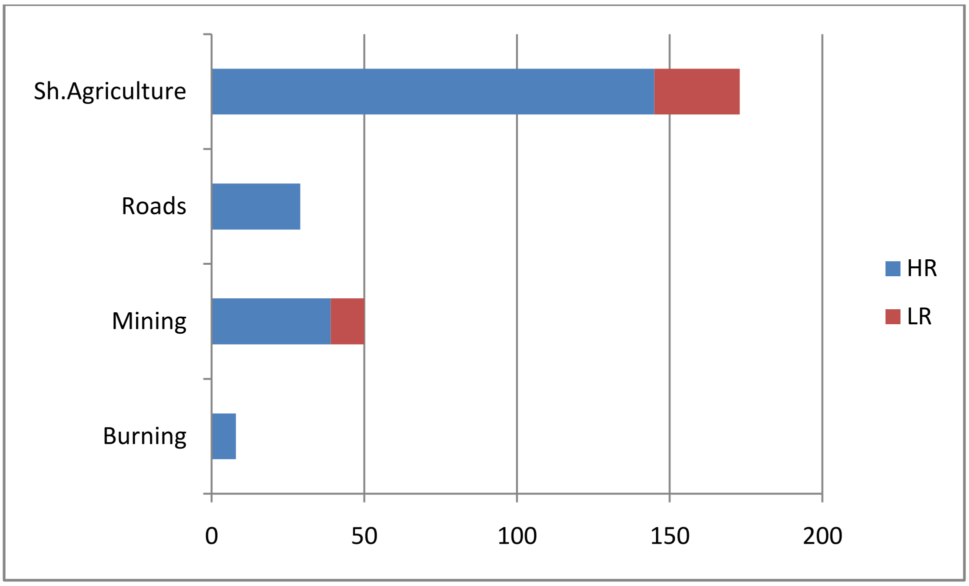
All	**Class**	**Reference Images**				
		No degradation	**Year 2 degradation**	**Non Year 2 degradation**	**Total**	**User Accuracy**
Year 2 degradation map	**No degradation**	13170	21	280	13471	97.77%
	Year 2 degradation	6	20	0	26	76.92%
	Non Year 2 degradation	98	0	276	374	73.80%
	Total	13274	41	556	13871	
Producer Accuracy		99.22%	48.78%	49.64%		97.08%

Table 1-10: Forest Degradation for Year 2 that intersect with verification samples

Degradation-Correct Year 2	Land use category	Driver
2	Cropland	Degraded burning
3	Cropland	Shifting Agriculture
1	Montane Forest Degraded	Mining
14	Mixed Forest Degraded	Mining

Degradation-Incorrect Year 2	Land use category	Driver
1	Cropland	Shifting Agriculture
4	Settlements	Mining Roads
16	Mixed Forest Degraded	Mining

Figure 3-3: Distribution of the degradation drivers for all periods (1990-2011)



5.2 Consistency

The validation team consists of three well qualified and experienced image interpreters, two of whom visited Guyana and participated in field visits and over-flights. They acted as mentors for the other interpreter. Every effort was made to inform the team validating the mapping about the geography of Guyana, forest types, definitions of land cover, definitions of deforestation, the processes driving deforestation and the rules that were followed by the original mapping team. The validation team were very familiar with satellite imagery, particularly Landsat TM, ETM+ and RapidEye, Quickbird and Worldview.

The analysis reported here used scenes from three different high resolution sensors covering a total of 2.4% of Guyana’s land area. Approximately 18,000 hectares were scrutinised. Assessment also included information for field inspections and aerial over-flights conducted in good conditions in April 2012. The geo-positioned aerial imagery provides valuable evidence that helped confirm the interpretations of the validation team, particularly with regard to the drivers for deforestation.

An experiment was conducted to ensure that the data used to validate the mapping was as precise as possible. This involved blind replication of two sample grids. Each interpreter analysed the same grids, which were in the High Risk stratum. The grids were purposely selected to include areas of high activity (mining, forest roads, agriculture, etc) and used Landsat, RapidEye, and Worldview-2 data. The results are shown, and demonstrate that with initial training the team were consistent over 93% of the time.

Table 1-11: Agreement Among Interpretation team Members

Source	Interpreter 1	Interpreter 2	Interpreter 3
Interpreter 1	Overall	89.47% | 96.68% 88.37% | 96.12%	89.75% | 95.29% 87.26% | 95.57%
Interpreter 2	92.66%		94.46% | 96.12% 89.75% | 94.46%
Interpreter 3	91.97%	93.70%	Deforestation | Drivers Degradation | Drivers

This exercise was followed by analysis of the disagreements and discussion among the team about how to follow the Indufor MRVS Image Interpretation Guide (Indufor 2012). The results demonstrate that it is difficult to achieve a level of image interpretation that is better than 95% correct; Foody (2010) discusses the impact of imperfect ground reference data and demonstrates the impacts it can have on reported Producer’s accuracy. This study of consistency does not allow us to conclusively attribute an error value to the reference data. However, it demonstrates that we have made best efforts to reduce interpreter bias through training and by acquiring a good set of data to evaluate interpretations.

