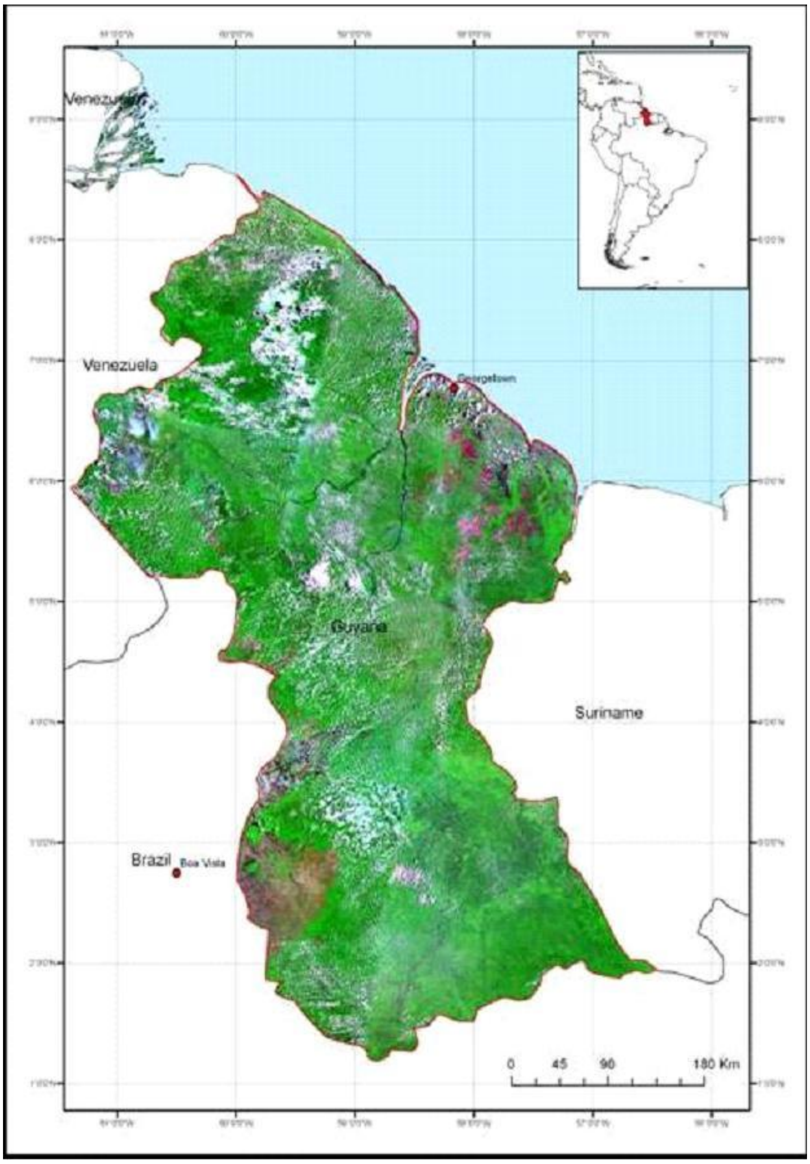

Guyana Forestry Commission

Guyana REDD+ Monitoring Reporting and Verification System (MRVS)

Interim Measures Report

Final

March 16, 2011

PREFACE

The Joint Concept Note (JCN) between the Government of Guyana and the Government of Norway identifies the stepwise and progressive development of 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 contributions to Guyana, is based on results achieved in keeping its deforestation and forest degradation below an agreed level.

In 2009, Guyana developed a national framework for a 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 in the Roadmap starts at 2010 and requires for a number of initial reporting activities to commence which will assist in shaping the next steps planned for 2011 and 2012.

The initial steps allow for a historic 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 the year October 1, 2009 to September 30, 2010.

The agreement between Guyana and Norway seeks to embark 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 for other partners seeing to take this same path, continuous learning and improvement are essential in the MRVS that is being developed.

This report aims to fulfil in part, the deliverables of Specific Activity Areas 1-3 of the first bid issued for the development of Guyana's MRVS as provided by the Remote Sensing and GIS consultant. Noteworthy is the fact that the contract for this work under year 1 of the MRVS Roadmap, extends to March 2011. At the completion of this contract, all specific activities identified in the Terms of Reference will be completed, specifically item 4 (the independent Accuracy 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

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

comprehensively monitored, reported and verified at the national scale. Both aspects of work are initial parts of year 1 of the Guyana MRVS Road Map.

Additionally, the report aims to fulfill the requirements of a number of "Interim Indictors for REDD+ Performance in Guyana" for the year October 1, 2009 to September 30, 2010, as identified by the JCN Table 2. The reporting on these intermediate indictors will allow for reporting to take place in the interim, whilst the full MRVS is under development.

This report describes the satellite imagery and GIS datasets, processing of these data, and 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 October 1, 2009 to September 30, 2010 will be subject to independent third party verification and is a requirement for the results-based financial support for 2011. As required by the JCN, the verification will take place for the first time in 2011, and will be conducted annually for the duration of the Guyana Norway Partnership.

This report is issued jointly by Pöyry Management Consulting Ltd (Pöyry) and the Guyana Forestry Commission (GFC).

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SUMMARY

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 agreed on for annual reporting whilst the MRVS is under development. 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 1 October 2009 to 30 September 2010.

Medium resolution satellite images have been used to calculate the forest area in accordance with Guyana's national definition of forest as at 1990[4]. The total forested area at this point was estimated as 18.3947 (± 0.4130) million hectares (ha) of which 15.5 million ha is administered by the State.

This area is greater than previous forest estimates as reported by FAO's Global Forest Resources assessment 2010, which is 15.2 million ha[5]. In Guyana's submission to FAO FRA 2010, a total of 3.58 million ha have been classified as other wooded land and an additional 0.9 million ha as other lands.

Forest change between 1990 and 2009 was monitored using a time series of Landsat TM and ETM+, and a composite of daily acquired MODIS (250 m resolution) taken as close to the end of the benchmark reporting period - September 2009. 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[6] between 1990 and 2009 is estimated at 74 900 hectares. Over the reporting period 1990 to 2009 this equates to a total deforestation rate of 0.41%.

Over the benchmark reporting period (1990-2009) this represents a forest loss of around 3 800 ha/yr^{-1} which when annualised is equivalent to 0.02%. As at the end of the benchmark period (September 30 2009) the area of forest is estimated at 18.39 million ha.

The values do differ from previous studies as reported in Cedergren (2009), although it is unclear if these studies have split deforestation and degradation. The upper value stated (i.e. Earthtrends) is 3% for the period 1990 to 2001 which represents about a 0.3% annual loss. The reported percentage to FAO is an approximation of the rate of deforestation for Guyana and was not subject to spatial or field assessments.

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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] 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.

[5] Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.

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

Interpretation of the change areas for the benchmark period identifies mining as the main driver of forest change (60% of the change), particularly between 2000 and 2005. Other noticeable trends show that agricultural development remains stable with an area of 200 to 500 hectares developed annually. Forestry-related activity has decreased, which is mostly accounted for by forest road construction and log landings. Harvesting in managed forest areas is small-scale and selective which means the forest cover remains intact and above the forest definition.

Based on the agreed performance indicators set out in the Joint Concept Note of the Guyana/Norway Agreement, the threshold for deforestation is determined by taking the current year rate (Year 1) and comparing this against the reference measure established for the interim period.

It is envisaged that the reference measure as well as the interim performance indicators will only apply whilst the MRVS is being developed and will be replaced by a full forest carbon accounting system in the future.

For the year 1 period (2009 to 2010) deforestation has increases to around 10 287 ha/yr. This is equivalent to an annual deforestation rate of 0.06%/yr which is an increase over the benchmark period (0.02%/yr). 'Best efforts' and will be reviewed independently to confirm their accuracy.

The main deforestation driver for the current forest year reported (Year 1) is mining with this accounting for 91% of the deforestation for this period. A majority (85%) 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 ongoing 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 whilst enabling continued sustainable development and improved livelihood of Guyanese.

A summary of the key reporting measures and brief description for these interim measures are outlined in Table S1. In this report, the analysis covers the benchmark period (1990-2009) and the first year of reporting (Year 1).

Outputs and results are also provided for the Intact Forest Landscape (measure ref. 2) and 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 calculated.

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 planting.

Table S1:
Interim Measures

Measure Ref.	Reporting Measure	Indicator	Reporting Unit	Reference Measure	Year 1 Period	Difference
1	Deforestation Indicator	Rate of conversion of forest area as compared to the agreed reference level	Rate of change $(\%)/yr^{-1}$	N/A	0.06%	N/A
2	Degradation Indicators	National area of Intact Forest Landscape (IFL)	Million ha	N/A	7.60[7]	N/A
2b		Determine the extent of degradation associated with new infrastructure such as mining, roads, settlements post the benchmark period	ha	N/A	92,413[8]	N/A
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	$000'm^3/yr^{-1}$	705.347[9]	695.043[10]	-10.304

[7] Note that in the January 2011 version of the Interim Measures Report (IMR), the definition of intact forests was applied with selectively logged/low intensity logged forests being included as intact forests. The definition of intact forests, taken from www.intactforests.org, outlines that these are to be treated as background influence. As part of the inclusive and participatory nature of the MRVS process, following verification activities and comments from stakeholders with specific recommendations regarding this indicator, allocated state forest areas are excluded from the intact forest landscape layer and reported as such, in this revised version of the IMR.

[8] This indicator as is required by the Joint Concept Note of the Agreement between Guyana and Norway, includes a buffering of 500 m 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 agriculture, 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 and may be subject to review. Note: in the January 2011 version of the IMR, 77,766 ha were recorded for this indicator. This total was since updated to record additional areas for Year 1 that were not included in the eligible areas for buffer for this indicator. This change in no way affects the gross deforestation indicator or any other indicator. The updating is specific to this indicator.

[9] Includes production volume and includes additional volume accounted for by Default Expansion factor of 25% as collateral damage. Production volumes are recorded in a custom designed database which is updated monthly by the GFC, subject to internal verification, and is backed up and stored monthly, offsite.

[10] Computed for the period October 1, 2009 to September 30, 2010 and includes collateral damage. Note that in accordance with the Forest Legislation, production for the purpose of royalty is computed using what is termed a 'hoppus/quarter girth' measurement which assumes a factor of 78.25% of the "true" volume. Since this is a legislative requirement, the GFC had previously reported, in the January 2011 version of the IMR, this production level. One recommendation of the verification process was to record the harvested volume for this indicator. As a means of addressing this recommendation, the GFC has increased the previously reported production volumes, for both the historic and current year, by a factor of 1.278 in the case of logs and doubling the total lumber volume to account for the conversion process. This therefore represents the volume harvested. Total production in year 1 was also adjusted for minor changes in procedural and illegal logging databases.

Measure Ref.	Reporting Measure	Indicator	Reporting Unit	Reference Measure	Year 1 Period	Difference
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)	000'm^3/yr^{-1}	105.802[11]	6.796[12]	99.006
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[13]	N/A
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 result of inter alia shorter fallow cycle or area expansion.	Not considered relevant in the interim period.	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

[11]Assume a level of 15% on harvested average annual production over the period 2003-2008 that includes collateral damage, of 705,347m^3. 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. Note that in keeping with the recommendation from the verification process to report on "true" volume and not "hoppus" volume, this total was re calculated to take account of collateral damage in both historic and year 1 totals. Additionally, minor adjustments were made to the total of illegal logging and procedural breaches volumes and incorporated in year 1 total (in all cases less than 5% materiality).

[12] Rate of illegal logging for the forest year October 2009 to Sept 2010 is informed by a custom designed database that is updated monthly, and subject to routine internal audits.

[13] Degradation from forest fires are taken from an average over the past 19.75 years. In the January 2011 version of the IMR, a total of 1,700 ha were used as a result of rounding to one decimal point. Following the verification process, recommendation was made to use two decimal points thus resulting in the change from the use of 19.8 years to 19.75 years in the average tally.

Acknowledgements

In addition to GFC, a number of agencies and individuals have assisted in providing inputs into the MRV program. The GFC would like to acknowledge the support of the Ministry of Agriculture and the Office of Climate Change for their strategic guidance. 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.

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- Guyana Lands & Surveys Commission for providing spatial data relating to, settlements and agricultural leases.
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- The Clinton Climate Initiative for strategic guidance in the development of the MRVS framework.
- Dr Andrew Haywood of Department of Sustainability and Environment (DSE), Melbourne, Australia, for advice related to statistical methods relating to validation of forest mapping.
- Dr James Sheppard of Landcare Research, Palmerston North, New Zealand for advice relating to multi-temporal normalisation of Landsat Satellite images.

CONTENTS

Appendices:

GLOSSARY

The following terms and abbreviations are used throughout the report.

CBERS	China-Brazil Earth Resources Satellite
ESRI	Environmental Systems Research Institute
FIRMS	Fire Information for Resource Management System
FRIU	Forest Resource Information Unit (GFC)
Geo FCT	The Forest Carbon Tracking Task force
GFC	Guyana Forestry Commission
GGMC	Guyana Geology and Mines Commission
GIS	Geographic Information System
GL&SC	Guyana Lands & Surveys Commission
GOFC-GOLD	Global Observation of Forest and land Cover Dynamics
GPS	Global Positioning System
IMR	Interim Measures Report
INPE	National Institute for Space Research in Brazil (Instituto Nacional de Pesquisas Espaciais)
ITTO	International Tropical Timber Organisation
JERS	Japanese Earth Resource Satellite
LCDS	Low Carbon Development strategy
LULUCF	Land Use, Land Use Change and Forestry
MODIS	Moderate Resolution Imaging Spectroradiometer
MOU	Memorandum of Understanding
MRVS	Monitoring Reporting and Verification System
NARI	National Agricultural Research Institute, Guyana
PALSAR	Phased Array Type L-band Synthetic Aperture Radar
PIFs	Pseudo-Invariant Features
Radar	Radio Detection and Ranging
REDD+	Reducing Emissions from Deforestation and Forest Degradation Plus
SFA	State Forest Area
SPOT	Satellite Pour l'Observation de la Terre
UNFCCC	United Nations Framework Convention on Climate Change,
USGS	United States Geological Survey
WWF	Worldwide Fund for Nature

1 INTRODUCTION

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 hectares. Guyana currently records a comparatively low deforestation rate. Earlier estimates were in the range of 0.1 - 0.3%, but this study suggests the historical and current actual rates are significantly lower than these percentages. 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 low deforestation rate. 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 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 first 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 and transparent assessment of forest area change for the historical period of (about) 1990 to 2009 using several times 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 October 1, 2009 to September 30, 2010 is also required. The results of the assessments are presented in this report.

Overview of National Process for MRVS Implementation

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 September 14, 2009 and October 27-29, 2009 respectively.

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 and advise on means by which key stakeholder groups are kept informed of progress in the development of the MRVS, as well as contribute 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) and Guyana Forestry Commission (GFC)), private sector (Forest Producers Association (FPA), Guyana Gold and Diamond Miners Association (GGDMA)), education (University of Guyana(UG)) as well as 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 relates 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 within State Lands and the granting of agricultural leases, which often fall within the State Forest Estate. The GGMC has 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 effective

environmental management and protection; and the sustainable use of Guyana's natural resources, while 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 which facilitate cultural, social and economic development, promote equity and advance of the rights of Amerindian people; based on the fact that the MRV would be developed along a capacity building approach and be community centred, the MoAA appropriately represents this. With the further inclusion of UG, FPA and GGDMA, the views of not only the private sector but one of the primary 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 for 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 involvement of entities such as the National Toshaos Council.
As of October 31, 2010, a total of five meetings of the MRVS Steering Committee were held. During this time, there have also been three meetings of the MRVS Technical Steering Committee.

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 in 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.

In the Terms of Reference for Bid 1 of the MRVS, two of the main deliverables include the design of a framework for building national capacities in the short, medium and long terms; and the implementation of the activities of the Bid, to provide for training to the GFC as well as other local bodies, to build capacity for future execution of the methods used in the MRVS efforts.

The same is also the case for Bid 2: Forest Carbon Assessment and Monitoring, whereby data collection, verification and analysis are being done by GFC and REDD Secretariat staff under the leadership and oversight of the consultants. In the case of this bid, a long term monitoring plan that will include capacity building needs, is also one of the deliverables of the contract. Practical training in implementation of each activity is also an important aspect of the project execution.

Recognising that effective capacity building is long term and sustained in nature, efforts will be scaled up throughout the course of the three year Roadmap implementation period, to progressively build higher levels of technical capacity as the MRVS implementation continues.

2 AREA REPRESENTATION

The total land area for Guyana as at 2009[14] is 21.1 million hectares, as determined from ground survey points and supported by mapping from medium resolution satellite imagery. This representation has been verified by the Government agency responsible for land surveying (GL&SC), however, it is recognised that limited control points are available along some border areas with neighbouring countries. This is especially relevant given that not all border areas (Brazil and Venezuela) are aligned to easily identifiable features such as rivers.

Situated in the tropics just outside the hurricane zone, at approximately 2 to 8° N and 57 to 61° W, Guyana's 460 km. coastline faces the Atlantic on the northern part of the South American continent. The Essequibo, Demerara, Berbice, and Corentyne Rivers drain into the Atlantic Ocean. Bounded on the north-west by Venezuela, on the south-west by Brazil, and on the east by Suriname, Guyana covers about 214,970 km² of land with varied topography, and 18,120 km² of inland water.

The coastal plain, only about 16 km. wide, but 459 km. long, is 5% of the country, and lies on average about 1.4 m below sea level at high tide. It is dissected by 16 major rivers and numerous creeks and canals for irrigation and drainage. 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. [15]

2.1 Forest Definition

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.

As at the benchmark period (30 September 2009) the total forest area that meets this definition has been estimated at **18.39 million** ha with an indicative accuracy of (91%)[16].

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[14] The coastal boundary has been edited to account for coastal erosion between 1990 and 2009.

[15] Guyana Forestry Commission. Forestry in Guyana, Lachlan Hunter, pg. 4

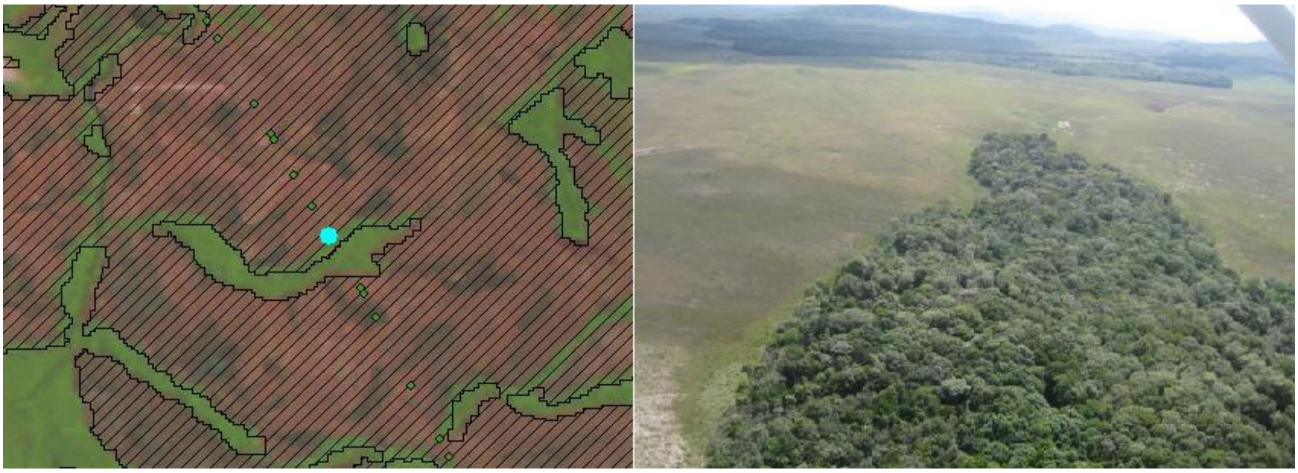
[16] The value provided is indicative only and has been determined as part of the internal consistency checks. A full accuracy assessment will be conducted by independent experts. This is timetabled for January 2011.

The forest area has been determined by excluding non-forest areas (including existing infrastructure) as at 1990, and from that point forward accounting for forest to non-forest changes that have occurred between 1990 and 2009. Field inspections and measurements over a number of non-forest sites have been used to verify the land cover type, the degree of canopy closure, the height of the vegetation and its potential to regenerate back to forest.

Figure 2-1 provides an example of a naturally occurring transition between forest and non-forest. The non-forest boundary is displayed in brown tones as identified from satellite imagery (left image) with the associated GPS located oblique aerial photograph also shown.

A further description of the forest/non-forest mapping process is outlined in Section 6.1.

Figure 2-1:
Detection and Mapping of Non-Forest



2.2 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.

Land Tenure arrangement in Guyana can be classified broadly into five main categories as presented in Table 4-1.

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 hectares 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. The area in 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 15.6 million hectares. This excludes Iwokrama, Kaieteur National Park and titled Amerindian Land. Combined the forested areas make up 2.9 million hectares.