5.3 Forest Area Estimates

Areas estimates are based on a model-assisted difference estimator, McRoberts (2010), to derive a Confidence Interval (CI) based on the assumption that the sample is randomly selected and unbiased.

The reference data consisted of 50 sample grids stratified into High and Low risk areas as described in the sampling design (Section 3.5) 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 60:40 between High and Low Risk stratum respectively. Note that the probability of encountering deforestation in each stratum can be estimated from the map data by query to the GIS; 84% of Year 2 deforestation is located in the High Risk Stratum and 16% in the Low Risk stratum. However, it was important not to under-sample the Low risk stratum as the drivers for deforestation are not known with absolute certainty. Therefore, despite randomisation, there are several possible sources of bias that include:

1. Selecting sample grids, from the random sample within each stratum, by availability of suitable reference data, because the reference data are themselves selected randomly and do not cover the whole population.
2. The reference data may be of variable quality and that quality may be distributed unevenly between strata.
3. The maps were produced from manual image interpretation and the validation also used manual interpretation based on a 1-ha minimum mapping unit. Operator bias could be present either in the distribution of errors in the maps and also in the interpretation of the reference data.

Although, the expectation is that probability-based estimators are unbiased, this cannot be assumed. An elegant approach that combines the advantages of simple random sampling with model-based estimators is the model-assisted difference estimator (McRoberts 2010; McRoberts *et al*. 2010a;McRoberts *et al*. 2010b). A model-assisted estimator used map data to make an initial inference but uses the probability-based sample to validate the result. In this analysis the model-assisted difference estimator has been applied separately to each stratum since forest area can be calculated easily from the GIS. Bias and Variance are estimated from the probability-based sample within each stratum.

At the 95% confidence level, the estimate of Year 2 forest area, based on the model-assisted stratified sampling design is 6,708,923 ± 79,765 hectares in the High Risk stratum and 11,669,068± 58,873 hectares in the Low Risk stratum. Combined, this gives a model-assisted Year 2 estimate of 18,377,991 hectares for Guyana compared with a figure of 18,378,301 hectares from the IAP/GFC map (**Table 1-12**).

The differences between the model-based estimates and the maps are shown in. Note that the observed difference between Durham and IAP/GFC of 310 ha does not appear to be statistically significant.

Note that the deforestation rate shown is calculated over a 15 month period and has been annualised.

Table 1-12: Summary of forest area estimates (in hectares) comparing mapped areas and areas estimated from a model-assisted difference estimator

Estimate	1990 (ha)	2009 (ha)	Year 1 (ha)	Year 2 (ha)	Deforest (ha)	Benchmark Rate (%)	Year 2 Rate[64] (%)
GFC Estimate	18,473,394	18,398,497	18,388,190	18,378,301	9,889	0.021	0.043
Durham Estimate			18,388,190	18,377,991	10,199		0.044

Table 1-13 and Table 1-14list the error matrices and the statistics used to estimate the forest area and confidence limits for the 95% and 99% confidence levels. Only the 95% confidence level data is reported in the conclusion and executive summary.

The following terms are relevant to the calculation of the confidence limits.

$\boldsymbol{\phi}$ = area to be estimated

x_i = random sample element

E =Expected value

$$\text{Bias }(\Phi) \quad = E[\Phi] - \ \Phi = \frac{predicted\ positive - predicted\ negative}{n}$$

$$\text{Variance}(\phi) = \frac{1}{n(n-1)}\sum_{i=1}^{n}(\bar{x}_i - x_i)^2$$

Comment from Norwegian Ministry of the Environment

Based on Table 3.7 (p.25), the area of deforestation estimated by the GFC and the area estimated by Durham can be compared to provide a non-site-specific estimate of accuracy of GFC deforestation (difference of 403 ha – note later revised to 310 ha by GFC). However, is it fair to state that a spatially explicit assessment of the accuracy of deforestation is not available? That is, the data are not available to assess if the locations mapped as deforestation are in fact deforested and it is not possible to construct an error matrix of the form of Table 12-9 for deforestation?

Response to Comment

A map is produced that shows the spatial distribution / pattern of errors. The overall estimations are, of course non-spatial.

Comment from Norwegian Ministry of the Environment

p.25: Formulas for estimating variance for the design implemented need to be provided. The variance shown on p.25 is appropriate for simple random sampling, but it would not be appropriate for a two-stage cluster sample, the design implemented for this assessment. The variance estimation formulas provided by McRoberts for the model-assisted difference estimator apply to simple random sampling and (as an approximation) to systematic sampling, but not to cluster sampling.

Response to Comment

"if the secondary units are drawn systematically from within the primary units, the design is not a true two-stage cluster sampling. In effect, the appropriate estimators to use in this case would be those given for single-stage cluster sampling" Kohl, Magnussen and Marchetti (2006).

In this case the formulas applied are for the model-assisted difference estimator are relevant to single stage sampling because each 10km by 10km square was assessed systematically by a regular sampling grid.

[64]The deforestation rate (0.043%) presented has been calculated for a 12 month period. This is lower than if the rate is calculated over 15 months.