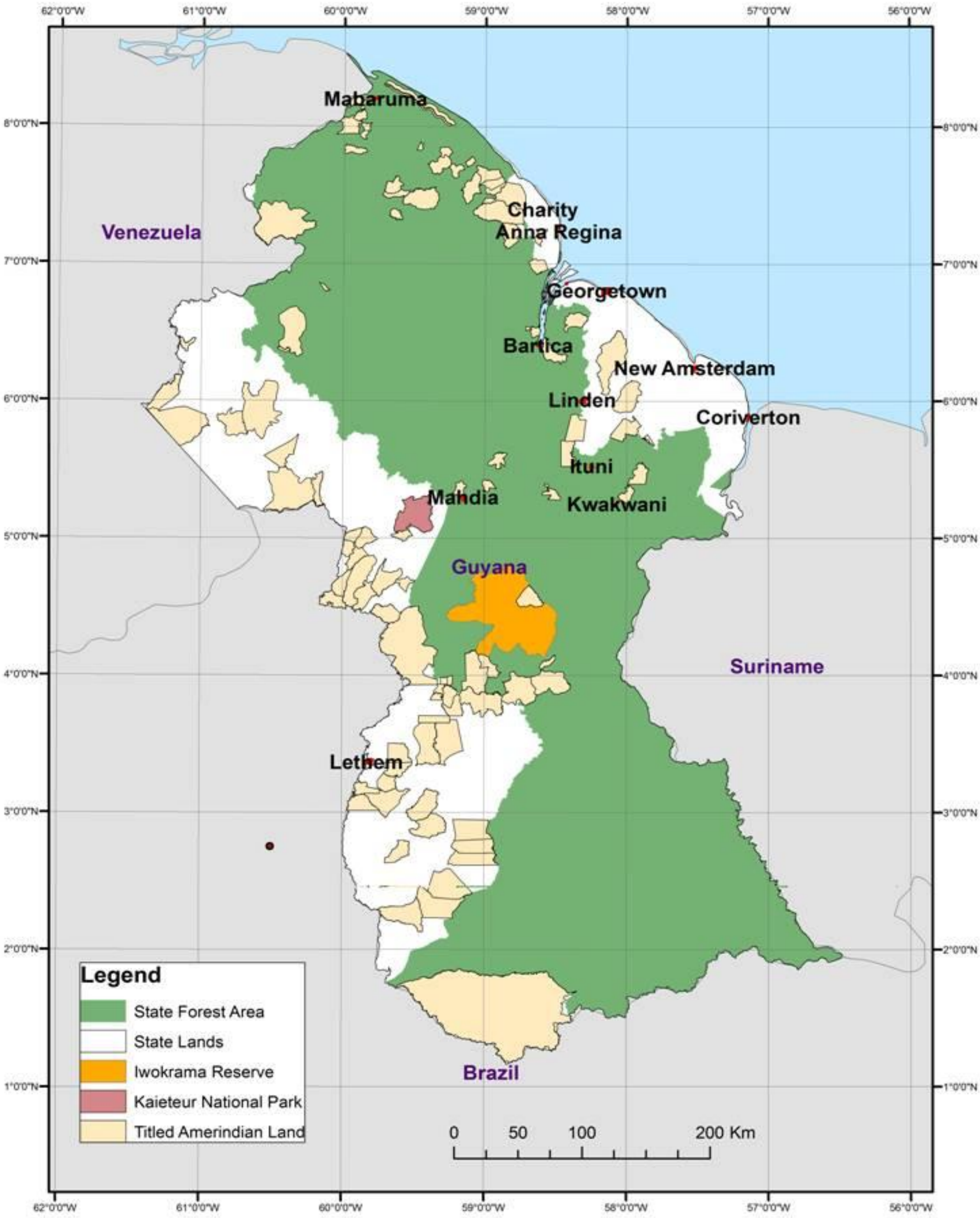
Table 2-1:
Land Allocation by Forest and Non Forest Area 2009[17]

Land Class	LCDS Status	Non Forest	Forest	Total
		(Area '000 ha)		
State Forest Area	Included	446	12,417	12,863
State Land[18]	Included	1,690	3,087	4,777
Iwokrama[19]	Excluded	7	343	350
Kaieteur National Park	Excluded	0.6	62	63
Titled Amerindian Land	Excluded until Opt in	589	2,488	3,077
Total Area (ha)		2,733	18,397	21,129

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

The distribution of these areas is shown on the following map (Map 2-1)

Map 2-1:
LCDS Eligible Areas



2.3 Forest & Land Cover Datasets

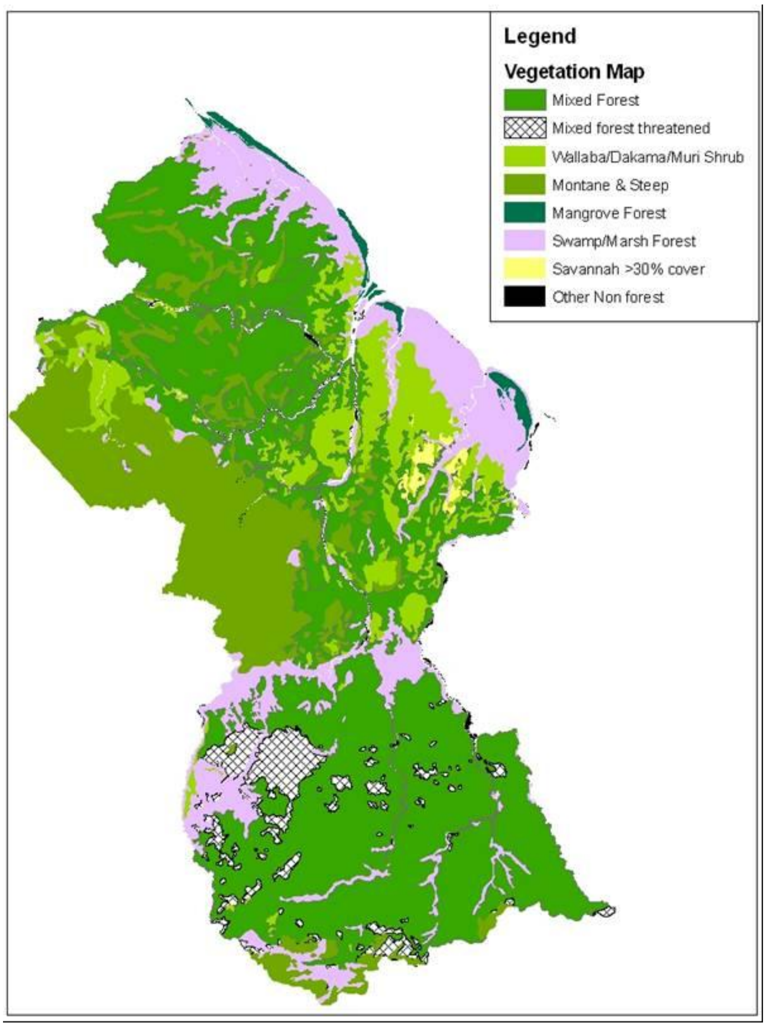
For the interim measures report the total land area is divided by forest and non-forest components as determined at 30 September 2009. This has been created from interpretation of the Landsat time series.

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 ongoing, 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 2-2). This is based mainly on national soil survey data made available by the National Agricultural Research Institute (NARI).

Map 2-2:
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 schema. This conforms to the six broad land use categories in accordance with IPCC reporting guidelines (Table 2-2). A description of the land use categories is provided in Appendix 1.

Table 2-2
Preliminary Land Use Categories

Class	**Land use Category**	**Land use type**	**Comment**
Forest Land	Forest Land	Mixed forest	Grouped as forest for Interim measure reporting with Guyana's definition of forest applied for quantification within categories
		Wallaba/Dakama/Muri Shrub Forest	
		Swamp/Marsh forest	
		Montane forest	
		Mangrove	
		Savannah >30% cover	
		Plantations	
Non forest	Grassland	Savannah <30% cover Grassland	Grouped as Non forest for Interim measure reporting with Guyana's definition of forest applied for quantification within categories
	Cropland	Cropland	
		Shifting Agriculture	
	Wetland	Wetland open water	
		Herbaceous wetland	
	Settlements	Settlements	
	Other land	Other land	

The intention is to update and refine these maps as appropriate using medium resolution 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.

3 MONITORING & SPATIAL DATASETS

The following section provides a summary of the satellite imagery and spatial data that has been assembled to map and monitor forest to non-forest change from 1990 to 2010.

The change analysis focuses on detection of forest change over three nominal periods as follows;

- 1990 to 2000
- 2001 to 2005
- 2006 to 2009 September

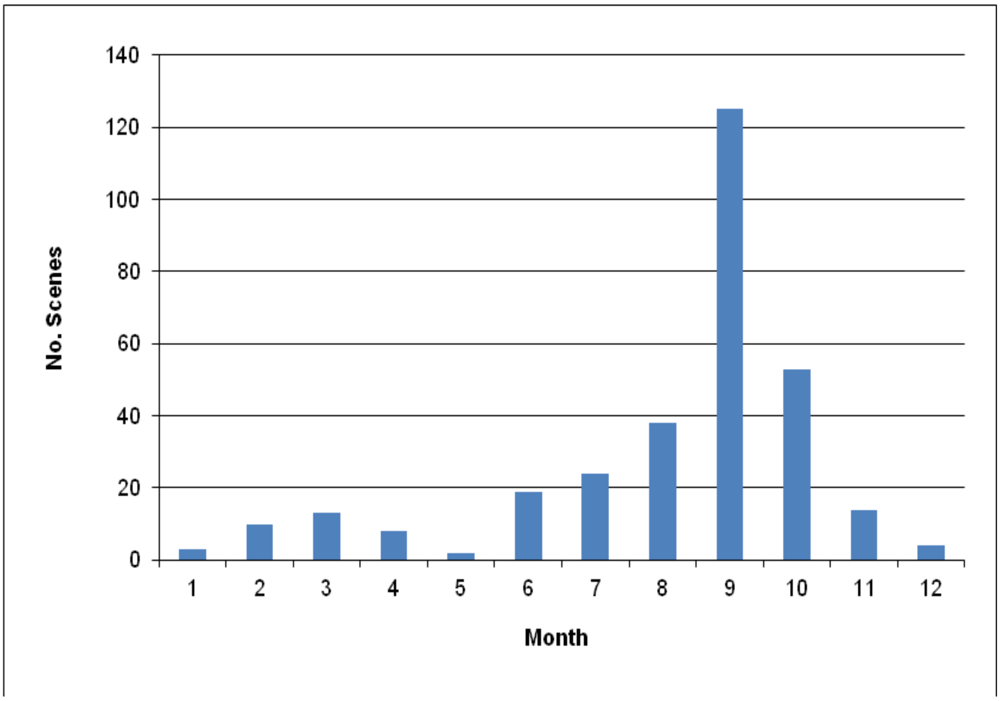
It is from these time periods that the Benchmark forest map is created. The benchmark map provides a snapshot of forest area as at 30 September 2009.

The 'Year 1' maps cover the first year after the benchmark map. For this period all forest to no-forest changes from 2009 to 2010 September are mapped spatially and reported.

3.1 Cloud Cover

Persistent cloud cover is an issue over Guyana with most cloud-free images acquired between August and November. Consequently the Landsat 1990 to 2009 time series assembled spans a number of years around the desired date. Ideally the reporting period should recognise this situation and be set to end in December with reporting due in March the following year to allow time for processing and analysis. The following figure shows that nearly 70% of cloud-free imagery assembled is captured between the August and November period.

Map 3-1:
Time Series Acquisition by Month 1990 to 2009



The Landsat images for the Year 1 map (Oct 2009 to Sept 2010) were also supplemented by images acquired by Disaster Management Constellation (DMC) satellites. These satellites cover a wide area at 22 m resolution with the ability to acquire images daily. This coverage will also be supplemented by Landsat images from USGS and INPE and radar images as provided by Geo FCT.

Additional spatial datasets have been assembled from various agencies to assist with demarcation of management areas and to provide supplementary information to assist with detection of forest change.

The process developed at GFC aims to enable areas of change (>1 ha) to be tracked through time, by driver. The approach adopted seeks to provide a spatial record of temporal land use change within forested land and non-forest land.

3.2 Data Storage & Structure

All spatial data has been migrated from the previous server to recently purchased Network Attached Storage (NAS). This process was completed in September 2010. The NAS is routinely backed up to a 400 GB tape drive and stored off-site.

All the relevant datasets that have been used during the analysis have been documented. This includes a description of the dataset, its path 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.

Many of these datasets are routinely updated by various agencies and this will allow for a central data repository be created which allows the various stakeholders to access the most updated information.

Remote sensing data and associated GIS layers are stored on the dedicated NAS. Raw image datasets as provided by image providers are retained and have been catalogued by the analysis period they relate to (i.e. 1990, 2000), sensor and path and row. New folders are created as these scenes are processed using ENVI image processing software and all associated files generated will also be retained. All images are named using a common format that identifies the satellite, path and row and image date (see Appendix 2).

Processed datasets will be held in an ArcGIS 10 Geodatabase with images copied into image catalogues and served across the network using ArcGIS image server.

FRIU currently has four GIS operators, a GIS manager and two remote sensing specialists. All desktop computers are running the latest version on ArcGIS as provided by ESRI under the Low Carbon Development Strategy (LCDS) assistance program. The ESRI offer also extends to training in GIS packages provided. Two copies of ENVI 4.7 have also been installed to enable image processing. Both are dongle versions and include maintenance contracts. Pöyry has provided customised toolbars for automated processing imagery in ENVI and ArcGIS.

4 DATA SOURCES

A combination of satellite and spatial datasets from three key agencies (Table 4-1) has been evaluated and assembled. These datasets form a base layer and also assist with identification of forest change events.

Table 4-1:
Agency Provided Datasets

Agency	Role	Data Held
Guyana Forestry Commission (GFC)	Management of forest resources	Forest resource management related datasets including forest concession, forest vegetation, and forest roads map.
Guyana Geology and Mines Commission (GGMC)	Management of mining and mineral resources	Mining concessions in large and medium categories.
Guyana Lands and Surveys Commission (GL&SC)	Management of land titling and surveying of land	Land tenure, settlement extents and agricultural leases that occur in the State forest, and base map on roads and rivers layer.

Several supplemental datasets have also been assembled. These relate to work conducted by GFC, Pöyry and the World Wildlife Fund (WWF). These studies have focussed on detecting historical forest change and have been integrated into the GIS system.

Active fire data derived from thermal bands carried on the MODIS satellite has also been acquired for 2000-2010. This data is freely available and is distributed via Fire Information Resource Management Service (FIRMS[20]). This dataset will assist in the detection of forest areas at risk from anthropogenic fire.

The following section provides details of image and GIS datasets considered relevant for monitoring and mapping temporal forest change. The image datasets are further divided by their application.

4.1 Monitoring Land Use Change

Much of the historical imagery used to create the benchmark map is taken from Landsat. This imagery is suitable for monitoring temporal forest and land use change at a one hectare scale.

Where appropriate other satellite imagery has been used to assist with the detection of forest change.

The following Earth observation datasets have been compiled:

Landsat

Earth observation data is provided by a historical Landsat multispectral scanner (MSS) at 80 m, Landsat 5 and Landsat 7 images at 30 m. These combine to offer the most comprehensive temporal coverage over Guyana. This archive is freely available and spans from 1987 to 2010, with relatively cloud-free coverage available for 2000, 2005 and 2009. In total 17 Landsat scenes are required to cover

[20] NASA/University of Maryland. 2002. MODIS Hotspot / Active Fire Detections. Data set. MODIS Rapid Response Project, NASA/GSFC [producer], University of Maryland, Fire Information for Resource Management System [distributors]. Available on-line [http://maps.geog.umd.edu]

Guyana. Approximately 155 scenes covering the 1990 to 2010 period have been downloaded.

These images have been 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[21] images.

Since May 2003 a scan line correction fault has caused a striping affect on the images. This fault has reduced the utility of Landsat 7 images for automated processing and mapping, although it is still practical to use it for monitoring temporal change. Landsat acquires images over the same area about every 16 days.

To ensure consistency, all imagery has been geo-referenced to a based set of 1990 era Landsat images. Each image identified for automated processing (i.e. low cloud cover) has been radiometrically calibrated using published sensor bias and gain coefficients (see Section 5). The Landsat series of satellites are unique in their temporal coverage. The long term continuity of both Landsat 5 and 7 is questionable as both have exceeded their anticipated lifespan. Alternative optical sensors with similar resolution include, SPOT, DMC and IRS. Radar imagery from several sensors also offers an alternative.

SPOT

The Système Pour l'Observation de la Terre (SPOT) coverage purchased by the World Wildlife Foundation (WWF) for Guyana spans 2006 to 2008. This dataset includes images from SPOT 2, 4 and 5 satellites, so the spatial resolution ranges from 10 to 20 m. In total 111 scenes are available with 67% of these 20 m resolution, and the majority acquired (65%) acquired between 2006 and 2007.

These images have been processed to level 2A meaning that it is already geo-referenced (not ortho-corrected) based on satellite orbital information and available worldwide small-scale digital elevation models (DEM). Consequently, an offset is observed between GPS datasets and the images and also between the geo-referenced Landsat mosaic. Work is ongoing to reference these images to the 1990 Landsat base. Priority has been placed on referencing images over areas of change.

Although any future SPOT acquisitions will need to be tasked, the likelihood of acquiring cloud-free data is increased due to the ability to adjust the sensors viewing angle to look to either side of the satellite's vertical (nadir) track. The off-nadir viewing capability increases the satellite's revisit period to around 5 days.

One of the main limitations of using SPOT operationally at a national scale is the acquisition cost of the images.

[21] 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.

CBERS

The China Brazil Earth Resources Satellites (CBERS 2 and 2B) carry two similar sensors, a multi-spectral camera with 20 m resolution and a wide field imager at 260 m spatial resolution. CBERS 2B also carries a panchromatic high resolution camera (HRC) with 2.7 m resolution 27 x 27 km extent. These images are also freely distributed by INPE, Brazil. A selection of the HRC scenes has been used to provide validation for the land cover stratification map and forest change. Due to a malfunction, CBERS 2B recently ceased acquiring image data.

DMC

GFC has tasked an image acquisition (September 2010 to January 2011) targeting the main change areas that are currently affected by cloud. The advantage of DMC is that it provides daily repeat capability. Currently three satellites are actively imaging the area of interest**.** The resolution of two of these satellites (UK DMC-2 and Deimos-1) is 22 m and the third (Beijing-1) is 32 m. The target cloud cover threshold is set to 10%. As at mid-September no completely cloud-free images have been acquired. DMC currently operates three satellites, but any image acquisition must be pre-ordered. Ideally this order would be in place to commence acquisition for the beginning of August each year.

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). Since February 2010 only two scenes over Guyana have been acquired (as at October 2010). The IRS revisit period is 24 days which limits the number of images that are able to be acquired. Further coordination is required with INPE to ensure that any images acquired are accessible from the online catalogues.

4.2 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 is not suitable for mapping areas but does provide the location of potential change for areas >20 ha. For the interim reporting period MODIS imagery provided the only low cost option available in the absence of Landsat images. In this case it was used to check for evidence of large-scale forest change (i.e. roading infrastructure, expansion of mining) in areas that were persistently covered in cloud.

In addition to the low cost the advantage of MODIS is its frequent revisit period. 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.

4.3 Radar

Several radar datasets exist over Guyana. Historical coverage 1995-96 is available from Japanese Earth Resources Satellite (JERS-1). These images cover the wet and dry season and have previously been used by FRIU to assist in the production of the 2001 national forest cover map. The individual tiles (100 m resolution) were mosaicked and the two time periods combined to create a single composite image.

Several radar datasets are actively acquired over Guyana. These are distributed via the Forest Carbon Tracking Portal (www.geo-fct.org). Relevant datasets identified include 2008-2009 RADARSAT 2 images, Phased Array type L-band Synthetic Aperture Radar (PALSAR) images.

The main advantage of radar is its ability to penetrate cloud. GFC has received 22 multi-temporal (12/10/2010) single and dual polarised (50 m resolution) Palsar scenes that provide partial coverage of central Guyana. These scenes span from 2008 to the end of the 2009 benchmark period.

Given the issues with cloud, a regular delivery of radar data should be pursued. Ideally multi-temporal dual polarised images would assist with the detection process. Processing of such data requires specialist knowledge and software to ensure a range factors and corrections unique to radar datasets are accounted for.

The Guyana Forestry Commission has concluded an agreement with Wageningen University (WU), the Netherlands on behalf of the Re-Cover project consortium that is financed by European Commission, for the duration of three years. This project is scheduled to commence in November 2010.

This project is expected to further enhance the GFC’s capabilities in the use of radar and optical data for forest area assessment. The agreement, which will be implemented by Wageningen, among its main outputs, provides for more detail and accuracy in forest area and forest type mapping using optical and Radar satellite data and explores the synergy multiple remote sensing datasets acquired by the GEO and Kyoto and Carbon initiative for that purpose.

The initiative is anticipated to focus on selected demonstration sites that are defined by Guyana and reflect regions of importance to REDD+, GEO task verification sites and FRA 2010 sampling points.

The historical detection and analysis of change has focussed on the application of Landsat images, as these have a wider temporal span and are freely available. Additionally, in Guyana there is a higher level of expertise in processing and interpreting optical data. At this stage, radar is identified as a viable option to be used to supplement cloudy areas and for verification purposes.