Table 1-13: High Risk Error Matrix used for Forest Area Estimates for Year 2

High Risk Stratum	Class	Reference Images			
		Forest	Non-forest	Total	User Accuracy
Year 2 Map	Forest	7070	312	7382	95.77%
	Non-forest	238	2377	2615	90.90%
	Total	7308	2689	9997	
Producer Accuracy		96.74%	88.40%		94.50%

Bias (ϕ)	0.00740222	Sensitivity	0.967433	Producer's accuracy (Forest)
		Specificity	0.883972	Producer's accuracy (Non-Forest)
Forest	6771842.032	Predicted positive	0.957735	User's accuracy (Forest)
Total land	8500000	Predicted negative	0.908987	User's accuracy (Non-Forest)
		Prevalence	0.944983	Correspondence
ϕinit (from model)	0.796687			
ϕ	0.789285			
Variance(ϕ)	5.50385204E-06	Area estimate		
		Upper	Lower	**CI Range**
95% CL	0.004692	6748806	6669041	79765
99% CL	0.007038	6768747	6649099	119647
ϕ init 95%	0.004692	6811725	6731960	79765

Table 1-14:Low Risk Error Matrix used for Forest Area Estimates for Year 2

Low Risk Stratum	Class	Reference Images			
		Forest	Non-forest	Total	User Accuracy
Year 2 Map	Forest	6522	15	6537	99.77%
	Non-forest	47	184	231	79.65%
	Total	6569	199	6768	
Producer Accuracy		99.28%	92.46%		99.08%

Bias (ϕ)	-0.00472813	Sensitivity	0.992845	Producer's accuracy (Forest)
		Specificity	0.924623	Producer's accuracy (Non-Forest)
Forest	11609257.15	Predicted positive	0.997705	User's accuracy (Forest)
Total land	12650000	Predicted negative	0.796537	User's accuracy (Non-Forest)
		Prevalence	0.990839	Correspondence
ϕinit (from model)	0.917727838			
ϕ	0.92245597			
Variance(ϕ)	1.35373969E-06	Area estimate		
		Upper	Lower	**CI Range**
95% CL	0.002327006	11698504.66	11639631.39	58873.262
99% CL	0.00349051	11713222.97	11624913.08	88309.893
ϕ init 95%	0.002327006	11638693.78	11579820.52	58873.262

Table 1-15: Weighted Error Matrix used for Forest Area Estimates for Year 2

Estimates weighted by stratum	Class	Reference Images			
		Forest	Non-forest	Total	User Accuracy
Year 2 Map	Forest	6742	134	6876	98.05%
	Non-forest	124	1066	1190	89.58%
	Total	6866	1200	8066	
Producer Accuracy		98.19%	88.83%		96.80%

Bias (ϕ)	0.00123977	Sensitivity	0.981940	Producer's accuracy (Forest)
		Specificity	0.888333	Producer's accuracy (Non-Forest)
Forest	18381099.18	Predicted positive	0.980512	User's accuracy (Forest)
Total land	21150000	Predicted negative	0.895798	User's accuracy (Non-Forest)
		Prevalence	0.968014	Correspondence
ϕinit (from model)	0.869083			
ϕ	0.867843			
Variance(ϕ)	3.96604024E-06	Area estimate		
		Upper	Lower	**CI Range**
95% CL	0.003983	18439118.12	18270637.90	168480.220
99% CL	0.005974	18481238.17	18228517.84	252720.330
ϕ init 95%	0.003983	18465339.29	18296859.07	168480.220

5.4 Deforestation Rate

TheIAP/GFC maps show a Year1 to Year 2 (Oct 2010 to Dec 2011) deforestation rate over a period of 15 months of 0.054%. The model-assisted deforestation rate over the same period is 0.053%. This compares to an estimate from Year 1 of 0.065% using the identical model.

Table 1-16: Annual Deforestation Rate by Driver

Change Period	Change Period	Annualised Rate of Change by Driver					Annual Rate of Change (ha)
		Forestry	Agriculture	Mining	Infrastructure	Fire	
	(Years)	Annual area (ha)					
1990-2000	10	609	203	1 084	59	171	2 127
2001-2005	5	1 684	570	4 288	261	47	6 850
2006-2009	4.8	1 007	378	2 658	41		4 084
2009-10	1	294	513	9 384	64	32	10 287
2010-11	**1.25**	**186**	**41**	**7 340**	**298**	**46**	**7 912**

The main source of disagreement in the area estimates derives from:

i) deforestation due to Year 2 mining that was not detected by the operators in the high risk stratum

ii) areas mapped as non-forest that were in fact forested and could be seen as forest on the high spatial resolution RapidEye, Quickbird or Worldview imagery. There were also areas where RapidEye was not available to the interpreters mainly because it was cloud covered, or sites were unluckily obscured by persistent cloud cover in more than one RapidEye scene.

The difference in area estimated from the random sample is in fact rather small although it carries a large uncertainty due to the low number of sample points that intersect with year 2 deforestation (or degradation). The estimate could be improved by tidying up mapping errors observed in Year 1 of the MRV process and by increasing the sample size.