4.4 Verification Datasets

Very little cloud-free high resolution satellite imagery (<5 m resolution) exists for Guyana in image archives. This is because often these satellites need to be tasked (pre-ordered) to cover specific areas. Currently, GFC has IKONOS images for part of the coastal zone. CBERS 2B HRC images are also available at no charge. Recently purchased datasets include, ALOS (10 m) and ASTER 15 m data (Map 4-6).

These datasets are particularly valuable for providing verification of land cover classification from medium resolution images and for conducting accuracy assessments[22] of both land cover and land cover change. Ideally these datasets should provide full coverage and be as close to the map creation date as possible. In practice high cloud cover means the coverage is incomplete. Any sampling design for testing classification and change accuracy will need to consider this situation.

Historical aerial photography (1:40 to 1:50 000 scale) also exists and was flown between the 1950 and 1970s. Only hardcopy prints are available and this coverage is shared between GFC and GL&SC. An overall index map that shows the approximate location of the flight runs is also available. Selected photos from this coverage have been used to verify the satellite classification of non-forest in inaccessible areas that have not undergone change.

4.5 Dataset Summary

Table 4-2 provides an overview of the images that GFC holds or that are currently available in image archives. A description of their application and basic technical specifications is also provided.

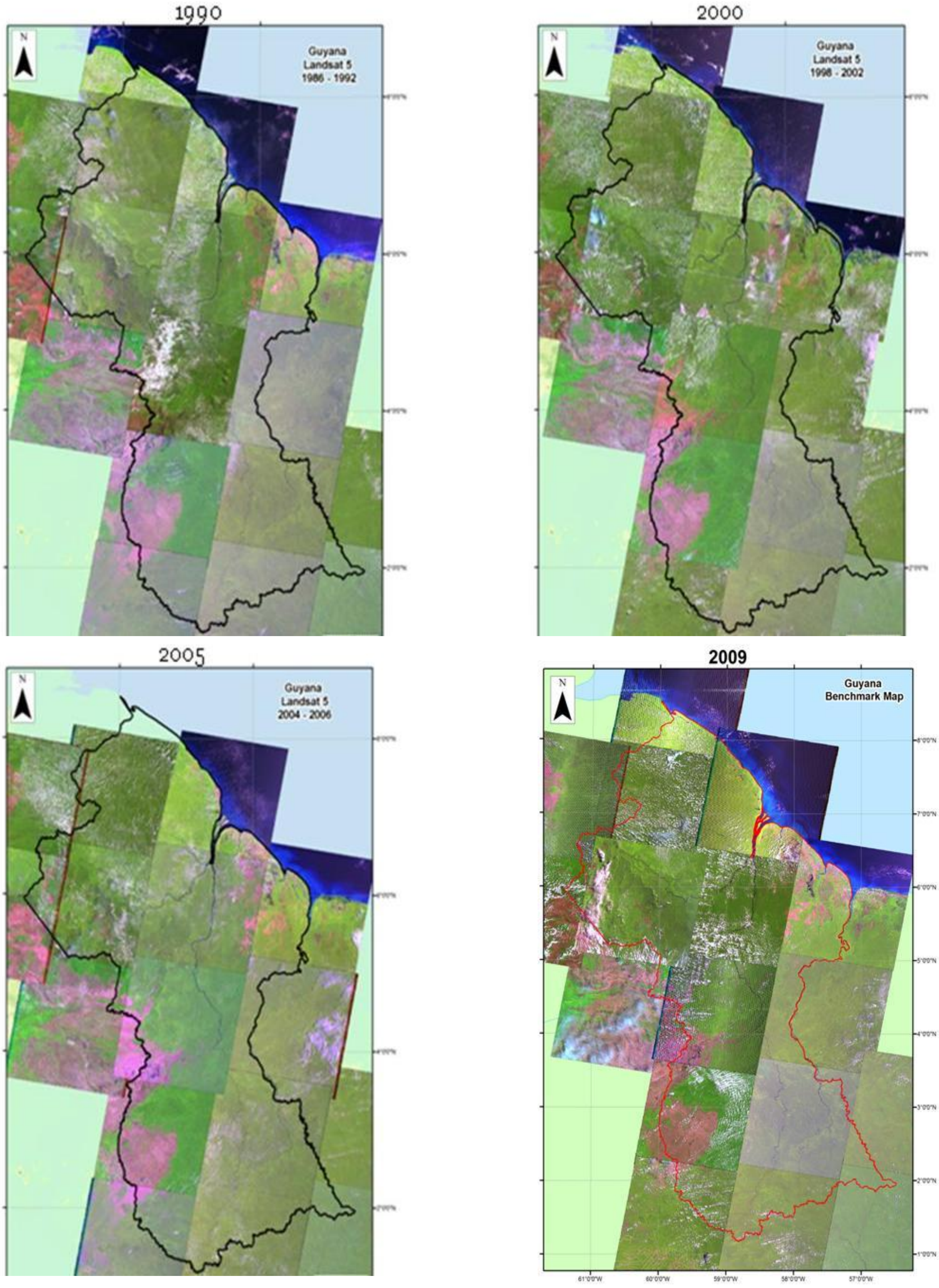
Table 4-2:
Satellite Imagery

Application	Satellite	Spectral Bands	Resolution	Image Extent (km)	Coverage
Land use & Forest Change Mapping	SPOT	VNIR & SWIR[23]	5, 10 or 20 m	60 x 60	Full coverage but cloudy
	CBERS[24]	VNIR	~20 m	120x 120	Scattered
	DMC	VNIR	22 m & 32 m	660 x 4100	Scattered cloud
	ResourceSat1 (IRS)	VNIR & SWIR	23.5 m (LISS-3) 56 m AWiFS	142 x142 & 774 x 774	Scattered only 2 LISS-3 scenes available
	Landsat 5 & 7	VNIR & SWIR and thermal bands	30 m VNIR & SWIR 90 m thermal	185 km	Full temporal coverage to Sept 2009
	Landsat MSS	VNIR	80 m	185 km	Scattered pre 1990
Monitoring Broadscale Forest Change	MODIS	VNIR	250 m	Approx. 2000 km	Daily coverage from two satellites Terra & Aqua. Complete coverage for end Sept 2009 and 2010
Radar	Palsar RADAR	Single and dual polarisation	50 m	~70 - 70	Selected scenes provided by GEO FCT for 2008-09 period
Verification & Accuracy Assessment	Aerial photography	Panchromatic with some colour images around coastal areas	1:40 000	Unregistered	Historical spanning from 1950-1970
	IKONOS	VNIR	1 m pan 4 m multi-spectral	11 x 11 km	Scattered around coastal regions
	Kompsat 2	VNIR	1 m pan 4 m multi-spectral	16 x 16 km	Scattered
	CBERS (HRC)	Panchromatic	2.7 m	27	Scattered
	SPOT 5	VNIR & SWIR	2.5, 5 m & 10 m	60 x 60 km	Scattered
	ASTER	VNIR & SWIR & thermal bands	15 m	60 x 60 km	Scattered
	ALOS	Visible & near infrared	10 m	70 x 70 km	Scattered

[22] A formal accuracy is planned for January 2011. This will be carried out by Independent consultant.
[23] Visible and Near infrared (VNIR) Shortwave Infrared (SWIR)
[24] CBERS ceased collecting data in May 12 2010

The following series of maps (Map 4-1 shows selected medium resolution Landsat coverage over Guyana for the benchmark period (1990-2009). These are supplemented by images covering the same footprint acquired during the same period. Map 6-3 shows the available Year 1 images for Landsat.

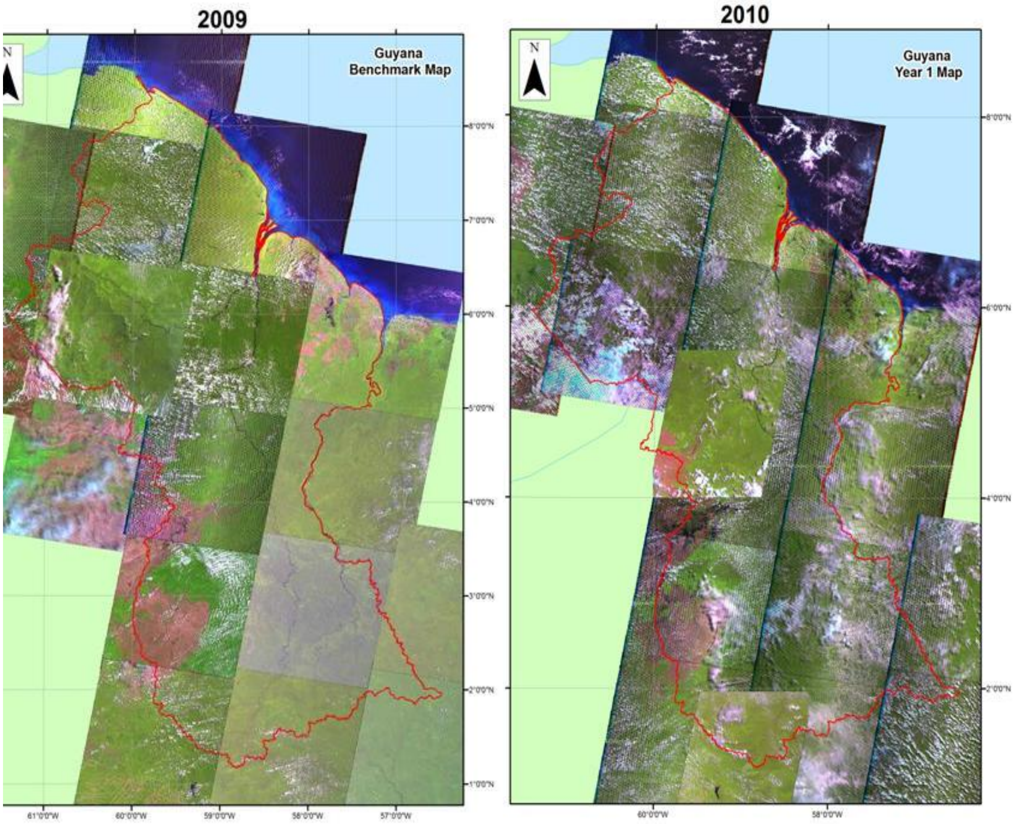
Map 4-1:
Guyana Image Coverage 1990 to Sept 2009



Map 4-2 shows the satellite image coverage for the 2009 Benchmark period and Year 1 change periods.

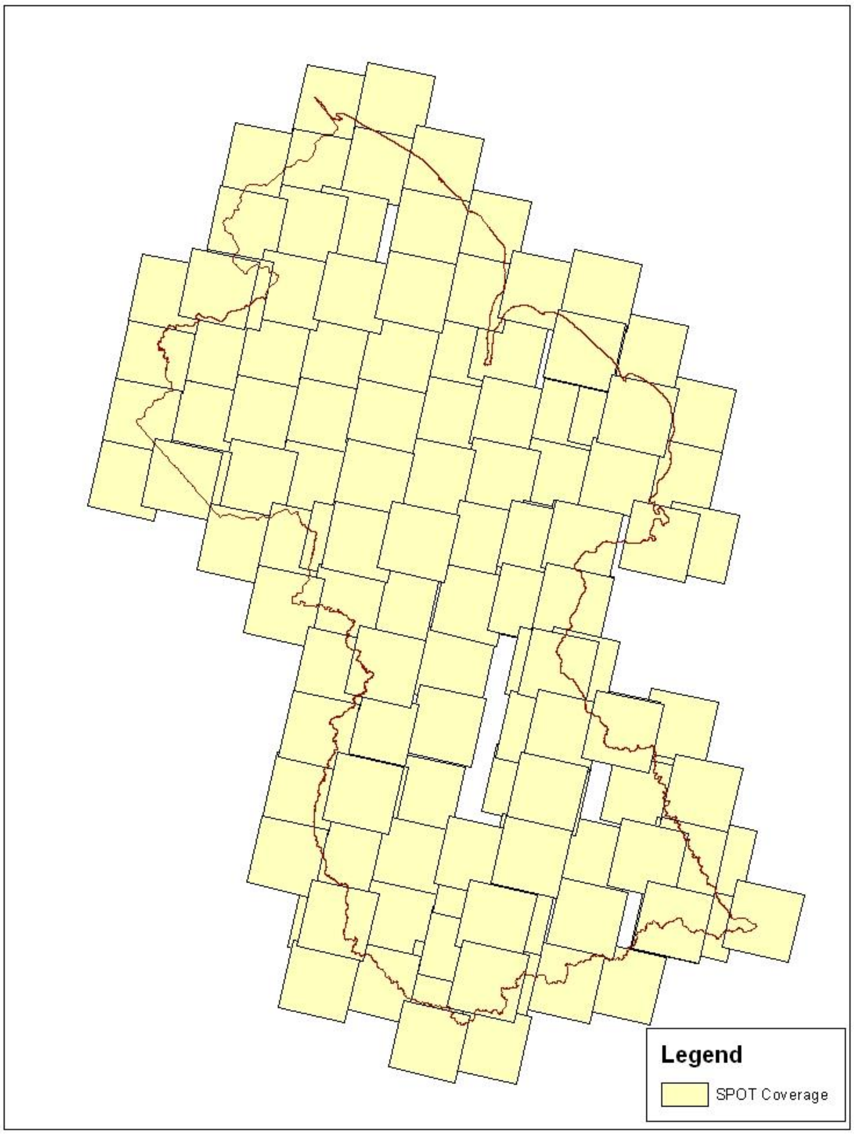
The Year 1 coverage will be updated as new images from either Landsat ResourceSat1 or DMC images and radar sensors are acquired.

Map 4-2:
Benchmark & Year 1 Imagery



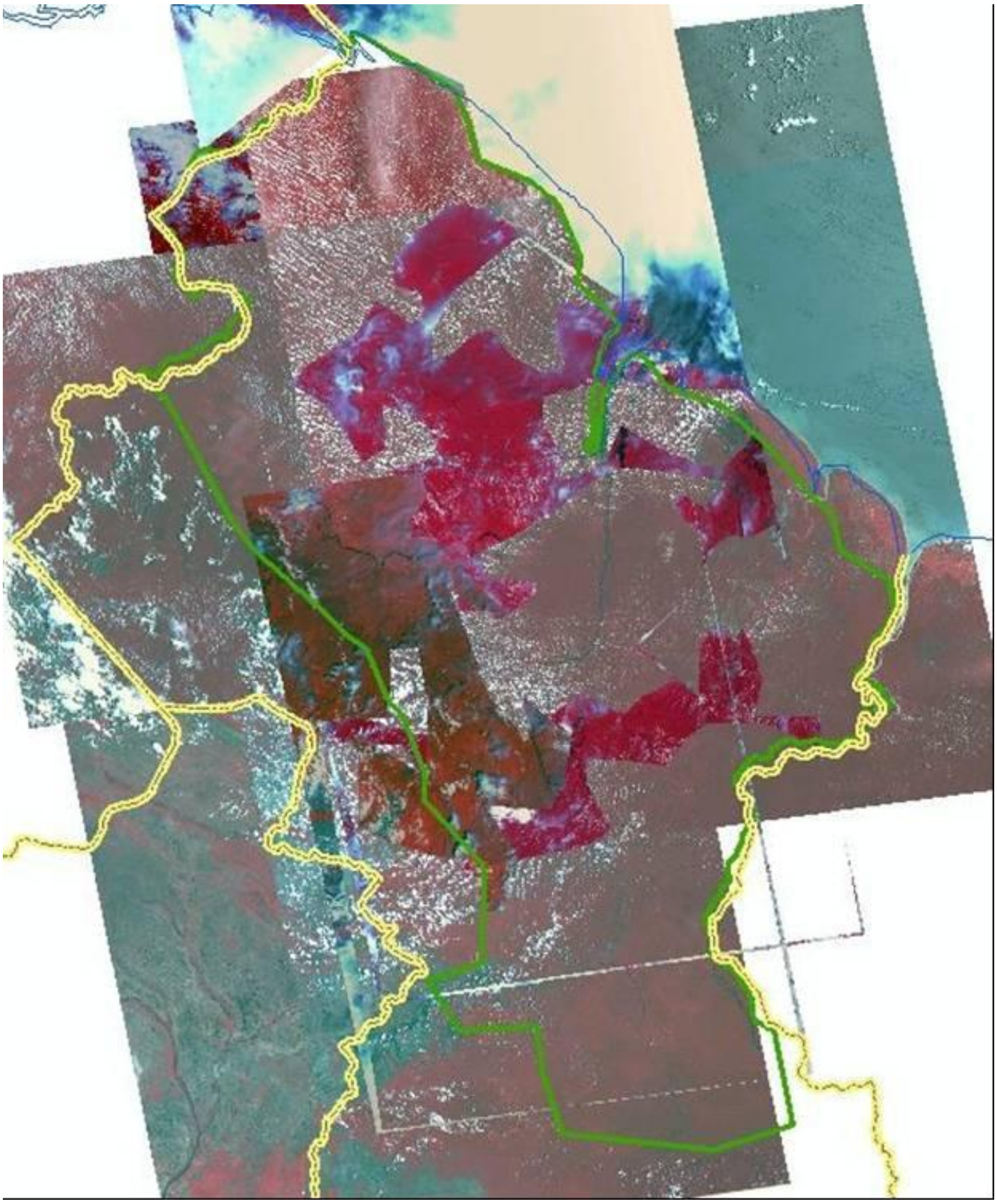
Map 4-3 shows the 2006-08 SPOT coverage (111 scenes). The coverage includes 10 and 20 m resolution images. The 10 m SPOT 5 scenes (25% of the dataset) if cloud-free are suitable for verification of change.

Map 4-3:
2006-2008 SPOT Coverage



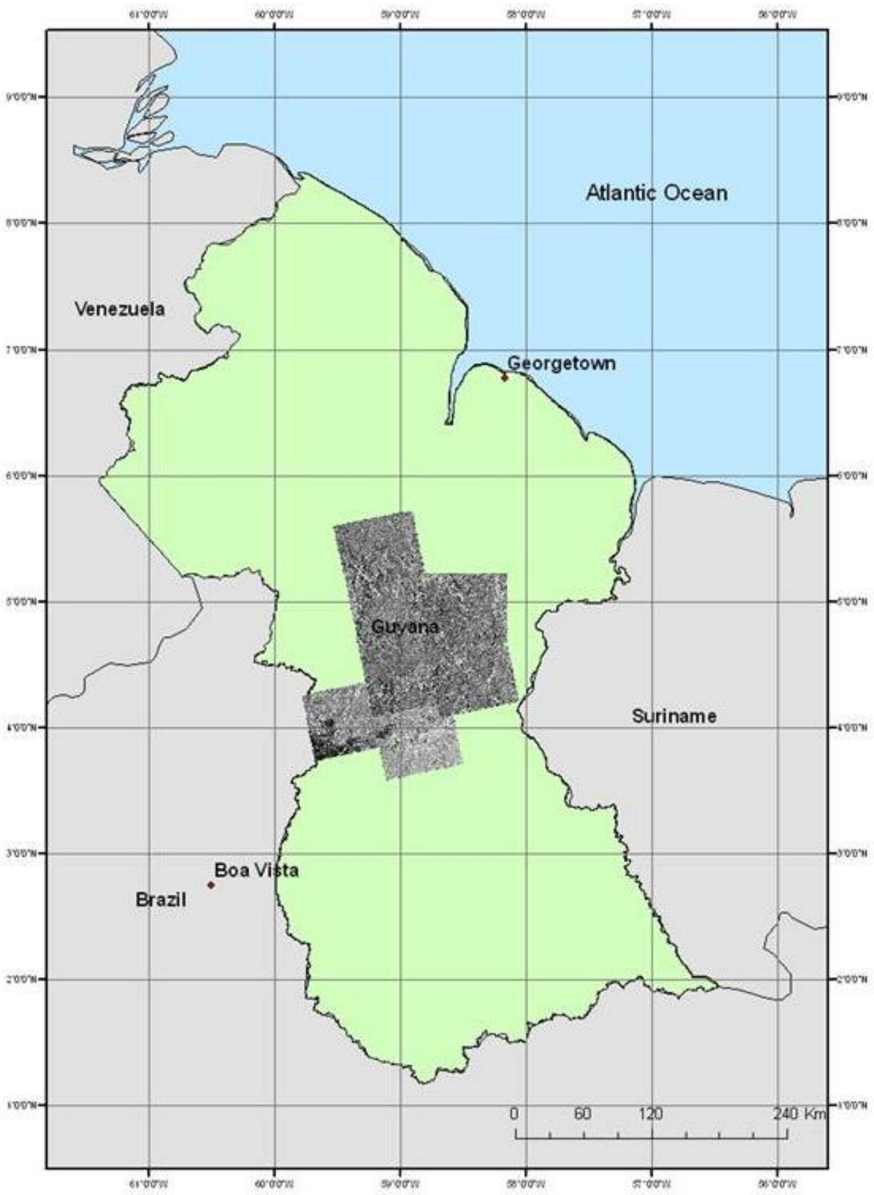
The extent of the area that is been delivered by DMC is shown on Map 4-4. The tasking program runs from September 2010 to January 2011. During September 18 acquisition attempts have been made. Due to the high cloud cover no processing other than geo correction has been applied. Manual interpretation methods will be used to identify change for the year 1 period.