Tidying up the maps is not easy while the Interim measures rules are in place since this would inevitably lead to adding forest that was mapped previously as non-forest back into the calculations. Secondly, doubling the sample size would add several weeks to the validation period for the MRV but it would not reduce the uncertainty in the area estimates by a very large amount. More importantly it should be noted that the estimates show very low bias which suggests that the mapping has been undertaken in a consistent fashion.

We conclude that the GOFC-GOLD handbook provides a widely accepted set of good practice guidelines for the use of satellite imagery in support of Monitoring, Reporting and Validating (MRV) forest resources and carbon stock changes. The methods used by IAP and GFC follow the good practice recommendations set out in the GOFC-GOLD guidelines to help identify and quantify uncertainty in the level and rate of deforestation observed in Guyana over the Interim Measures Period – Year 2.

6. DISCUSSION

The results divide into three important areas that warrant further discussion:

i) reliability of the procedures used to identify deforestation and attribute the correct driver (reason for the change) from satellite imagery

ii) representativeness of the sample used to estimate bias and precision of the forest area mapping;

iii) assessment of the process to assist validation and verification in future years.

6.1 Reliability

There is a large literature highlighting the difficulties associated with mapping and verifying deforestation rates in the world's humid tropical forests (e.g. Achard et al. 2002; Grainger 2008; Hanson et al 2008; Hanson et al 2010). Any approach that uses satellite imagery to overcome the lack of reliable forest inventory data will need to account for errors caused by areas obscured by clouds (and cloud shadows) and low spatial resolution imagery. In addition to errors where deforestation has been missed, there is also the difficulty of interpreting and accounting for areas of degradation that do not constitute deforestation.

The approach taken by GFC to develop a wall-to-wall mapping exercise is ambitious but will generate very precise, location specific data. Once established in a GIS the data can be up-dated relatively easily but adding to the map units when new deforestation is identified from new imagery or fieldwork. The Interim Measures agreement, however, cause difficulties when modifying mapping data in a GIS as areas "deforested" or "degraded", because once accounted for these land over classes should remain with the same label. In reality, there are many cases where sampling has revealed misclassification of areas that are labelled as "defo-rested" or "degraded" but which are actually intact forest. These areas have been omitted from the analysis of to avoid confusion and to avoid introducing bias into the forest area estimates and deforestation rate.

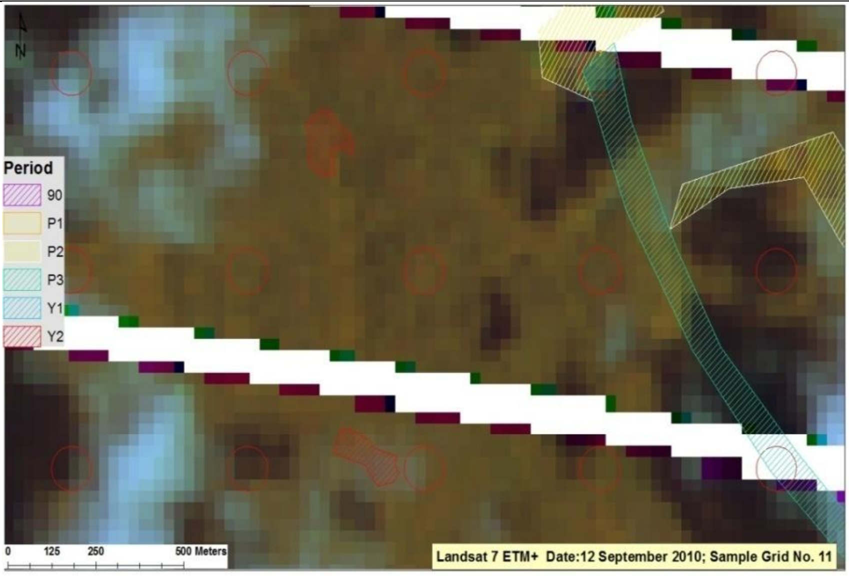
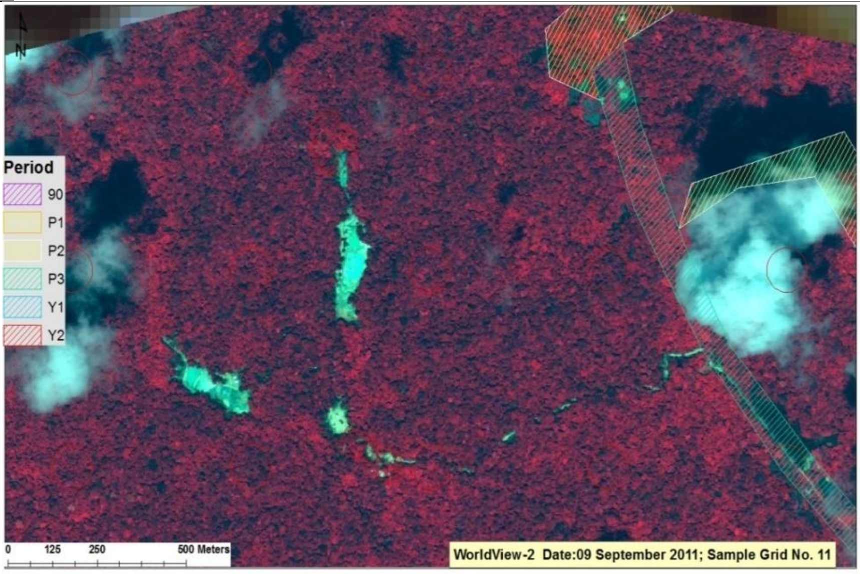
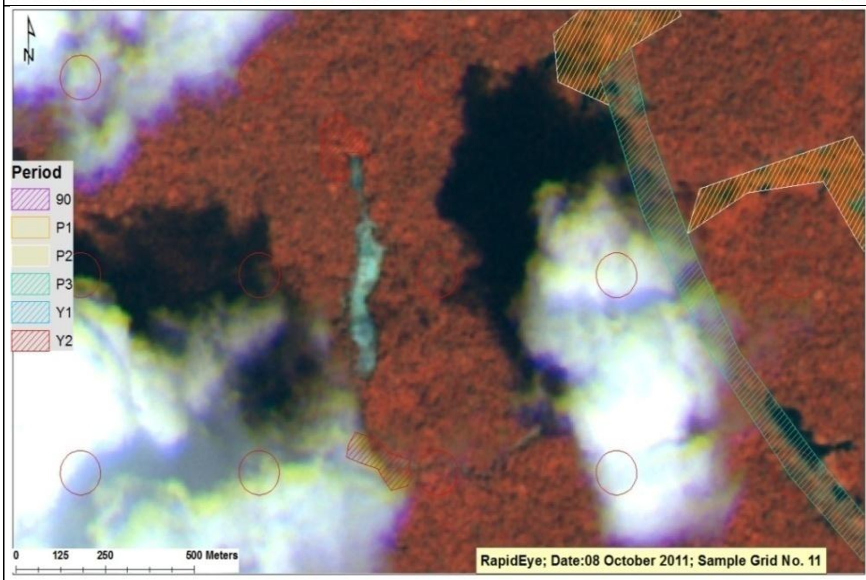
The validation exercise, although a small sample of the total land area suggests that the maps correspond well to actual land cover and the forest area is mapped very precisely. The map-shows examples of areas of mining that have been missed in the Year 2 map. The figure illu-strates a mining dredge site that has been deforested between September 2010 and September 2011. The interpreters did not have the WorldView-2 data available to them and also missed the site on the RapidEye.