Map 4-4:
DMC Coverage As at October 5 2010



Through the GEO FCT program selected radar scenes have provided (see Section 4.3). These provide multi temporal coverage over central Guyana. These scenes offer the potential of verifying the changes detected using the Landsat imagery. At the time of writing this work was still ongoing.

Map 4-5:
Available Palsar Radar Scenes



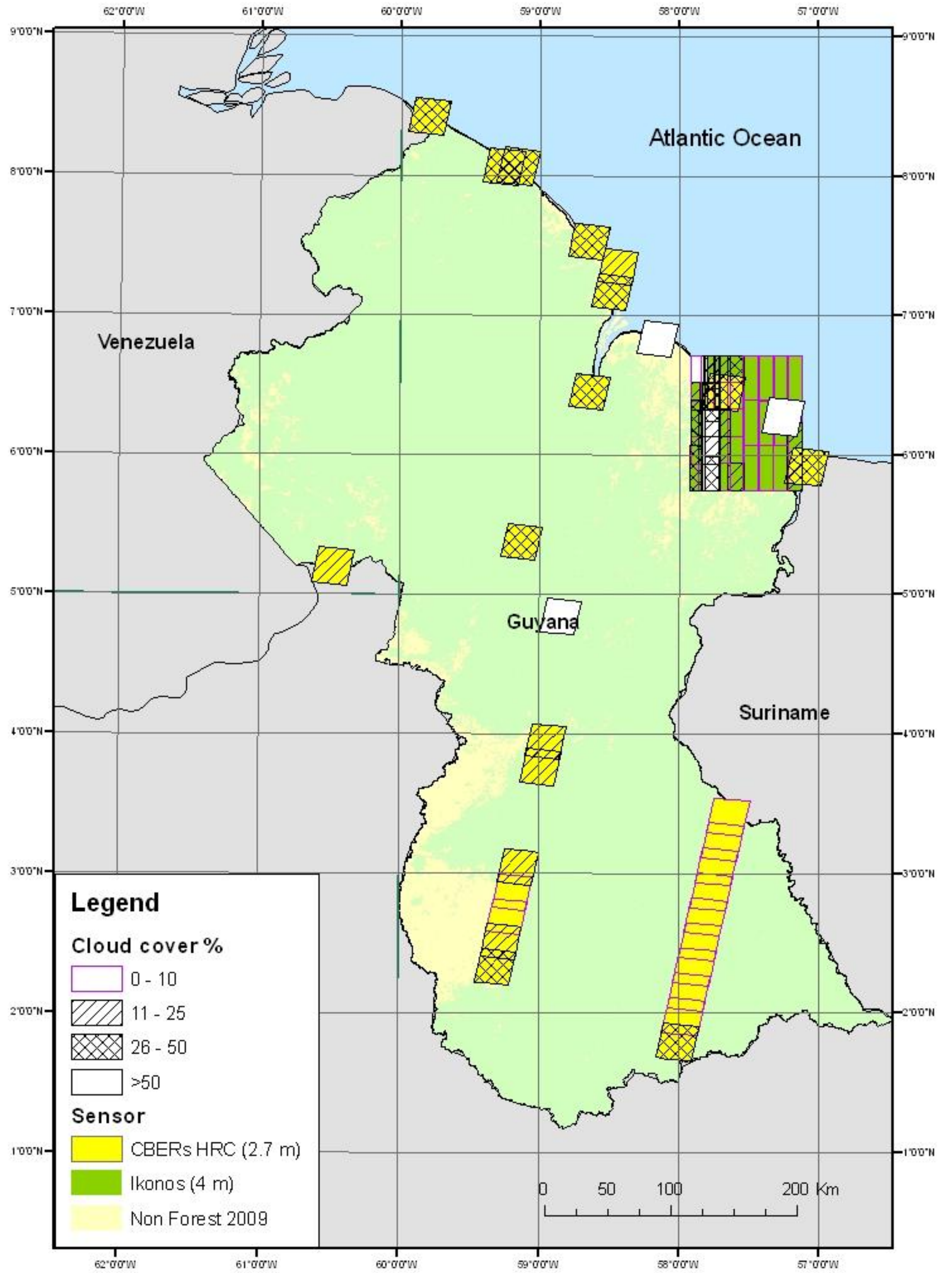
High Resolution Images

The current coverage of high resolution image by cloud cover score is shown in Map 4-6.

It is envisaged that a selection of these images along with RapidEye acquisition (planned October 2010 to January 2011) will be used for providing verification of land cover classification from medium resolution images and for conducting accuracy assessments of both land cover and land cover change.

A selection of these scenes has already been used for an internal verification exercise as part of the quality assurance process (see Section 6).

Map 4-6:
High Resolution Image Coverage



4.6 Agency Datasets

The following datasets have been provided by the various agencies involved in the management of land and resources. Some of these datasets have been used to identify boundaries of titled land or management and also assist in guiding change detection analysis.

Many of these datasets are routinely updated and it is important that the GFC's central GIS be continually updated and accompanying naming conventions be developed to ensure the most up-to-date datasets are made available.

4.7 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 Draft National Forest Plan that has been developed to address the forest policy.

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 4-3.

Table 4-3:
GFC GIS Datasets

Data Group	Layer Name	Created/ Update freq	Description
Admin	guyana_boundary	August 2010	Updated country boundary for Guyana.
Hydro	waterbody	August 2010	Waterbodies layer, digitised from geocorrected Landsat imagery.
Soil & Vegetation	soil_data	1960s	National Soil map of Guyana. Produced by NARI.
	simpleveg	2001	National vegetation map of Guyana. Produced by Dr ter Steege.
	regionalveg	1960s	Regional vegetation map for Guyana. (partial coverage only)
Forest Reserves	forest_ResAlloc_2010	6 monthly	ArcView3.3 Project containing a number of shapefiles detailing all forestry allocated areas – roads, reserves and Amerindian areas.
	GFC_Reserves_dd	NA	A merged layer of GFC's forest reserves.
	bio-reserves_dd	NA	A merged layer of national bio-reserve/protected areas.
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 – 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)
Roads	gps roads_dd	3-6 months	All GPS roads and trails as at August 2010.
Gazetteer	placenames	N/A	Place names incl. villages, topographic and rivers features
Amerindian Areas	Ameridian_ areas_GL&SC	Upon titling process being finalised.	Titled Amerindian areas in Guyana. Divided into administrative regions. From GL&SC.
Agricultural Leases	GFCAGleases	Upon titling	Agricultural leases that fall within the State Forest Estate (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 permit/licence/claim	Large and Medium scale mining areas including dredge locations.

4.8 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, levies payable under the Mining Act, and hall marking.

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. The extent of several concessions has also been captured using GPS.

GGMC also holds a spatial layer that defines the location of large and medium scale mining concessions.

4.9 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.

4.10 Additional Data Sources

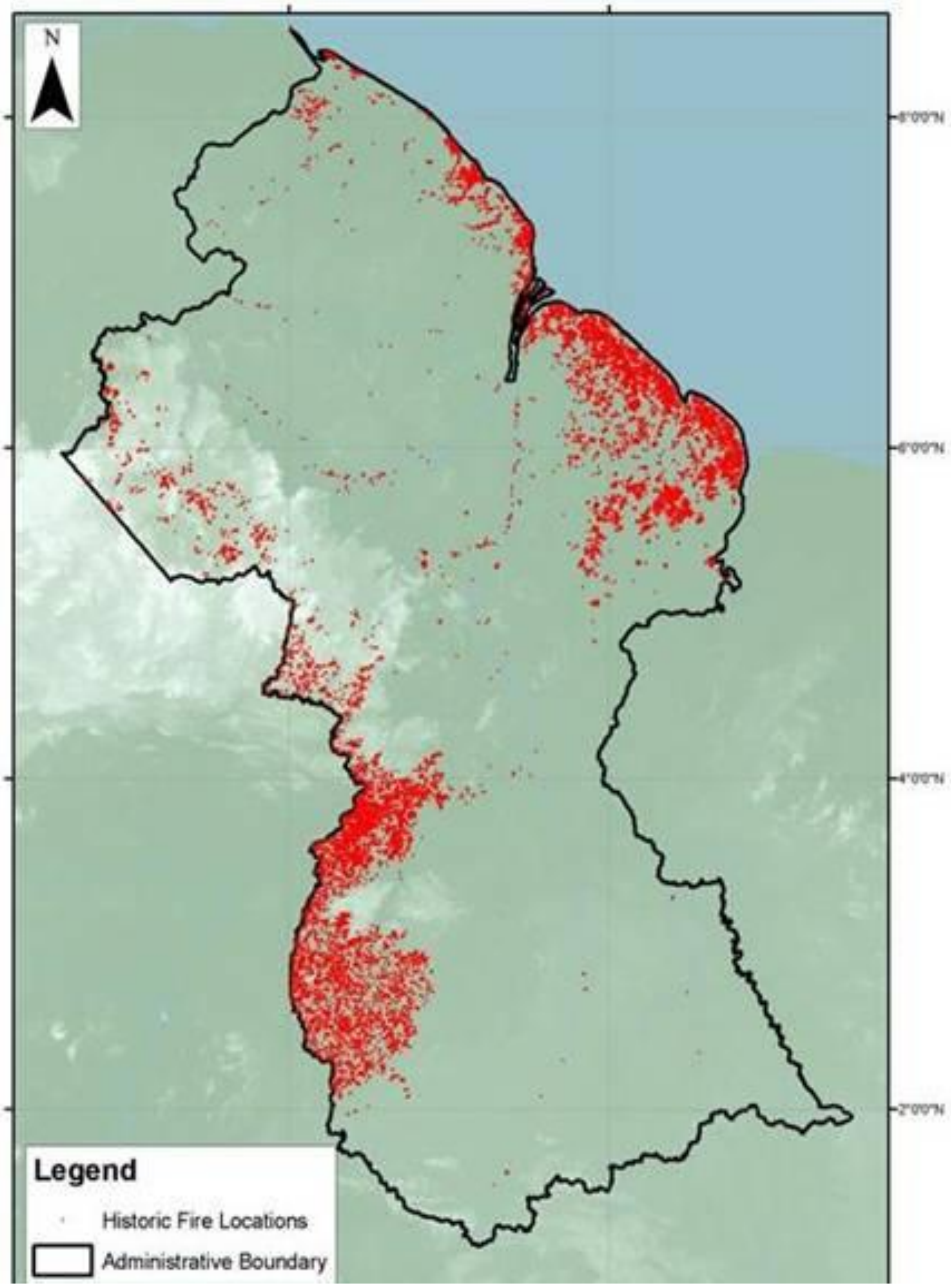
The Fire Information for Resource Management System (FIRMS) data provides information about historic and present day fire locations using the Moderate Resolution Imaging Spectroradiometer (MODIS).

Each fire is ranked by confidence. According to the FIRMs website the following explanation on the accuracy of the dataset is provided.

"In any given scene the minimum detectable fire size is a function of many different variables (scan angle, biome, sun position, land surface temperature, cloud cover, amount of smoke and wind direction), so the precise value will vary slightly with these conditions. 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".

This dataset has been used to identify land which is at threat from fire and also identify areas recently burnt. Map 4-7 shows the identified fire locations from 2000-2010. There is a strong correspondence between fire locations and the southern savannah regions and the main agricultural zone along the coast.

Map 4-7:
Fire Locations 2000 to August 2010

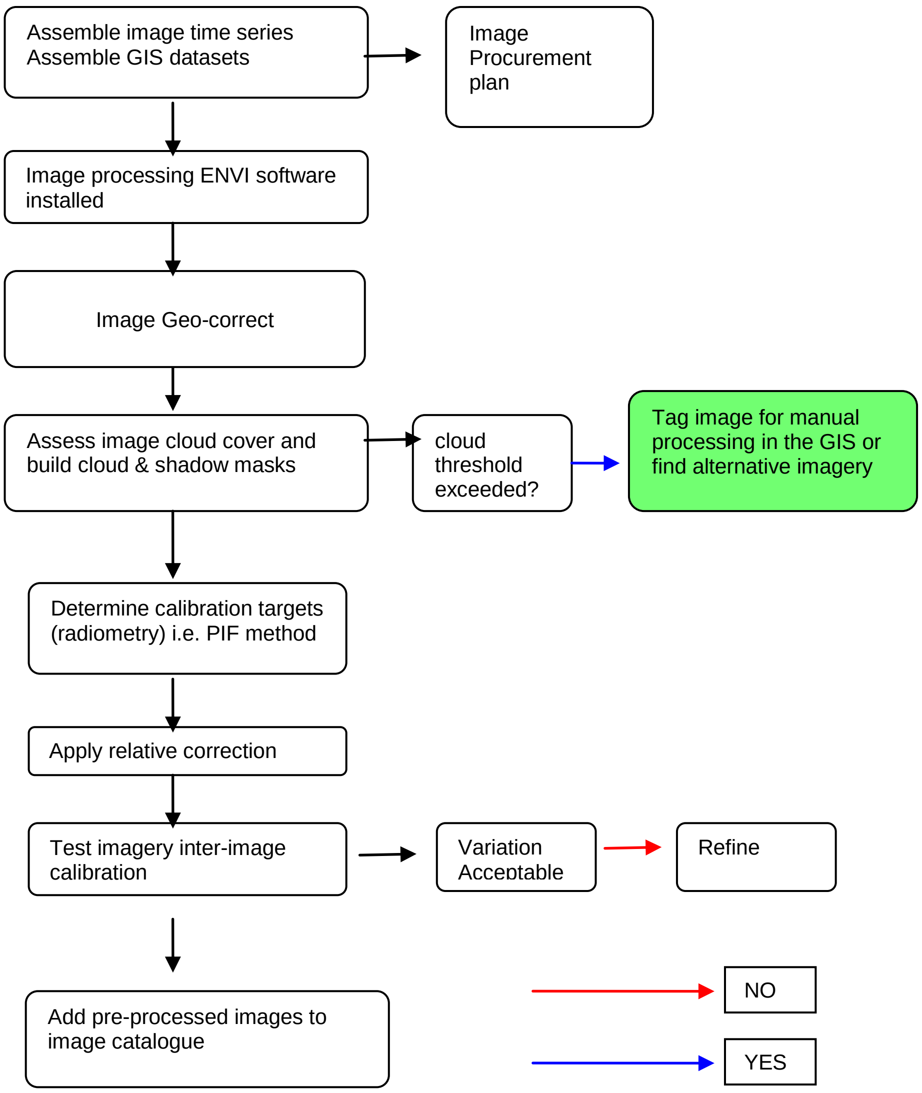


5 IMAGE PROCESSING

The image processing focussed principally on processing the Landsat and MODIS satellite images. Several additional image datasets were made available to GFC, but these were only used for reference purposes in order to verify or attribute the drivers of forest change. The degree of image processing conducted depended on the cloud cover of each scene.

As part of the continuous improvement process, orthorectification of data use to the extent required for robust analysis, improvement in file/folder naming conventions, and enhancement of quality control with regards to maintaining knowledge of ground control points collected, have been identified as priority. Furthermore, the GFC has commenced work in the development of SOP, specifying how the different remote sensing and GIS operations have to be performed, and stating clearly the QA/QC measures and the archiving procedures. A Mapping and Satellite Image Interpretation Guide has been developed as one step in this process.

Figure 5-1:
Image Processing



Automated methods are generally preferable where possible because the interpretation is repeatable and efficient (Herold, 2009). However, Landsat scenes with excessive cloud cover were not processed using automated methods as it is time consuming to create and edit the cloud masks required to automate the forest change detection. These scenes were evaluated for change manually in the GIS[25]. This is an acceptable approach that is recognised in the GOFC GOLD sourcebook. The only processing undertaken on these scenes was to geo-correct them against the base 1990 dataset (see Section 0).

5.1 Image Geo-correction

All satellite images were geo-referenced to the 1990 base 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.

The accuracy of the base map was verified against available GPS tracks. In areas of limited ground control, the images with a greater number of control points were referenced first. All subsequent images were matched to these scenes using the image overlap. Each rectified image was checked by observing the mismatch in overlaps with other rectified images, ensuring mismatches were less than one pixel[26].

5.2 Cloud Masking

The objective of generating the cloud mask is to identify all cloud and shadow pixels within an image. If not removed then any cloud will be identified as change in any subsequent automated change detection process[27] and will also influence the effectiveness of image normalisation process.

Figure 5-2 provides an overview of the process used to generate the cloud and cloud shadow mask. The method adopted is the same as that by Martinuzzi, Gould, Ramos González (2007) in a technical paper published by the United States Department of Agriculture (USDA).

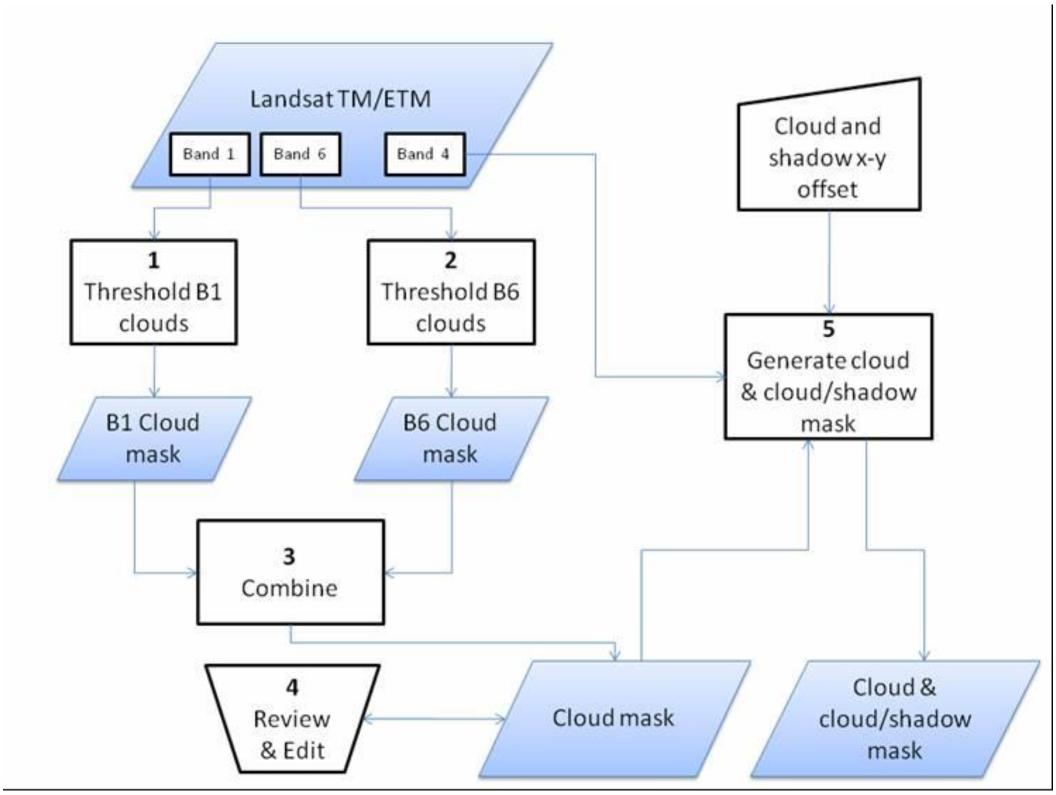
The cloud mask is created by first creating two intermediate cloud masks based on threshold values for Landsat band 1 (blue) and band 6 (thermal). The two masks are then combined to create a single mask of the common cloud pixels. Including the mask from the thermal band can assist in separating clouds from features that have similar spectral response in the blue band (i.e. bareground or settlements).

[25] A customised toolbar was created to assist with this process.

[26] The target root mean square error (RMSE) of the geo-correction was one pixel. This aligns with Good Practice Guidelines in GOFC GOLD Sourcebook.

[27] The automated change areas were visited in the GIS and the type of change identified any cloud-related changes not picked up during screening were deleted at this point

Figure 5-2:
Process Flow for Cloud and Cloud Shadow Masking



Based on the type of cloud and scene content, band 6 may prove ineffective at separating clouds and other landscape features. If this was the case then only band 1 was used. To reduce misclassification the band 1 results were reviewed and edited to ensure bright areas of non-cloud are not being masked.

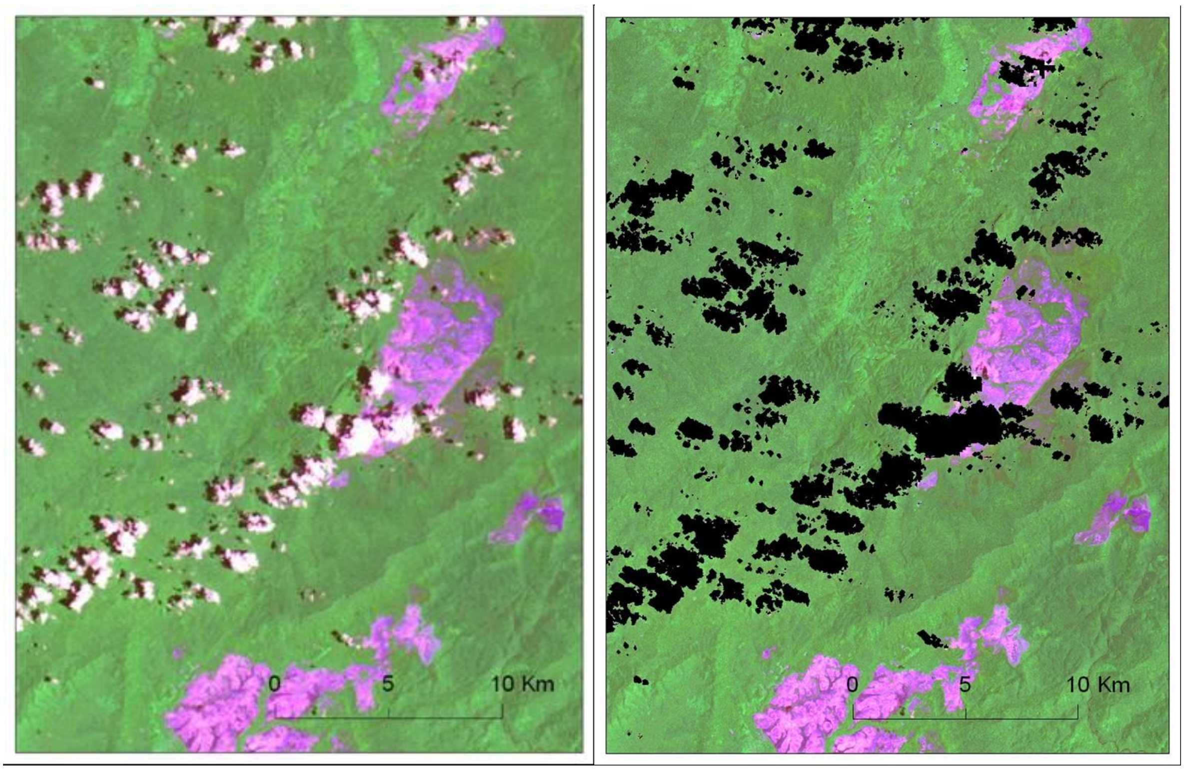
If appropriate, each mask was buffered depending on how effective the density slice was at separating cloud. This step was skipped for either band 1 or band 6 or both, if the thresholding alone was able to capture all the cloud but, at a minimum, at least a 2 pixel buffer for the band 1 mask is needed.

The cloud mask was systematically reviewed against a true colour composite (RGB) of the scene for which the cloud mask was generated. During this process areas of potential change or settlements were targeted and edited as necessary to ensure the thermal band (band 6) was successful in separating them.

The shadow mask was derived by combining the common pixels from a threshold drawn from band 4 (near infrared) and a copy of the cloud mask that is offset an x-y distance (in metres) The x-y offset is determined from an average distance between cloud and shadow observed within the image.

The result of the cloud masking process is shown in Figure 5-3. The left image shows the Landsat image with cloud identified as white and shadow offset in black. After the cloud masking is applied the combined cloud and shadow extent is delineated.

Figure 5-3:
Satellite Image & Resulting Cloud Mask



5.3 Radiometric Normalisation

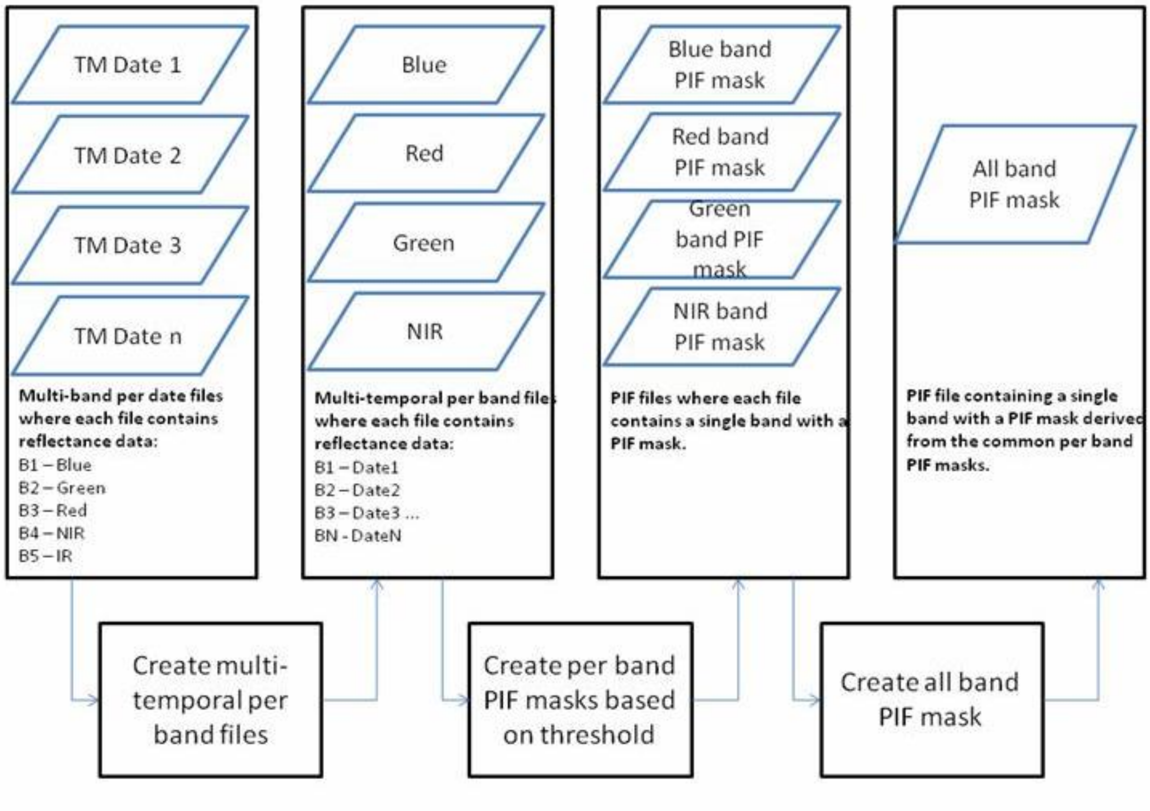
Several normalisations methods exist and for this work a relative calibration was considered the most appropriate method. The method selected was published first by Du, Teillet, and Cihlar (2002) and improved by Paolini, Grings, Sobrinos, Munoz, and Karszenbaum (2006) and uses Pseudo-Invariant Features (PIFs). The objective of the process is to normalise a series of multi-temporal images to a selected base image. This allows valid change detection between coincident images that have been acquired at different times by effectively normalising for differences in solar illumination and atmospheric effects such as haze.

PIFS are pixels that do not change from image to image within a multi-temporal time series. The differences in the reflectance values of PIFS can be assumed to be impacted by linear effects so those pixels can be used to develop a linear regression. The application of this regression to all pixels within an image effectively normalizes the image to a reference image. The advantage of the methodology is that it allows the selection of PIFS statistically rather than through a subjective process as is the case with some other relative normalization methods and it provides a means to quality control the normalized output.

An overview of the process is shown in Figure 5-4. PIFS are first identified for each spectral band through application of Principal Component Analysis. These single band PIFS are then combined to provided a set of PIFS common to all bands for all periods in the time series. The combined PIFS are then used to derive correction coefficients between time series images and a selected reference image. Application of these derived coefficients to each image results in a set of images normalized to the reference image.

All multi-temporal Landsat files for a specific path/row were normalized to a user selected reference file with the temporal group after first converting DN values to at sensor reflectance values using published conversion algorithms.

Figure 5-4:
Image Normalisation Process



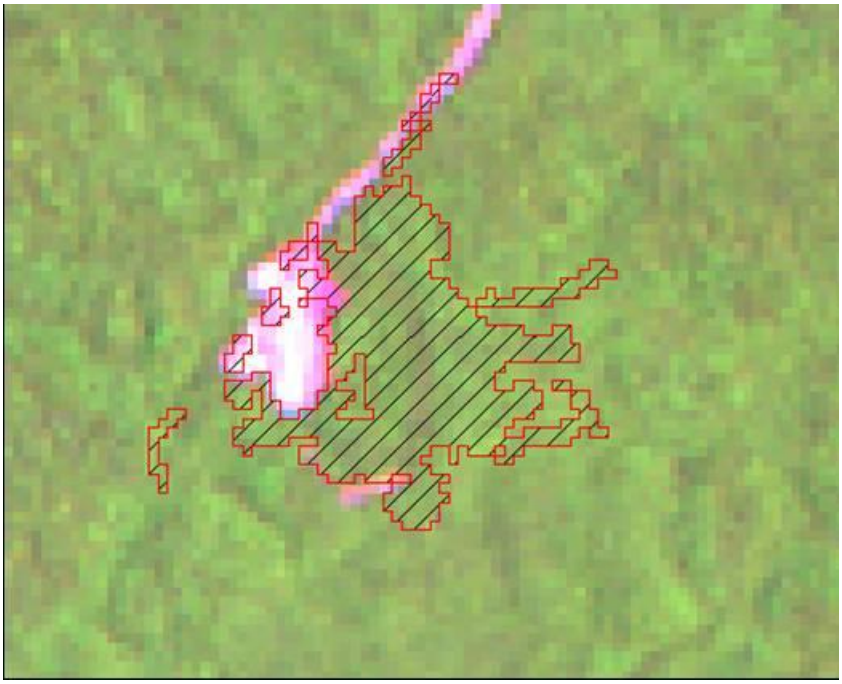
5.4 Automated Change Detection

The automated change detection process produces a vector layer delineating the forest gain and loss for each of the time periods. The vector layer is subsequently input into the GIS for review, editing and attribution. It should be noted that a perquisite for successful detection of change is cloud-free imagery. The high cloud cover in single date and multi-temporal scenes prevented the extensive use of automated techniques. Overall manual interpretation was conducted on more than 90% of the images analysed

Automated change detection was performed in ENVI using the normalized image time series as input. An EVI was calculated for each image and the cloud mask was applied to the EVI results to excluded cloudy areas from the analysis. Before and after masked EVI images were subtracted to generate a classified image of differences. This image was filtered as needed to reduce noise and then converted to a vector layer compatible for input into the GIS. The use of the EVI is noted to have limitations, in particular, the susceptibility to seasonal and inter-annual variability of climate (Brando, *et al*, 2010). As such the use of the EVI in this project is treated as only one aspect in the decision-making process and not used in isolation hence the level.

The following examples show the output from the automated change for a permanent mining area. The change detected covers the period from 1989 to 1999.

Map 5-1:
Area Prior to Change in 1989



Map 5-2:
Mapped Change in 1999

5.5 Processing MODIS

Given the persistent cloud cover issue daily acquired MODIS 250 m[28] imagery was also processed to provide cloud-free coverage at the end of the benchmark and year 1 periods.

[28] A single MODIS 250 m pixel is approximately equivalent to 6.25 ha

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 Brazil for near real time detection of monitoring of hotspot areas (DETER[29])

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 close to the end of September of 2009 to 2010 were ordered 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 (centred 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 processed to create a cloud-free mosaic for the month of September of 2009 and 2010. There are two prerequisites to avoid misclassification of change; all cloud must be screened out and the images used must be accurately co-registered

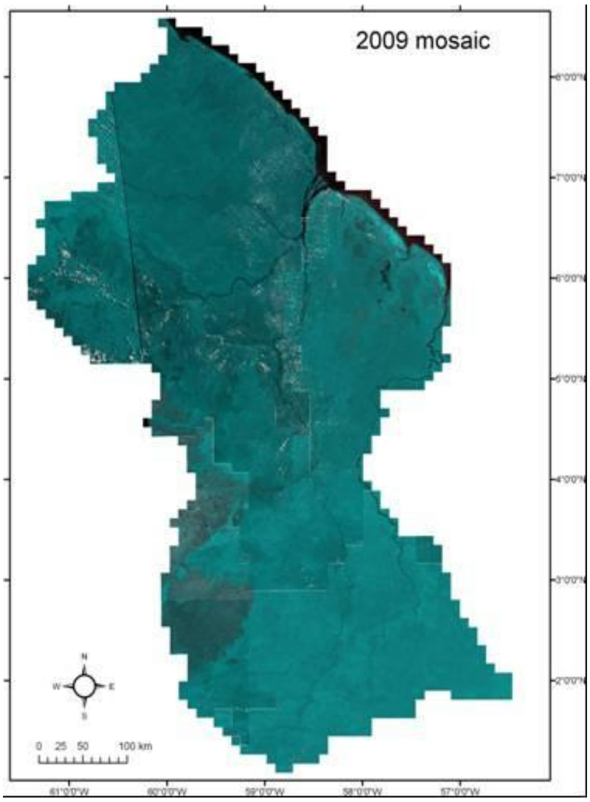
An image screening routine was developed that divided the images into 10 x 10 km tiles and evaluated individual tiles in the scene. Tiles were excluded from further analysis based on their cloud content. A second screening process selected those tiles closest to the end of the period. The result of this process is a national cloud-free mosaic for the years 2009 and 2010 (Map 5-3, Map 5-4).

The processed mosaics were used to identify change areas under persistent cloud in both the benchmark and year 1 periods (see section 7.1). It should be realised that this approach is only valid for larger change areas (>20 ha).

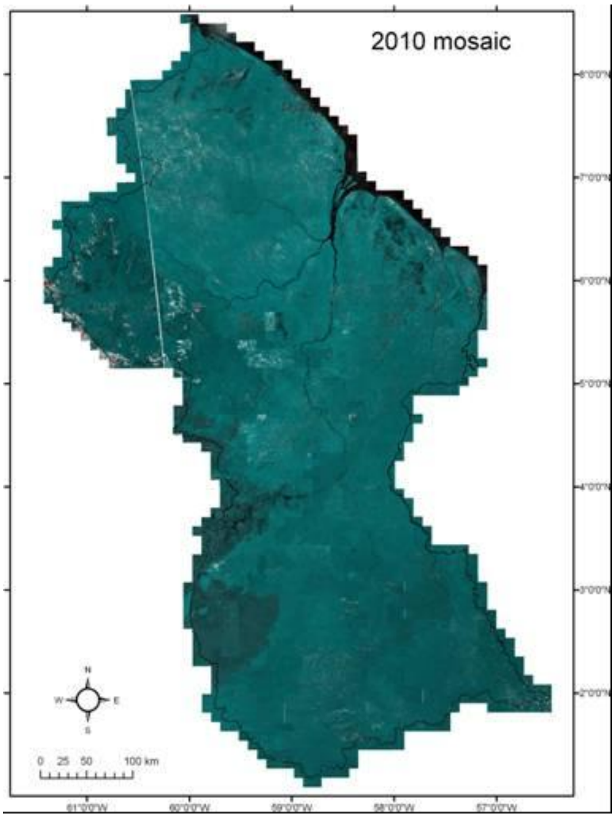
In addition recently delivered radar (nominal resolution of 50 m) images were also evaluated for the benchmark period. Radar images offer another source of verification that has not been extensively used in this analysis due to limited availability. Future work should seek to integrate radar datasets to improve the efficiency of ongoing detection forest change monitoring.

[29] http://www.obt.inpe.br/deter

Map 5-3:
MODIS Cloud-free Mosaic September 2009



Map 5-4:
MODIS Cloud-free Mosaic September 2010



6 DETERMINING THE FOREST & NON-FOREST AREA

The method adopted uses IPCC Approach 3 for estimating land use and for assessing land change at the national level. As a first step the forest area or mask was determined.

Approach

The method employed in this assessment in mapping forest and non forest areas, as well as mapping changes by drivers, employs the IPCC Approach 3. This method effectively provides the same information as Approach 2 but with additional information on the location of forest changes and allows for each polygon to be analyzed through time and changes attributed to each.

From a technical standpoint, Approach 3 is the only feasible approach for REDD+, as historic assessments and annual operational monitoring are required and change detection is required in a location and time specific manner, on a continuous basis.

Preliminary Land-Use Categorization

The assessment also outlined a preliminary land use classification scheme for Guyana and will be finalized in collaboration with the work of Winrock International, following carbon assessment and mapping. The Preliminary scheme that has been developed under this assessment draws on IPCC categorization and guidelines, the GFC existing vegetation classification and satellite imagery analyses. The classification scheme allows for sub categories to be defined, and stratification done in a consistent and reliable way.

Minimum Mapping Unit

The MMU used for Guyana is one hectare and this is linked to the minimum area size. It has been noted by several expert sources that Remote Sensing data analyses become more difficult and more expensive with smaller MMU, as this requires an increase in mapping efforts, which usually results in a decrease in mapping accuracy.

In keeping with Guyana's consideration of one hectare for measurement of land area under its new forest definition, the MMU should also be one hectare. This is appropriate as the optimal option, because it will allow for the consistency in application of the forest definition and the MMU.

Wall-to-wall versus sub-sampling remote sensing approaches

In keeping with international best practice, and particularly to address the issue of domestic leakage, 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.

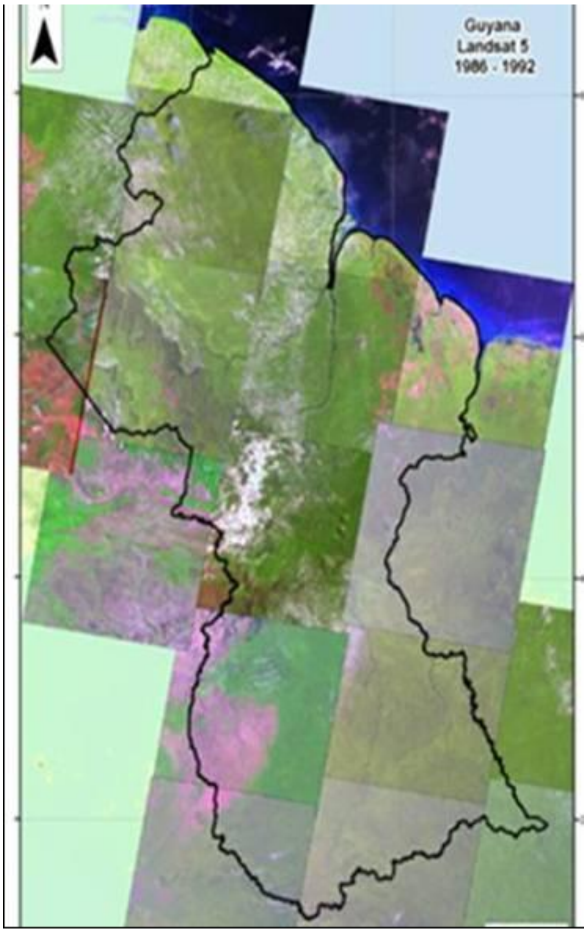
Presently reporting satisfies interim measures outlined in Section 2. This requires that changes in forest land to other land uses be reported relative to the benchmark map. Currently changes occurring between lands defined as non-forest are not reported. Changes from non forest to forest however, are being reported. The basic premise is eventually that 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.

6.1 1990 Forest and Non-forest Mapping

The forest and non-forest mapping used the cloud-free mosaic of Landsat images drawn from the 1990 era (1986-92). The process involved determining the crown cover threshold between the two classes.

Map 6-1:
1990 era Landsat Images



For ground surveys crown cover refers to the density (percentage) of the crowns of woody plants above a certain height. While it is not possible to determine tree height from optical satellite imagery the colour and texture of vegetation are used as indicators in estimating crown cover percent.

The method adopted used a combination of automated (calculation of vegetation indices) and manual interpretation and editing. The objective of the approach was to identify all natural and manmade non-forest areas as at 1990. Once completed this provides the forest mask from which changes post 1990 are identified, attributed to drivers and tracked. Landsat scenes were calibrated to top of atmosphere radiance using published satellite sensor bias and gain settings as described by Chander, Markham and Helder (2009). The purpose of this calibration is that it allows comparison between images acquired at different time periods.

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

Previous work in Guyana (Watt & von Veh, 2010) used the normalised vegetation index (NDVI) as defined in Equation 6-1 and as described by Rouse *et al*. (1973). This vegetation index ratios the red and near infrared bands and when applied provides a scale from -1 to 1 with positive values associated with vegetation cover (usually 0.4 and above).

Equation 6-1:
Normalised Vegetation Index

$$\mathrm{NDVI} = \left(\frac{\mathrm{NIR} - \mathrm{Red}}{\mathrm{NIR} + \mathrm{Red}}\right)$$

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 inclusion of this band corrects 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 defined by the following equation:

Equation 6-2:
Enhanced Vegetation Index

$$\mathrm{EVI} = 2.5\left(\frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{RED}}}{\rho_{\mathrm{NIR}} + 6\rho_{\mathrm{RED}} - 7.5\rho_{\mathrm{BLUE}} + 1}\right)$$

The EVI values range from -1 to 1 with values closer to 1 representing closed canopy forest. Field measurements were conducted to verify the EVI values. This involved estimation of forest canopy cover using a spherical densiometer [30]across 15 transects covering two Landsat scenes. Additional field measurements from biomass plot network were also used to evaluate the classification. For these sample points the mean EVI value over 3x3 pixel matrix (90 x 90 m) were extracted. This represents the minimum mapping unit of the analysis.