The graphic shows roads and mining dredge sites and examples of deforestation and degrada-tion. The area is mapped as degradation. In fact there are areas of apparent degradation missed and extensive areas mapped as degraded that appear to be intact mixed tropical forest.

The graphic below also show a temporal sequence of mining-related deforestation across the same area as viewed from different satellite sensors.

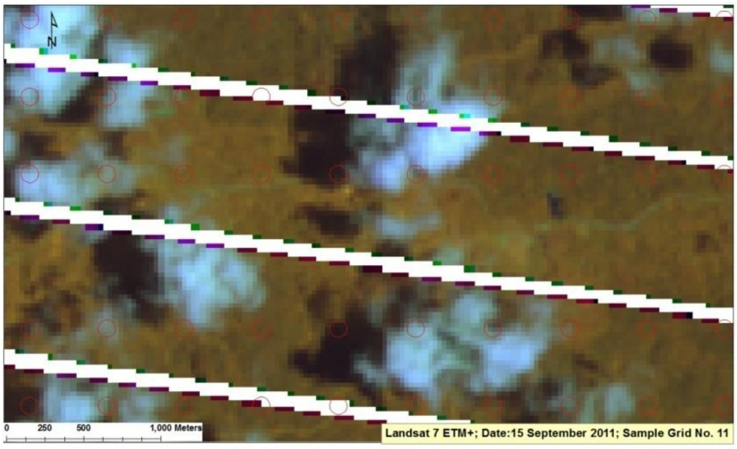
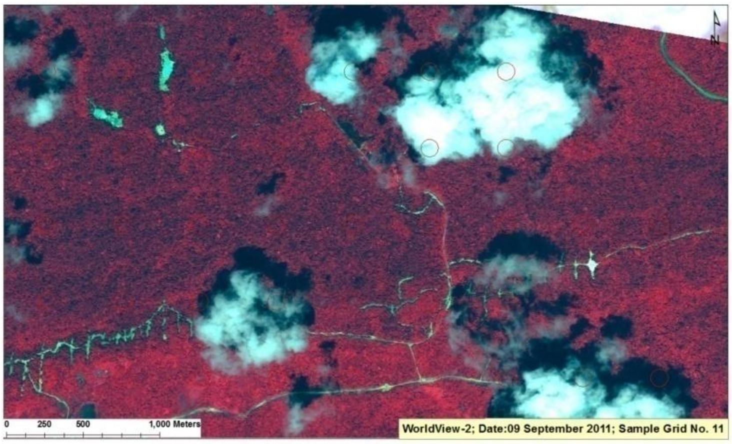
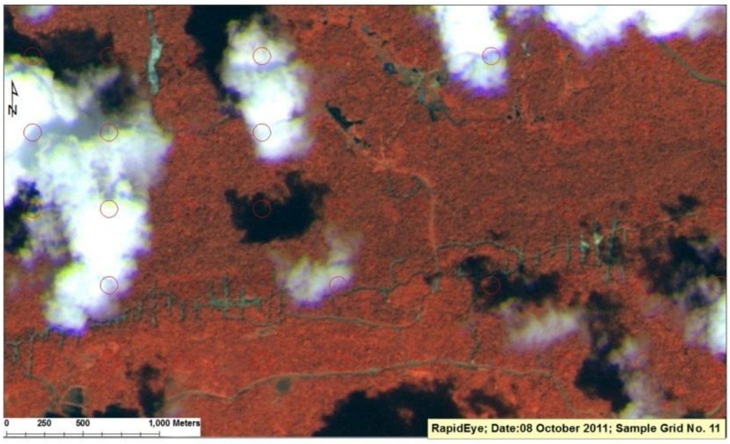
The difficulties of mapping all potential mining areas even with RapidEye data are due to oc-clusion by cloud and cloud shadow.