From these measurements a relationship was developed that provided an indicative range of values. These were then used to guide the non-forest delineation. The analysis showed some variation between sites with the EVI forest threshold value ranging between 0.5 and 0.6. These values are known to vary across scenes, so scenes were normalised to each other in an effort to improve consistency.

Figure 6-1 shows the densiometer field measurements for a single transect. The values shown relate to canopy openness scores (%) and range from 100% for bare ground to 9% for closed canopy. These points are overlaid on the Landsat imagery

[30] The Spherical densiometer estimates forest canopy cover percent using a spherical-shaped reflector mirror engraved with a cross-shaped grid of 24 quarter squares with delineates a plot overhead.

where pink tones represent bare ground. It is acknowledged that given the resolution of Landsat data the exact boundary between forest and non forest is quite difficult to delineate especially in diverse areas that show gradual transition from low scrub to forest. In terms of remote sensing techniques laser-derived vegetation height measurements from airborne Light Detection and Ranging (LiDAR) offers the ability to rapidly capture accurate height information over diverse range of sites.

Figure 6-1
Field Densiometer Measurements

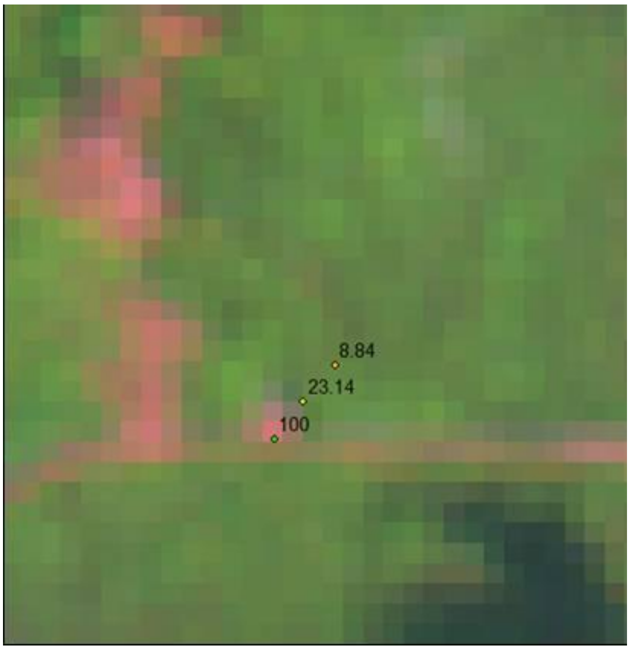
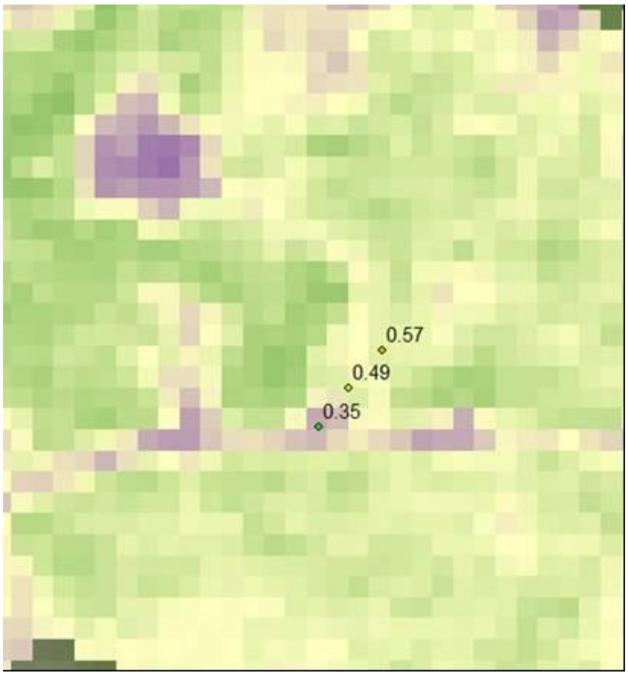


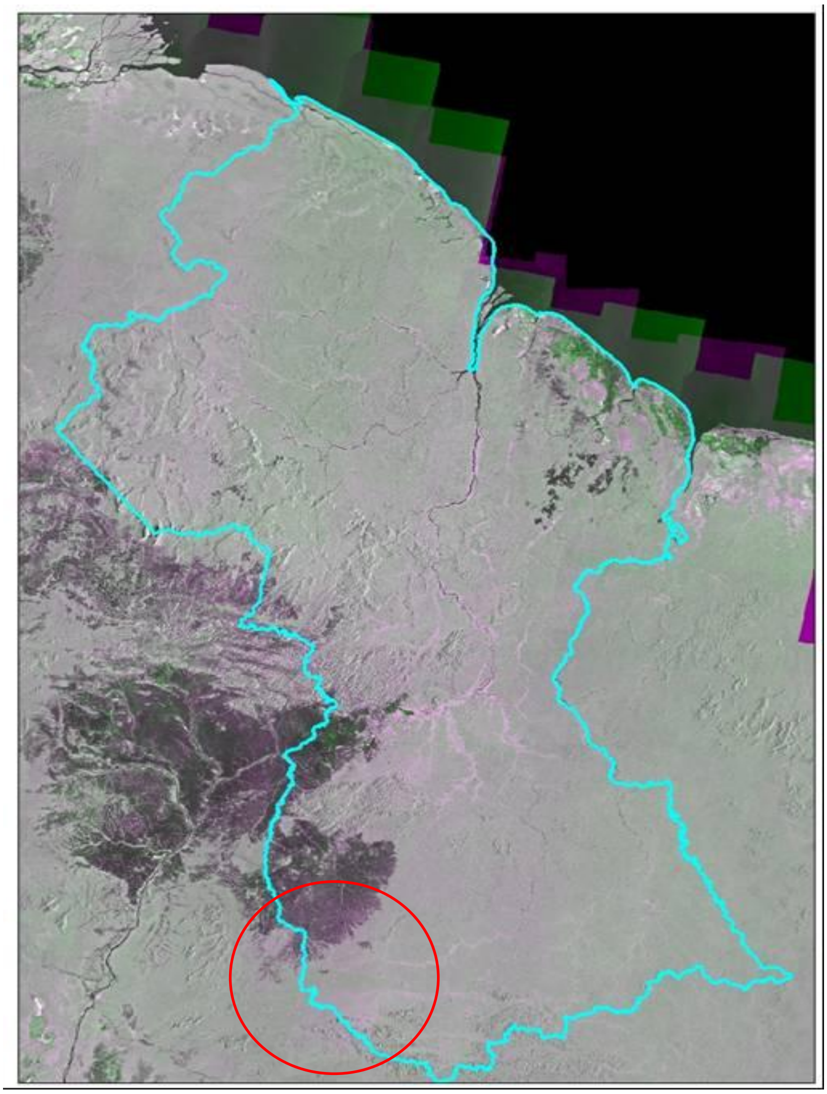
Figure 6-2:
EVI Image and Values



The EVI derived forest/non-forest map was used as a guide for the forest/non-forest mapping. The EVI derived forest/non-forest map was input into a GIS, where it was systematically, using a 10 x 10 km grid, evaluated by an operation using all available 1990 datasets. The forest/non-forest boundary was adjusted if the operator's interpretation of the available dataset differed from the EVI derived boundary. Care was taken to separate change events post 1990 from non forest areas.

Additional reference datasets included the SPOT 2 and 5 (10 to 20 m resolution datasets) and historical 1950 to 70s aerial photography. This classification was also compared against the JERS-1 radar images (100 m resolution) from 1995/96 Global Forest Mapping program (GRFM/GBFM[31]). These images cover the wet and dry season and have previously been used by FRIU to assist in the production of the 2001 SFA forest cover map. The contrast provided between the wet and dry season images also assisted with identifying seasonally inundated areas that are not readily apparent on dry season optical imagery. These areas tend to have a lower backscatter as do non-forest areas such as naturally occurring savannah. These areas appear black (highlighted) on the radar image.

Map 6-2:
1995-96 Seasonal Radar Image composite



[31] http://www.eorc.jaxa.jp/JERS-1/en/GFMP/index.html

7 DETERMING HISTORICAL FOREST CHANGE

The benchmark map forest map was created by accounting for historical forest change for three time nominal periods (as below) spanning from as close to beginning of the period 1990 to the end of period September 2009.

- 1990 to 2000
- 2001 to 2005
- 2006 to 2009

When evaluating the results, two aspects of the analysis should be considered; the time between periods is unequal, and the images used for each time period where compiled from images that span either side of the designated time period.

Due to high cloud cover the process adopted for change detection focused on manual interpretation of the satellite imagery. The manual method involved placing a GIS-generated grid that divided Guyana (including titled Amerindian areas) into series 10 x 10 km tiles that were then inspected sequentially for change. This is the same approach as used for the non-forest mapping. For cloud areas all images for the particular time period were evaluated. MODIS images were also analysed over areas of persistent cloud to check for large-scale change. The percentage of cloud persistent over Guyana for the benchmark and year 1 periods is estimated at 1.8% and 2.9%, respectively

Direct interpretation of multi date images is a recognised approach as it allows for consistent tracking of change areas through time (GOFC GOLD, 2009). The target reporting objective for the national monitoring system is tier/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).

For each temporal, the area converted to non-forest and the main drivers of the change were documented. 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, 2009). 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 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, included;

- Forestry (clearance activities such as log landings)
- Mining (ground excavation associated with small and large scale mining)
- Infrastructure such as roads (included are harvesting and mining 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 are identified as:

- Selective and illegal harvesting of timber
- Shifting cultivation
- Fire

For the benchmark reporting period and the interim phase of the MRVS certain changes such as shifting cultivation and changes associated with forests under SFM are not required to be reported spatially. Additional interim measures are in place to monitor harvest volumes from forests under SFM (see Section 9).

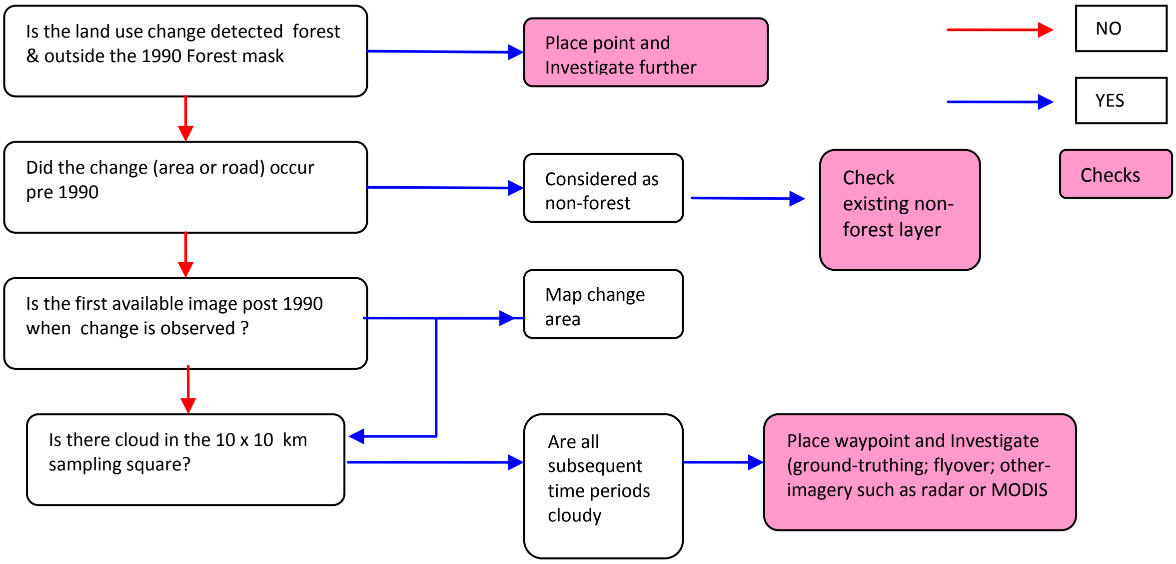
However, for completeness it is important that historical changes are monitored spatially to ensure that the drivers of change and transition of the change through time (i.e. regeneration or continued degradation) are recorded[32]. Degradation itself is identified in a number studies as contributing up to 50% of forest carbon loss. All naturally occurring disturbances, such as erosion and wind damage were also identified to ensure that these events are differentiating from anthropogenic changes.

To assist with interpretation of change events and drivers examples were provided to the interpreters along with a rule-based decision tree (see Appendix 5). To assist with classification an aerial over-flight over change areas that collected GPS-located oblique photographs was conducted in August 2010. These photos are tied to the GIS to assist with driver identification.

In addition to these a set of rules that covered issues related to the pre-analysis of the images were defined. Issues identified included the timing of imagery relative to the change, errors in the forest classification and persistent cloud cover obscuring areas.

32 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.

Figure 7-1:
Pre-analysis Decision Tree



A conservative approach has been taken in relation to mapping changes observed when no base image was available as at 1990 with these features mapped as change (this was the case for one scene).

7.1 Persistent Cloud Cover

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 first period it was observed in. If areas are under persistent cloud cover then it is not possible evaluate the area for change.

The impact of cloud was assessed by generating cloud and Landsat gap masks (caused by a sensor defect) for each Landsat and DMC[33] image to identify those areas of persistent cloud.

The masks were combined to provide an estimate of area under cloud and a GIS layer created that showed the spatial distribution of cloud.

Table 7-1:
National Cloud Cover by Period

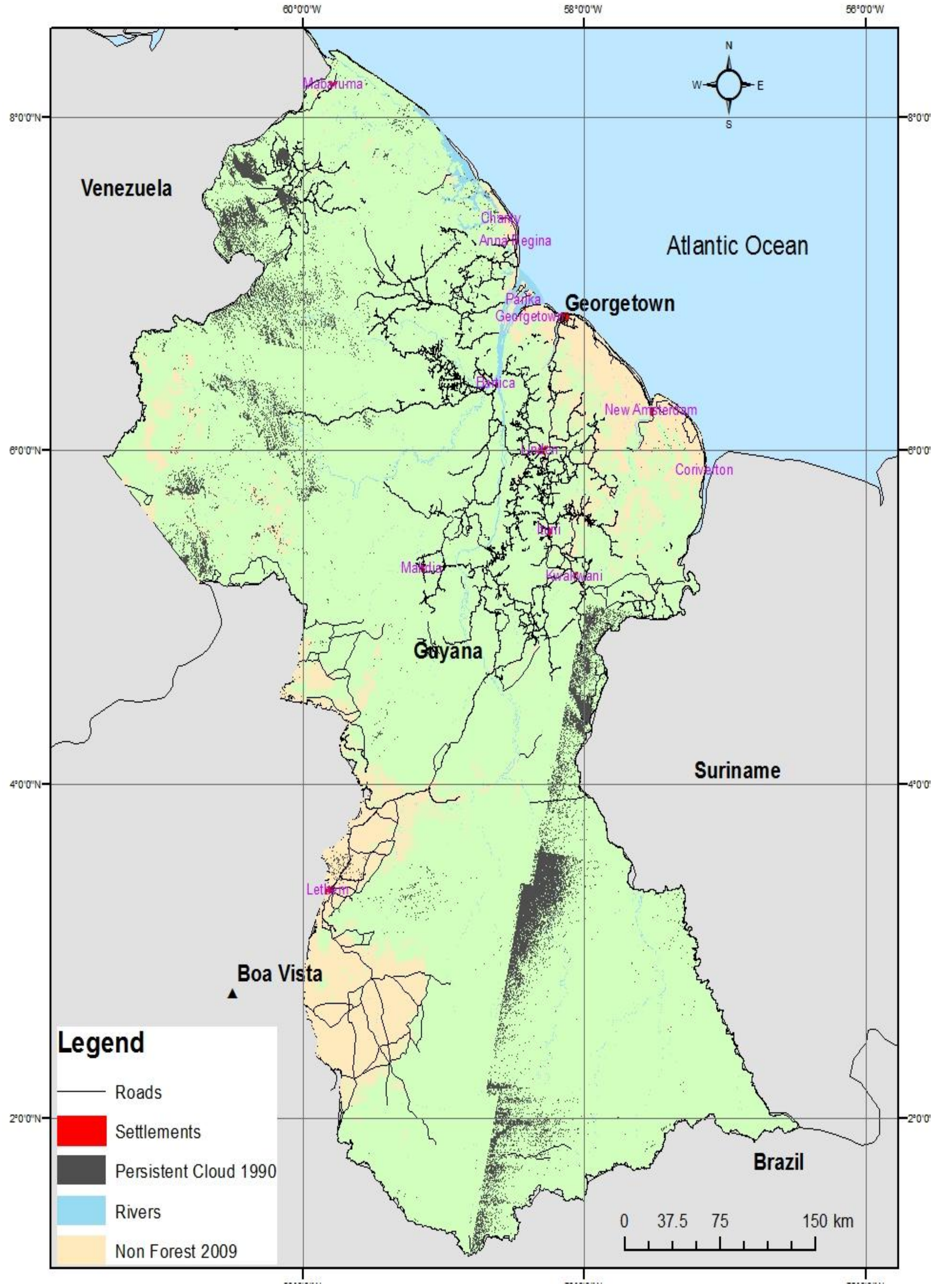
Period	Cloud cover (%)
1990	4.4
1990-2000	4.4
2000-2005	3.6
2006 - 2009 (Sept)	1.8
2009-2010 (Sept)	2.9

The analysis shows that the cloud cover post 1990 is reasonably consistent at around 3%. The spatial distribution of the cloud shows two patterns with cloud cover in the north where most of the change is occurring being quite scattered and over south Guyana concentrated in a remote areas or over non forest areas.

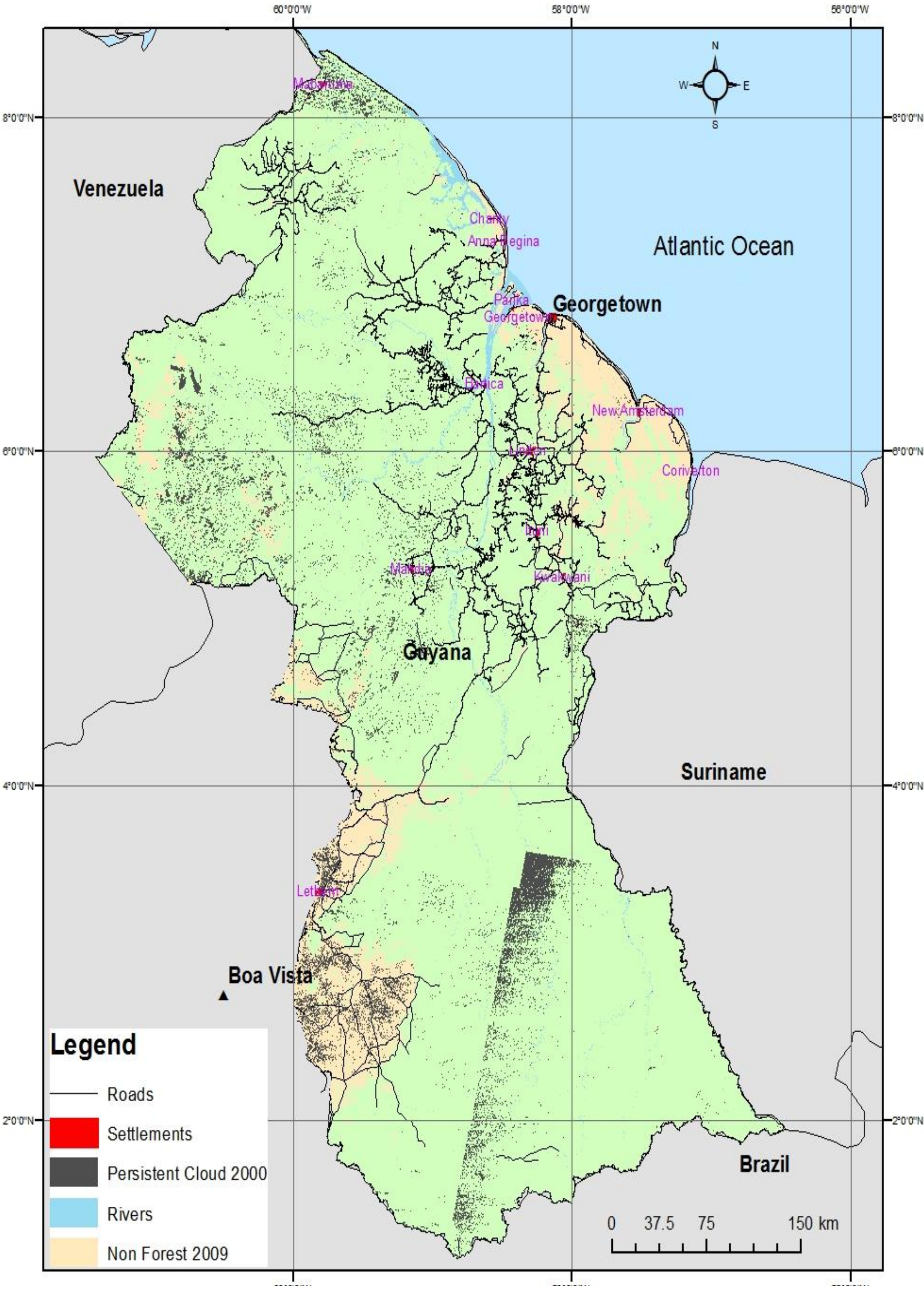
The distribution of the cloud for each period is shown on Map 7-1.to Map 7-4

[33] DMC images were tasked to cover the end of the Year 1 period.