Figure 54: Areas of Missed Mining

Imagery	Description
	An example of Year 2 mining not observed on the Landsat imagery
	The development of the mining dredge is clearly visible in the Worldview-2 imagery from September
	RapidEye imagery from and October 2011.

The following examples show Deforestation and degradation features as depicted at different spatial resolutions from Landsat 7 ETM+ WorldView-2 and RapidEye images.

Figure 55: Deforestation & Degradation Features at Different Spatial Resolutions

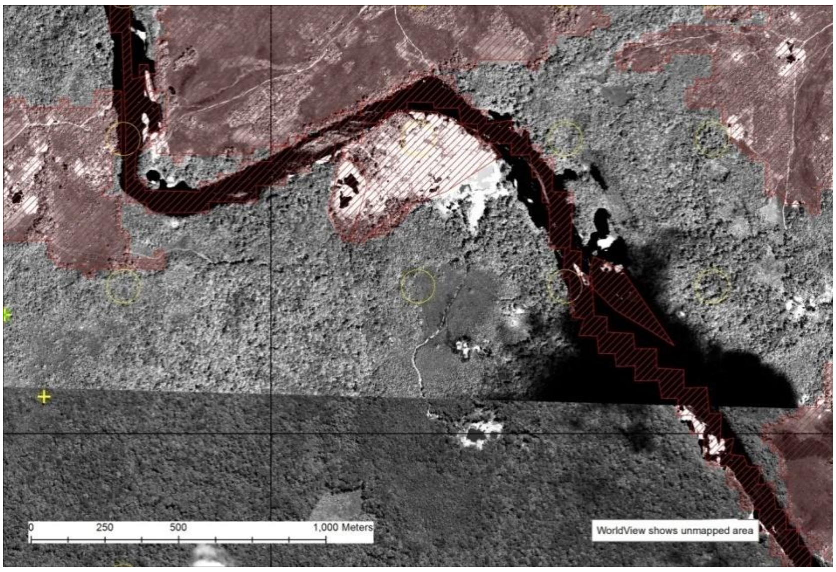
Imagery	Description
	Deforestation and degradation features from Landsat 7 ETM+ (30 m resolution). Note the failure of the scan line corrector creates striping across the scene.
	WorldView- 2 (1.9 m resolution) The difficulties of identifying and interpreting changes related to road construction, mining and forest degradation are illustrated by comparing the Landsat and Worldview data - both from September 2011.
	The RapidEye (5 m resolution) imagery of 08 October 2011, one month later illustrates the pace at which development can proceed.

<table>
<tr>
<td>
</td>
<td>GIS overlay shows land cover changes mapped.

The red outlines represent Year 2 deforestation and the yellow diagonal hashed area represents areas mapped as Year 2 forest degradation – much of which appears on the high resolution imagery as intact forest.</td>
</tr>
</table>

Shifting cultivation is not reported during the interim measures period. It is clearly visible on the high resolution WorldView-1 image and is currently mapped as non-forest (red hatching).

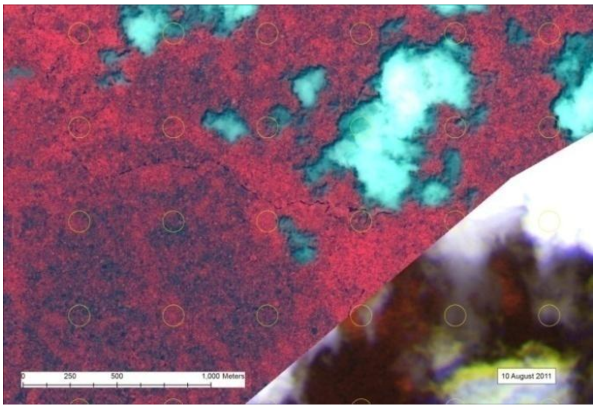
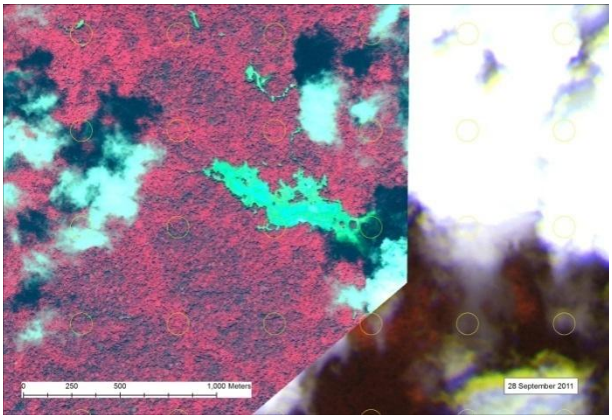
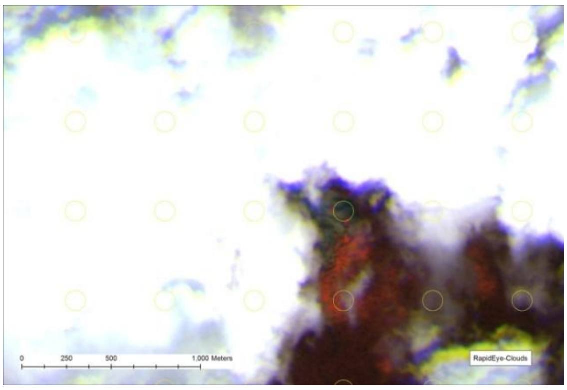
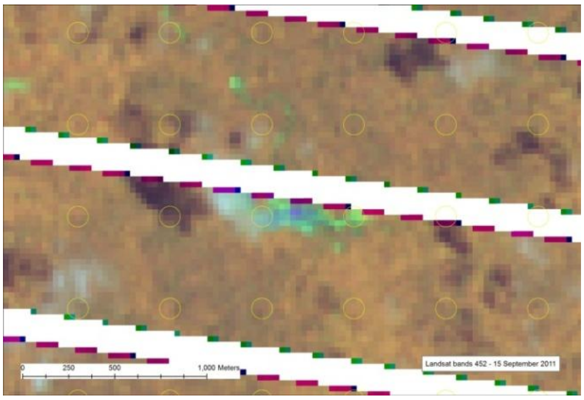
Figure 56: Shifting Cultivation

<table>
<tr>
<th>Imagery</th>
<th>Description</th>
</tr>
<tr>
<td>
</td>
<td>WorldView-1 (0.6 m resolution) panchromatic imagery showing areas of shifting agriculture (north of river) and non-forest areas that remain unmapped due to the spatial resolution of Landsat TM, ETM+ imagery.

Shifting Cultivation is not reported during the IMR period.</td>
</tr>
</table>

The final series of examples show four images taken from the same area and shows Year 2 mining-related deforestation between 10 August 2011 and 28 September 2011.

Figure 57: Temporal Change Across Sensors

Imagery	Description
	Forested at 10 August 2011
	Worldview-2 false colour infrared image from 28 Sept 2011 depicting deforestation caused by road construction and dredge mining
	RapidEye data mostly cloud covered
	Landsat 7 ETM+ Year 2 deforestation partial visibility on 10 September 2011

6.2 Drivers of Forest Change

The results demonstrate that mining is the overwhelming driver for deforestation and that infrastructural development associated with mining is also important. Degraded forest is also strongly associated with mining but perhaps surprisingly the areas that show as degraded on high spatial resolution imagery are rather limited.

This means that, despite the stratification of the sample into low and high risk zones, the sample size is too small to intersect with some of the mapped drivers such as burning. Burning was observed by the verification team in February 2012 although this has only been seen in areas of shifting agriculture close to the interior savannah of southern Guyana.

It is also evident that it is extremely difficult to interpret mining-related degradation from medium resolution optical satellite imagery such as Landsat TM and ETM+ imagery. It is often difficult to interpret degradation using RapidEye, especially without a detailed knowledge of the processes that lie behind the degradation.

The high resolution imagery such as Quickbird, IKONOS and Worldview-2 are sufficiently detailed to allow interpretation of forest structure and canopy openings in a way that is impossible with Landsat imagery. A lack of suitable high resolution imagery means that it is not possible to establish detailed temporal patterns for deforestation drivers from benchmark period to Year 2 incorporating 1990, 2000, 2005, 2009, 2010 and 2011. However, the analysis shows the cumulative data for the period 1990 to 2011 which shows that agriculture and infrastructure were the principal drivers.

In the Year 2 period Oct 2010 to Dec 2011 it is clear that mining and mining infrastructure are the prime causes of both deforestation and forest degradation. The majority (85%) of mapped deforestation sites lie in the "high risk" strata which suggests that the variables used to generate the high risk stratum which are related to the presence of humans and accessibility are good predictors of the geographical distribution of areas at risk from deforestation and degradation.

Given the uncertainty over causes and driving forces for tropical deforestation globally (Geist and Lambin 2002), the data held in the GFC-MRVS for Guyana presents an excellent opportunity to understand and perhaps better manage these processes in future.