Map 7-1:
Cloud cover 1990



Map 7-2:
Cloud Cover 1990-2000



Map 7-3:
Cloud Cover 2000 to 2005

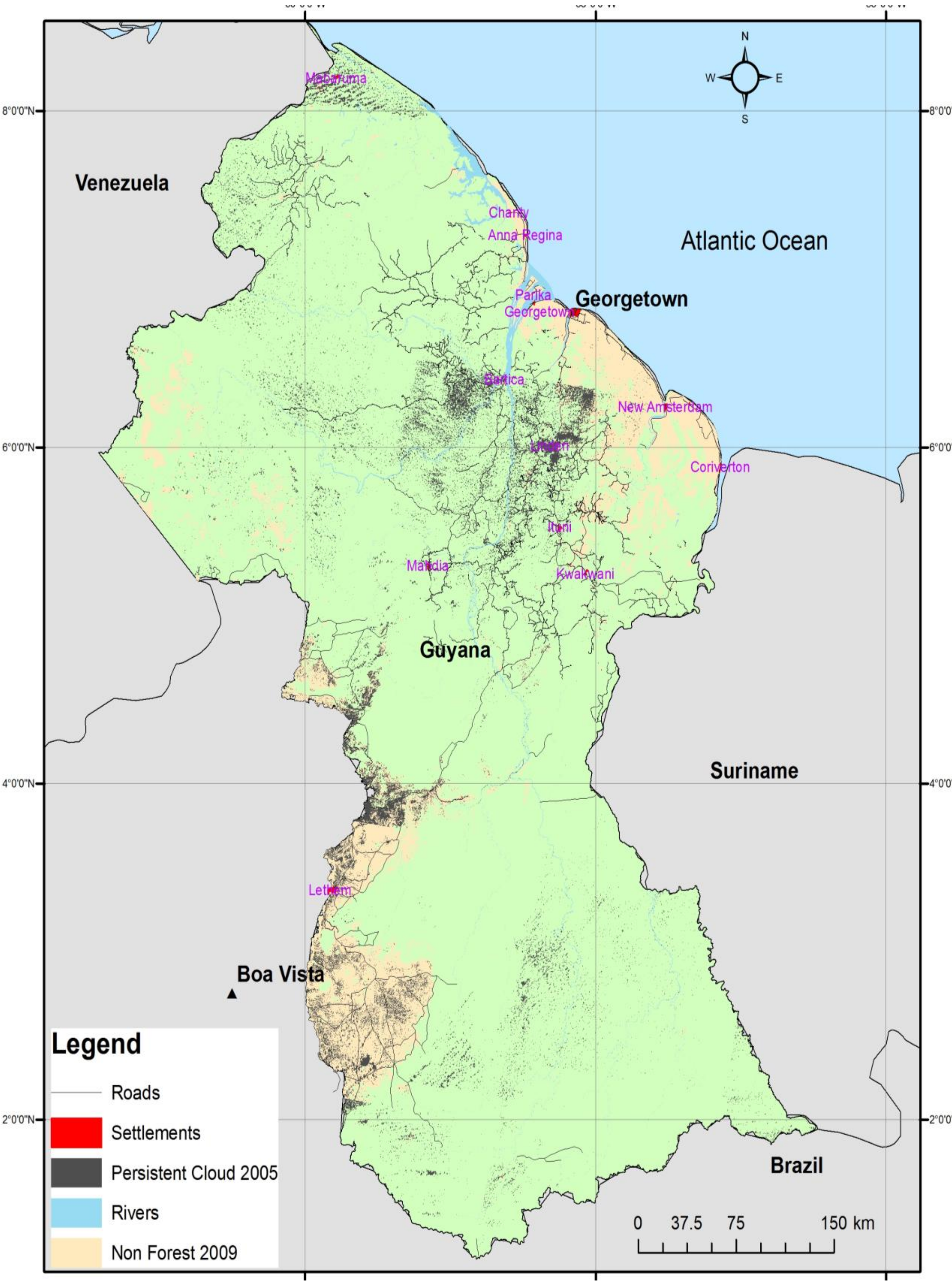
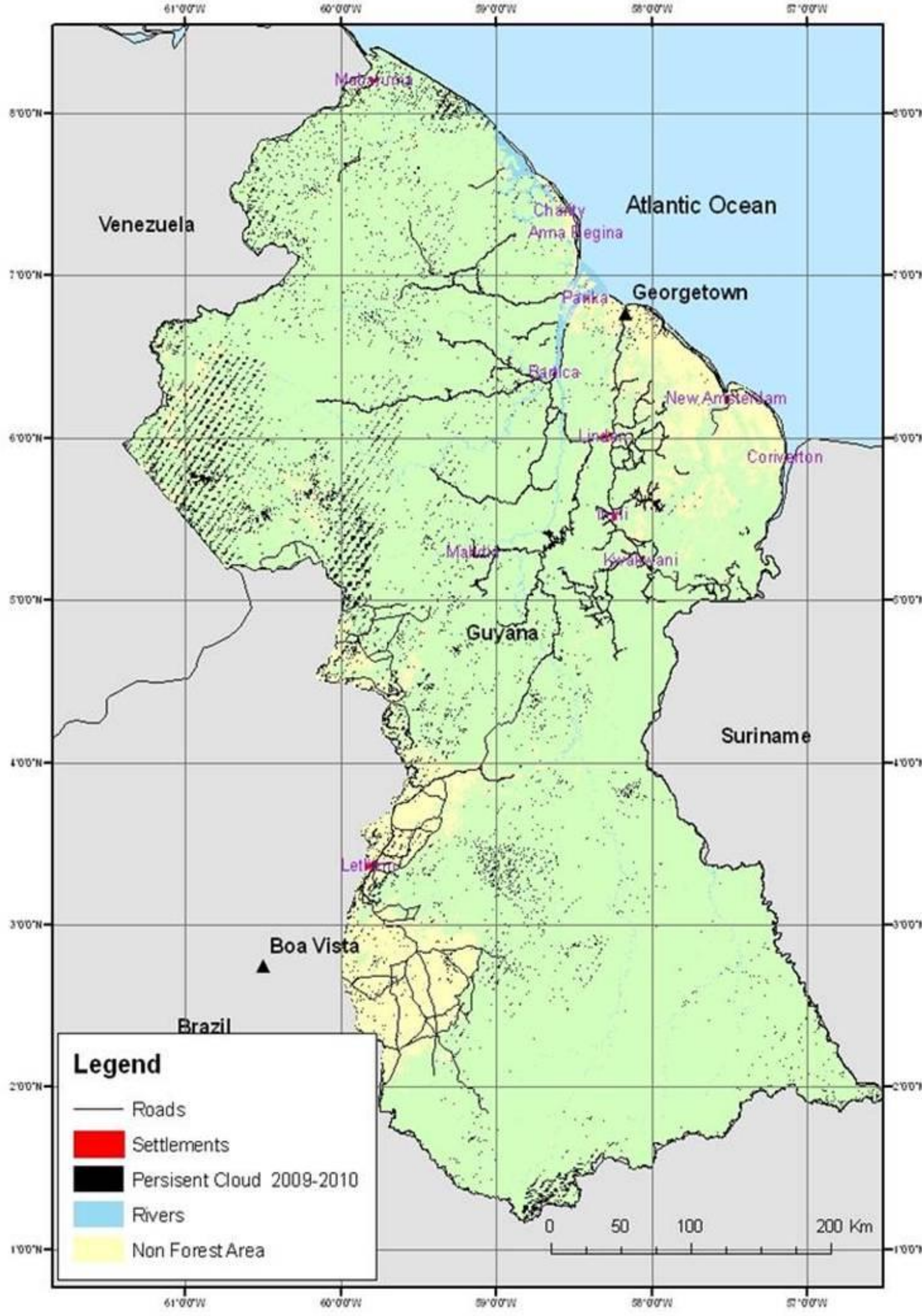


Figure 7-2:
Cloud Cover 2006 to 2009

Map 7-4:
Cloud Cover 2009 to 2010



For these areas three options are available; ground inspections in accessible areas, aerial over-flights or evaluation of alternative image datasets.

Due to time limitations interpretation of alternative imagery was considered the most efficient option. This involved evaluating MODIS and available Radar images for change. The resolution of MODIS restricts the minimum mapping unit (MMU) to about 20 ha (Morton *et al*, 2002) and is used to guide to assist in the detection of change areas.

The problem of cloud cover is addressed by viewing multiple images for each time period. An alternative image source is usually available for all cloudy areas. Where cloud cover is persistent across time periods and imagery, the area is assumed to be unchanged and can be revised in subsequent years if change is identified. In the absence of alternative image sources in areas obscured by persistent cloud for the forest/non-forest mapping, 1995/96 radar images were consulted if there was still doubt then the area was assigned to the surrounding land cover type and boundaries were interpolated. In the absence of alternative image sources for the forest change mapping, a pragmatic approach was taken. If an area was not observed then it could not be mapped. However, if these areas are identified in subsequent periods they were mapped and included in that period.

7.2 Identification of Land Cover Change & Drivers

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 is quite 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.

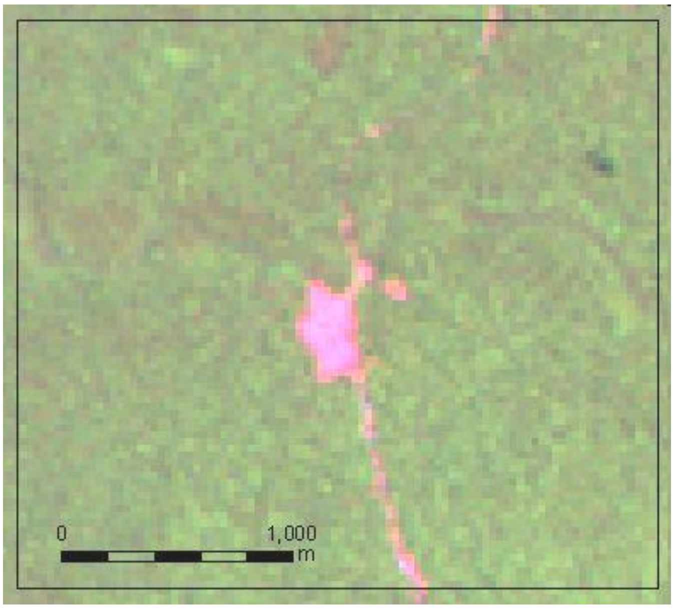
Supplementary GIS layers were also included in the decision making process to reduce this uncertainly. The following description and examples provide a summary of the main characteristics of each driver and were used in conjunction with a decision tree to classify detected change (See Appendix 5).

7.3 Forestry

Forestry activity within the State Forest Area is recognized most noticeably by the appearance of roading. As part of a 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.

On satellite images 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 and clearfell areas are identified from the typical red/pink spectral signature of soil (Figure 7-3).

Figure 7-3:
Example of a Forest Landing



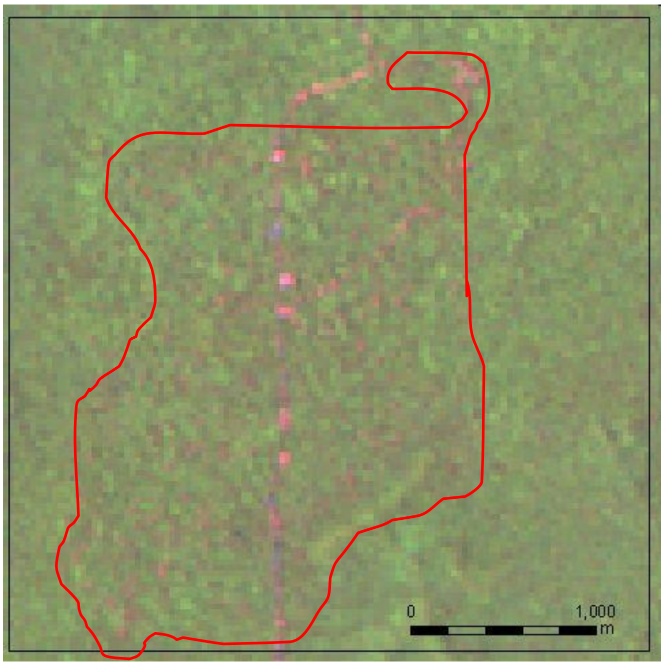
The extent of forest harvesting is difficult to estimate because it is mostly selective, although required annual operating plans often assist in identifying active areas. Small scale harvesting and degradation of forest is not readily apparent from the Landsat imagery because of the low intensity practiced in Guyana (8-10 m^3/ha) the spatial resolution and the time lags in temporal coverage. Removal of forest by selective harvesting is identified by the presence of small bare or grassy patches near roads (Figure 7-4).

The area of forest degradation associated with selective harvesting has a higher level of uncertainty as it relies of estimating the area by the level of degradation using the degree of canopy closure as a guide.

It is generally accepted that tropical forests degradation caused by low intensity harvesting is difficult to detect from medium resolution images without ancillary information (i.e. forest harvest plans or analysis of ancillary datasets such as road networks), or use of more complex method such as mixture models (i.e. Spectral Mixture Analysis (SMA). For remote sensing methods to be considered the datasets need to be well calibrated and substantially cloud-free to justify the effort. The approach taken was to map the degradation area by delineating the extent observed as shown on Figure 7-4. [34]

[34] Work on forest degradation mapping has commenced and it is hoped that in future annual reporting periods, a national account of this variable can be presented. It is envisaged that annual coverage of satellite images, coupled with continued mapping of planned and actually forest harvest areas as reported in forest annual and management planning, will assist in the monitoring of forest harvesting activities within the SFA.

Figure 7-4:
Example of Forest Degradation Adjacent to a Road



7.4 Mining

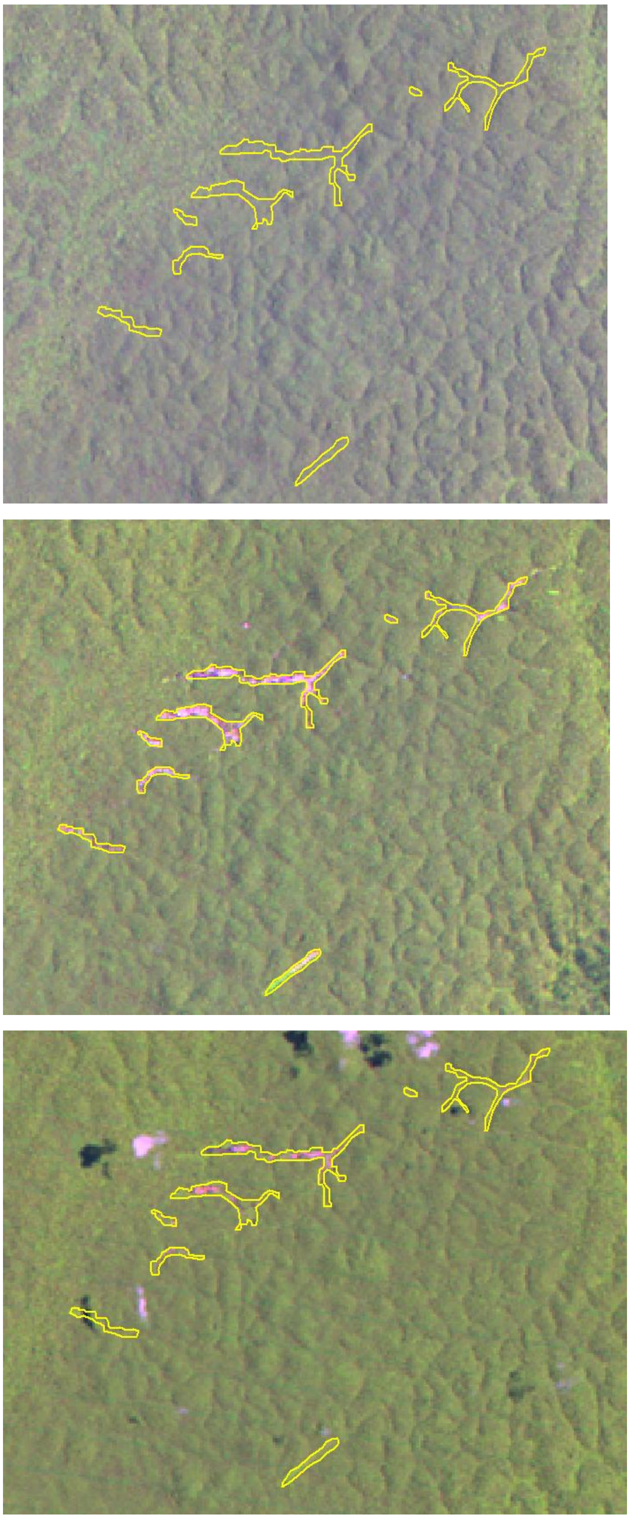
Mining activity produces forest clearings with very variable shapes and sizes and with sharp boundaries The clearings often occur in clusters along streams or near water bodies and in remote areas with limited road infrastructure. Since 2009 GGMC have been locating and record large and medium scale mining operations with accompanying dredge sites, with GPS, every six months. Work has also commenced in mapping small scale operations,

Areas cleared by mining activity have a distinctive spectral response from other change with sand, mud and rock depicted in pink or grey colours and pools of water appearing blue in colour (Figure 7-5)

Figure 7-5:
Example of Deforestation Associated with Mining Activity

Smaller scale mining also exists (Figure 7-6). 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.

Figure 7-6:
Strip Mining

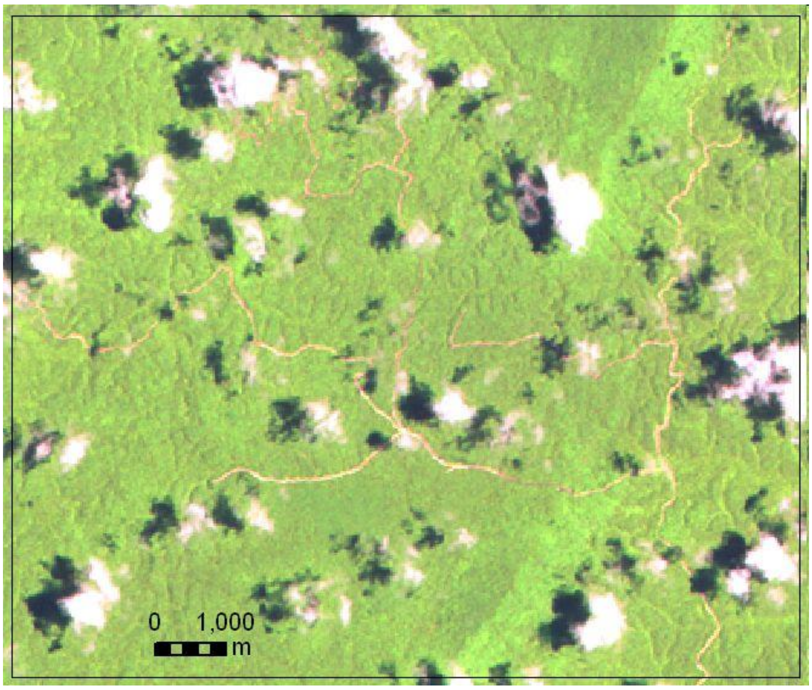


7.5 Infrastructure

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 7-7).

The roads were traced from the imagery as linear features and converted to areas by applying a 20 metre wide buffer on either side of the features and where appropriate the buffer was edited. This width is considered to be realistic as it corresponds to the image resolution at which bare ground is detected. Road lines captured with GPS[35] (since 2003) were also overlaid to ensure that road lines were completed. This dataset also contains information about the class of road. Where possible the driver of the road construction was also attributed.

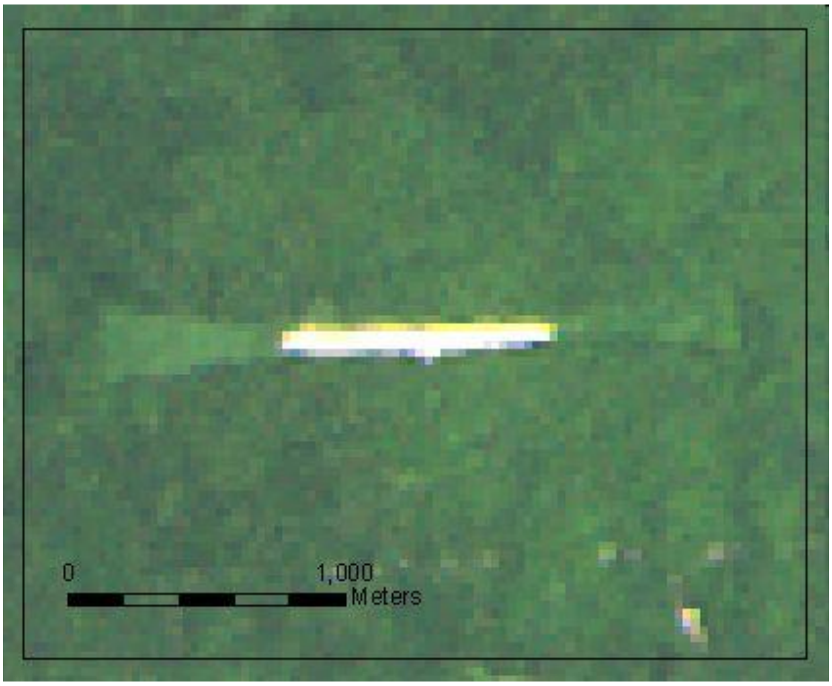
Figure 7-7:
Example of Infrastructure Activity



Airfields are readily identified by their distinctive shape and length and are often associated with mine workings (Figure 7-8).