7. SUMMARY AND CONCLUSIONS

We conclude that the quality of the mapping undertaken by GFC-IAP based largely on interpretation of Landsat TM, ETM+ and RapidEye imagery is of a good standard. The prevalence statistic is a good measure of overall correspondence between the map and reference data. We found that for Year 2 the prevalence weighted over both strata was 0.986 or 98.6% agreement. This is a very high figure, much better than one would expect from automated classification of multispectral remotely sensed data, and is almost certainly explained by the meticulous and painstaking manual process of interpretation and on-screen digitizing. We also note that the verification reference data are not perfect, about 14% of the sample area could not be used because of missing reference data or because the ground was obscured by cloud or cloud shadow. Missing reference data were excluded from the analysis.

1. We conclude that the GOFC-GOLD handbook provides a widely accepted set of good practice guidelines for the use of satellite imagery in support of MRVS for forest resources and carbon stock changes. The methods used by IAP and GFC in this report follow the good practice recommendations set out in the GOFC-GOLD guidelines to help identify and quantify uncertainty in the level and rate of deforestation in Guyana over the period October 2010 to December 2011 (Year 2).
2. The Year 2 forest degradation data has a correspondence (prevalence) between reference image interpretation and IAP/GFC mapping of 0.97 or 97.08%. This statistic is derived from 13,871 one hectare plots sampled from both strata and excludes areas of cloud cover and areas beyond the Guyana border and coastline. Year 2 degradation, however, represents a small proportion of the total sample, not sufficient to justify the calculation of an estimate of area.
3. The deforestation mapping was assisted by computer-based image processing that was used to automatically threshold Landsat TM, ETM+ and RapidEye data by using the Enhanced Vegetation Index (EVI). The second stage is one of manual interpretation and editing of the polygon boundaries generated from the EVI threshold.
4. The Year 2 forest area map (IAP-GFC) and the estimate from this study differ by a very small amount that is probably due to difficulties with interpreting Landsat imagery when RapidEye coverage is not available or when sites are missed due to persistent cloud cover. The GIS data file containing all of the sample areas is available and can be used to help cross check interpretations from high spatial resolution imagery with field-based interpretation.
5. The estimate of 1990 forest area, based on the stratified sampling design is 5,933,659 ± 17,609 hectares the High Risk stratum and 11,983,321 ± 55,695 hectares the Low Risk stratum. Combined, this gives a sample-based estimate of 17,916,980 hectares for Guyana for 1990 compared with a figure of 18,473,394 hectares from the Pöyry-GFC map.
6. The IAP-GFC maps show a deforestation rate over the 15 month period of Year 2 of 0.054%. This study shows a deforestation rate over the same period of 0.053%.

8. RECOMMENDATIONS

Assessment of tropical deforestation and degradation is a far from trivial exercise that requires a high level of experience in satellite image interpretation, GIS data handling, spatial analysis and statistical estimation. The MRVS GIS for Guyana contains many hundreds of satellite images and the vast majority of these are needed to undertake the assessment because single-period duplication helped circumvent cloud cover and multi-period imagery was needed to track changes as part of the interpretation process. The high spatial resolution imagery had large file sizes that made use of the GIS for map quality assessment a slow and painstaking process. The process of validation was based on 10x10 km^2 grid squares randomly distributed within high and low risk strata. It took approximately 1.5-2 hours to interpret the 361 one hectare sample plots in each square. Time permitted a sample of 50 10x10 km^2 grid squares within the terms of reference and the budget.

The interpreters underwent a training exercise designed to give a 'glimpse' of all the different satellite imagery and example of different types of deforestation driver. The group did a blind assessment of the same grids so that any disagreements could be highlighted, discussed and any interpretation bias removed before the validation process began.

With regard to improving the validation process for Year 2 assessment, we make the following recommendations:

7. The RapidEye data are of generally excellent quality and ideally suited to for the task. We recommend that the RapidEye data coverage be extended into the low-risk strata next year to help identify areas mapped as non-forest that are actually degraded or intact forest but were mislabelled from poor quality Landsat data in the past. It would greatly assist Accuracy Assessment if the planning for the acquisition of high resolution imagery used to validate the mapping over the PSU grid squares could done early in the Year 3 process (August to December).
8. The identification and addition of navigable water bodies to the GIS has helped improve the mapping and should improve the definition of high risk strata by helping to predict areas of forest at risk. We recognise that the acquisition of RapidEye data, as it extends to large areas of Guyana, will result in the need to update and improve the quality of the maps (back casting) and we support this process as it will result in better quality maps are area estimates.
9. Ensure that GFC staff are familiar with the validation process and have powerful workstations to be able to undertake some of this work in house.
10. Allow sufficient time for the independent validation. The sample size used in 2012 appears insufficient for a full quantitative analysis of degradation drivers, particularly when sampling low-risk strata. We estimate that a sample of 80—100 Primary Sampling units will provide a sufficiently large sample to yield an area estimate, particularly if the additional PSUs are allocated to the high-risk stratum where Year 2 degradation is most like to found.
11. Perhaps design the over-flights and field work to take place after the photo-interpretation to allow particular areas of ambiguity or uncertainty to be validated.
12. We witnessed an effort from GFC to improve their standards of surveying and mapping and this GIS exercise presented a good opportunity for this. We recommend that GFC will continue the effort and define standards for spatial data acquisition as clearly as possible and apply appropriate quality control measures.

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