[35] Most roads are captured using GPS (Garmin 12XL & GPSMap 72). The positional accuracy under unobstructed conditions can be +/- 20 m.

Figure 7-8:
Example of an Airfield



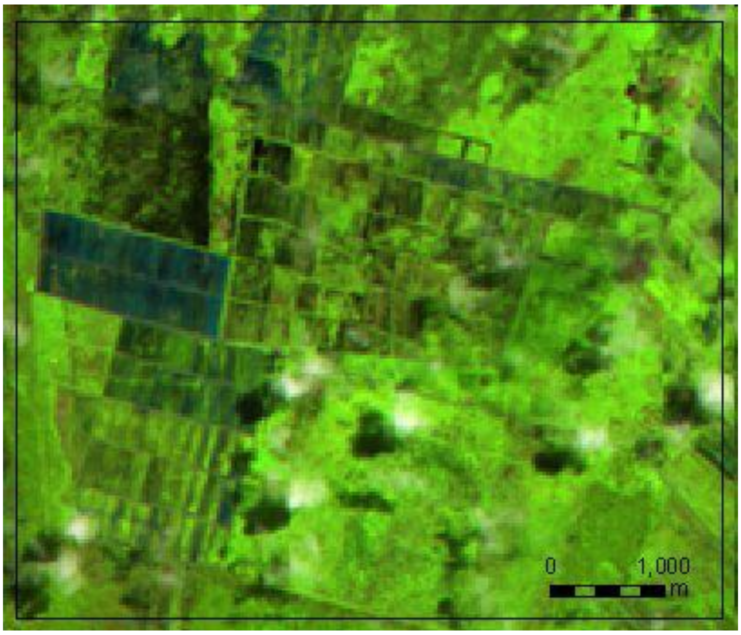
7.6 Agriculture

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 7-9). The converted land generally lies adjacent to existing established farmland.

Figure 7-9:
Example of Agricultural Fields

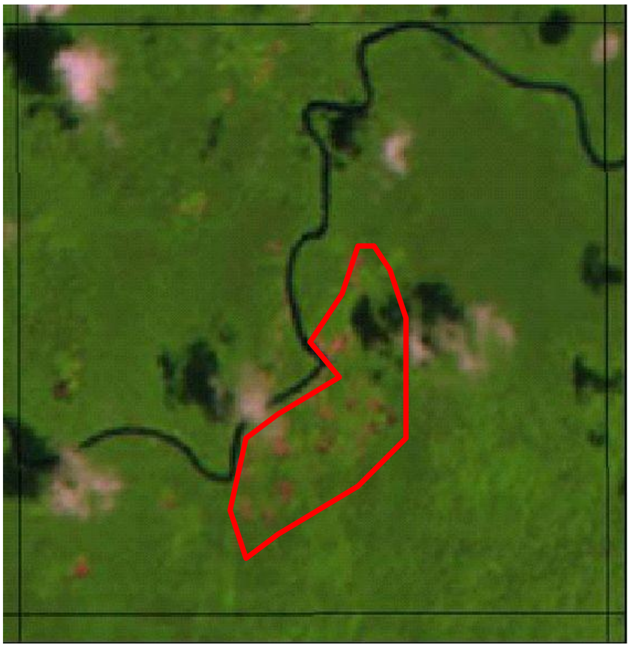


Areas of shifting cultivation are not considered in the interim MRVS, but do represent a change (albeit temporary) in carbon stock. They are often presented in the landscape as a mosaic of land cover that are often small and scattered, appearing in different states spanning from bare land to grassland 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 7-10). 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 7-10:
Example of Small-scale Shifting Agriculture



7.7 Fire - Biomass Burning

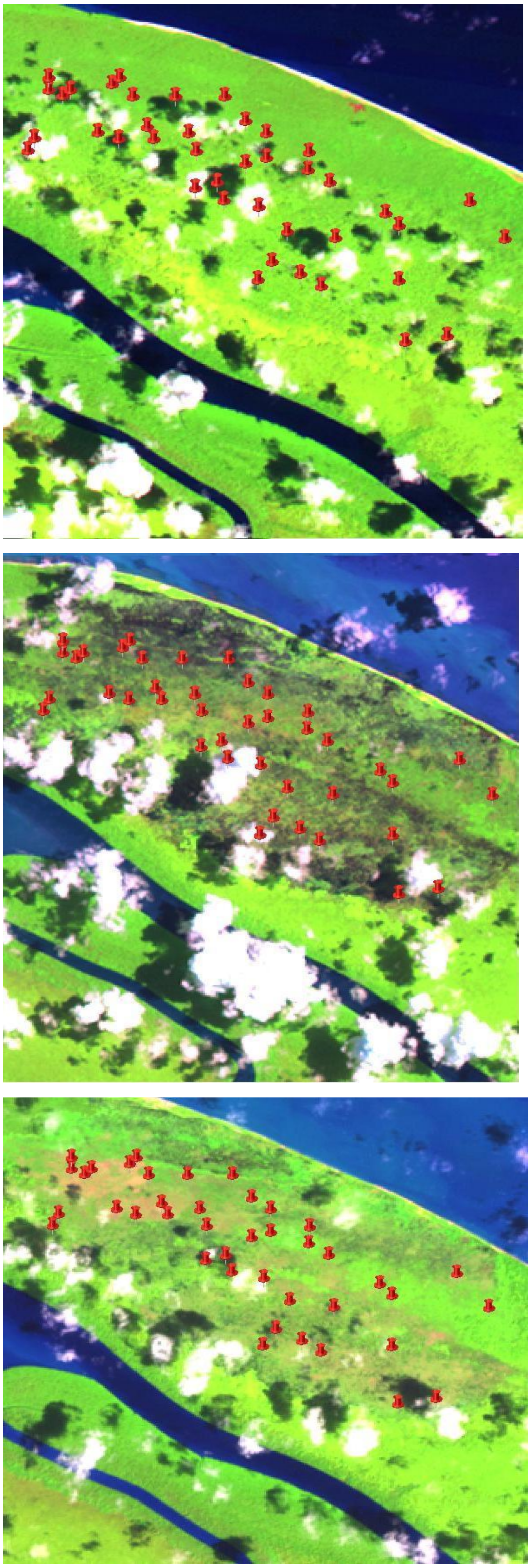
The cause of all fires (biomass burning) is assumed to be human induced or anthropogenic events. The Fire Information for Resource Management System (FIRMS) and the 500 m burnt area product provides information about historic and present day fire locations using the Moderate Resolution Imaging Spectroradiometer (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[36]. 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.

The following sequence (Figure 7-11) shows a coastal area before the fire event in 1990, the fire in 2001 followed by partial regeneration in 2005. The red markers represent the MODIS fire points from 2000 to 2005.

[36] 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".

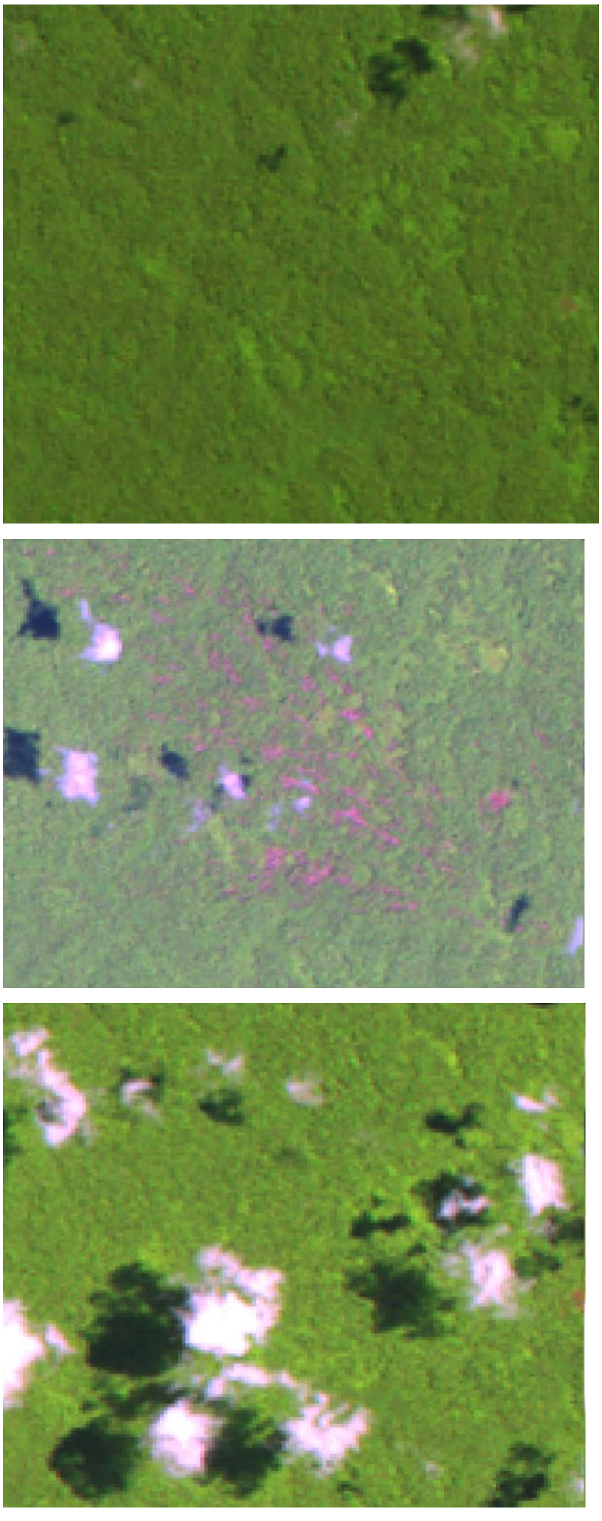
Figure 7-11:
Temporal Sequence of Burning



7.8 Naturally Occurring Events

Changes are also observed outside of accessible, populated and managed areas. Depending on the intensity of the event these can be fragmented or clustered. The following example shows a suspected wind damage event. The image sequence shows the area in 1990, the wind event in 2000 and the recovery in 2005. These areas are not included as change, as they are not anthropogenic.

Map 7-5:
Wind Damage



8 FOREST CHANGE 1990 - 2010

The results presented summarise forest change for the benchmark period 1990 to September 30, 2009 (19.75 years) and also for the year 1 period (October 1 2009 to September 30 2010.

For each period the national rate of deforestation for Guyana's total forested area (18.36 million ha)[37] and also the area deforestation in the State Forest area (12.9 million ha) are calculated.

The intention is that this analysis be used as a benchmark against which all future change is referenced. The results for the benchmark and year 1 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.

The accuracy of the results reported are dependent on a number of factors, some which are outlined in section 6. Certainty is reduced if areas are small or fragmented (<1 ha), or comprise a range of land use. In these instances it is difficult to determine the exact land use, as pixels[38] contain a range of spectral signatures that may be common to several land uses. Cloud cover also increases the level of uncertainty. This impact has been minimised where possible by using a combination of multiple scenes and lower resolution MODIS images.

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

- Forest change is reported for three periods, 2000, 2005, and 2009, however, due to data availability and cloud contamination images from around these dates were required to build a national cloud-free mosaic.

  To compensate, the overall rate of change from 1990 to September 2009 (19.75 years) and the approximate annual rate of change for each time period have been calculated.

- Forest is defined in accordance with Guyana's national definition of forest. The forest cover estimated as at 1990 (18.47 million ha) is based on this threshold and was determined using a vegetation index and manual interpretation of historical aerial photography and satellite images. Targeted and existing field measurements were also used to verify this classification. Ongoing field measurements as scheduled for the carbon monitoring program will assist in verifying this classification.

- Degradation (shifting cultivation and forest harvesting) were mapped when observed. The image resolution and time lag between the periods evaluated meant it was not always possible to accurately determine areas of forest degradation, so most likely areas mapped will be conservative. In a tropical environment, areas very quickly regain vegetation cover that has a similar appearance to the surrounding vegetation. This essentially masks the event. More frequent monitoring is required to more effectively map these areas.

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[37] This is the1990 forest area less the area deforested. Under the MOU with Norway Guyana is required to report on all forest changes. This includes changes that occur in titled Amerindian areas.

[38] This is effect is often referred to mixed pixels.

- Only those roads visible on the images or corroborated from GPS sources were included in the analysis. All roads were treated as deforestation events. This is a conservative approach as some 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 1990-2010

The total area converted from forest to non-forest between 1990 and 2009 is estimated at 74 917 ha. This is calculated by subtracting the initial 1990 forest area from the 2009 September forest area (19.75 years). The estimate includes 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 have been applied to calculate the area of deforestation from 2009 to 2010 (year 1 period). The total area of deforestation for this period is calculated at 10 280 ha (Table 8-1).

Table 8-1:
Area Deforested 1990 to 2010

Period	Forest Area ('000 ha)	Change ('000 ha)	Change (%)
Initial forest area 1990	18 473.39		
Benchmark (Sept 2009)	18 398.48	74.92[39]	0.41%
Year 1 (Sept 2010)	18 388.19	10.28	0.06%

Based on the initial 1990 forest area the forest cover change for 1990-2009 period is estimated at 0.41% (i.e.<1%). The FAO (1995) equation as cited in Puyravaud (2003) has been used to calculated 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.

Annualised this represents a average change rate of about 3 800 ha/yr^{-1} which is equivalent to a deforestation rate of - 0.02%/ yr. Compared to the period mean the deforestation rate triples for the year 1 period and is estimated at 0.06%.

[39] Note that submission of deforestation rate estimate to the Forest Carbon Partnership Facility (FCPF), computed deforestation rate as an accumulated total that was not benchmarked to a reference level. This was a Quick Assessment that was done to determine total forest/non forest change and the drivers behind each change. This assessment was effective in achieving this intended purpose. As such, the FCPF estimate that uses images as of 2007-2008, estimated an accumulated rate up to this time and not just during that two year period. This reported rate is similar in method to the accumulated rate up to September 2009, as is presented in this report as 74. 920ha. It should be clarified that the FCPF total is not an annual total and using images from the 2007-2008 period is not tantamount to assessing change in just the 2007-2008 periods.

This 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 which is essentially the same as Guyana's total deforestation rate from 1990 to 2009.

The following figure shows the annual deforestation trend by the separate periods analysed. The trend suggests that deforestation rates have increased since 1990 and recent trends continue then it may well continue to rise.

Figure 8-1:
Annual Rate of Deforestation by Period from 1990 to 2010

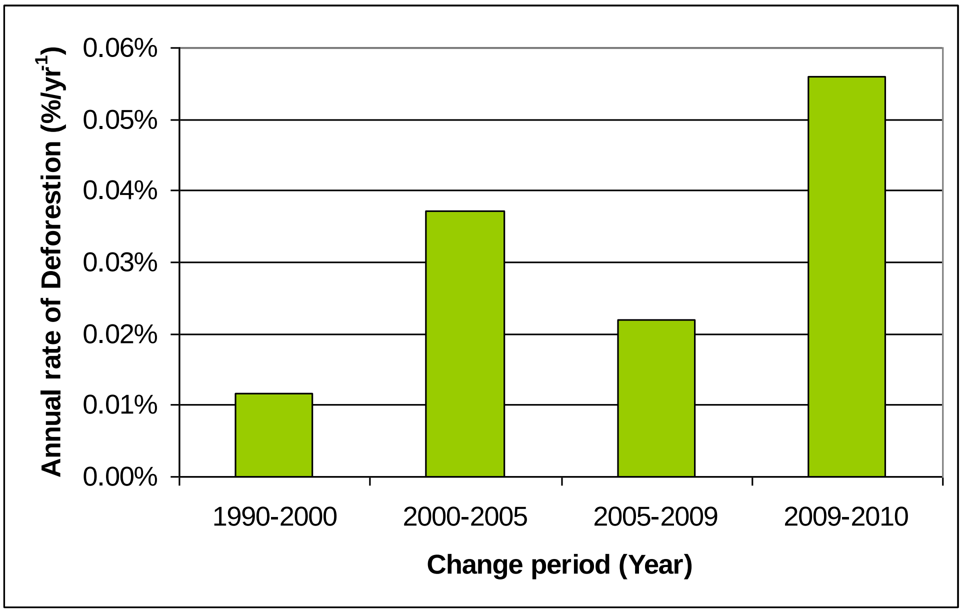


Table 8-2 provides a breakdown by forest change drivers for the benchmark and year 1 periods. Interpretation of the change areas during the benchmark period identifies mining as the leading contributor of deforestation (60% of the total), particularly between 2001 and 2005.

This trend continues with the area of deforestation attributed to mining showing a sharp increase in year 1 with over 9,000 ha deforested in a single year. For this period this equates to 91% of all recorded deforestation.

Table 8-2:
Forest Change Area by Period & Driver from 1990 to 2010

Driver	Benchmark Period			Year 1 2009-10
	1990 to 2000	2001 to 2005	2006 to 2009	
	Area (ha)			
Forestry	6 094	8 420	4 784	294
Agriculture	2 030	2 852	1 797	513
Mining	10 843	21 438	12 624	9 384
Infrastructure	590	1 304	195	64
Fire (deforestation)	1 708	235		32
Area Deforested	**21 267**	**34 249**	**19 400**	**10 287**
Total Forest Area of Guyana	18 473 394	18 452 127	18 417 878	18 398 478

Total Forest Area of Guyana Remaining	18 452 127	18 417 878	18 398 478	18 388 190
Deforestation %	0.01%	0.04%	0.02%	0.06%

Other noticeable trends show that fire contributed to large area of deforestation between 1990 to 2000. This coincided with the dry conditions associated with the El Niño weather pattern. The main areas burnt during this period are located along the coast and inland near Linden

These trends are also observed in the annualised rate of change which shows the contribution of the individual drivers over time. Agricultural development remains stable with an area of 200-500 hectares developed annually. The area of forestry-related deforestation has decreased, although most of the deforestation detected is associated with road construction activities rather than the process of harvesting. It is also likely that some roads have been allocated to mining as mining activities often uses forest infrastructure for access.

Table 8-3
Annualised Rate of Forest Change by Period & Driver from 1990 to 2010

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**	**9384**	**64**	**32**	**10 287**

8.2 Changes in Guyana's State Forest Area

The total change in State Forest Area (SFA) between 1990 and 2009 is estimated at 63 646 ha. The SFA accounts for 85% of all deforestation for the benchmark period. When annualised this represents a change rate of 3 200 ha/yr which is equivalent to a deforestation rate of - 0.03%/ yr.

Deforestation from 2009 to 2010 (year 1 period) in the SFA is calculated at 8 910 ha. It is clear that a majority (87%) of all deforestation in Guyana is occurring within the boundary of the SFA.

Table 8-4 and Table 8-5 provide a breakdown by forest change drivers for the benchmark and year 1 periods. Deforestation associated with mining and forestry activities dominate the SFA. Mining in particular has increased substantially in the 2009-10 year 1 period. Fire and Agriculture are less prominent and contribute less than 2% of the deforestation observed.

Table 8-4:
SFA Forest Change by Driver from 1990 to 2010

Driver	Benchmark Period 1990 to 2000	Benchmark Period 2001 to 2005	Benchmark Period 2006 to 2009	Year 1 2009-10
	Area (ha)			
Forestry	6 026	8 253	4 293	270
Agriculture	384	247	62	3
Mining	10 122	19 930	12 007	8 582
Infrastructure	374	1 228	89	24
Fire (deforestation)	564	67		32
Area Deforested	17 470	29 725	16 451	8 910
Total Forested SFA Area	12 481 363	12 463 894	12 434 169	12 417 718
Total Forested SFA Remaining	12 463 894	12 434 169	12 417 718	12 408 807
Deforestation %	0.01%	0.05%	0.03%	0.07%

Table 8-5:
SFA Annualised Forest Change by Driver from 1990 to 2010

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	603	38	1 012	37	56	1 747
2001-2005	5	1 651	49	3 986	246	13	5 945
2006-2009	4.8	904	13	2 528	19		3 463
2009-10	**1**	**270**	**3**	**8 582**	**24**	**32**	**8 910**

8.3 Changes in Guyana's State Lands

The deforestation in State Lands between 1990 and 2009 is estimated at 8 161 ha, which is approximately 11% of all deforestation for the benchmark period. When annualised this represents a change rate of 412 ha/yr which is equivalent to a deforestation rate of - 0.01%/ yr.

Deforestation from 2009 to 2010 (year 1 period) in State Lands is calculated at 848 ha. Table 8-6 and Table 8-7 provide a breakdown by forest change drivers for the benchmark and year 1 periods. Deforestation associated with agricultural development dominates both periods analysed. The scale of mining and forestry activities is also starting to increase.

Table 8-6:
State Lands Forest Change by Driver from 1990 to 2010

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

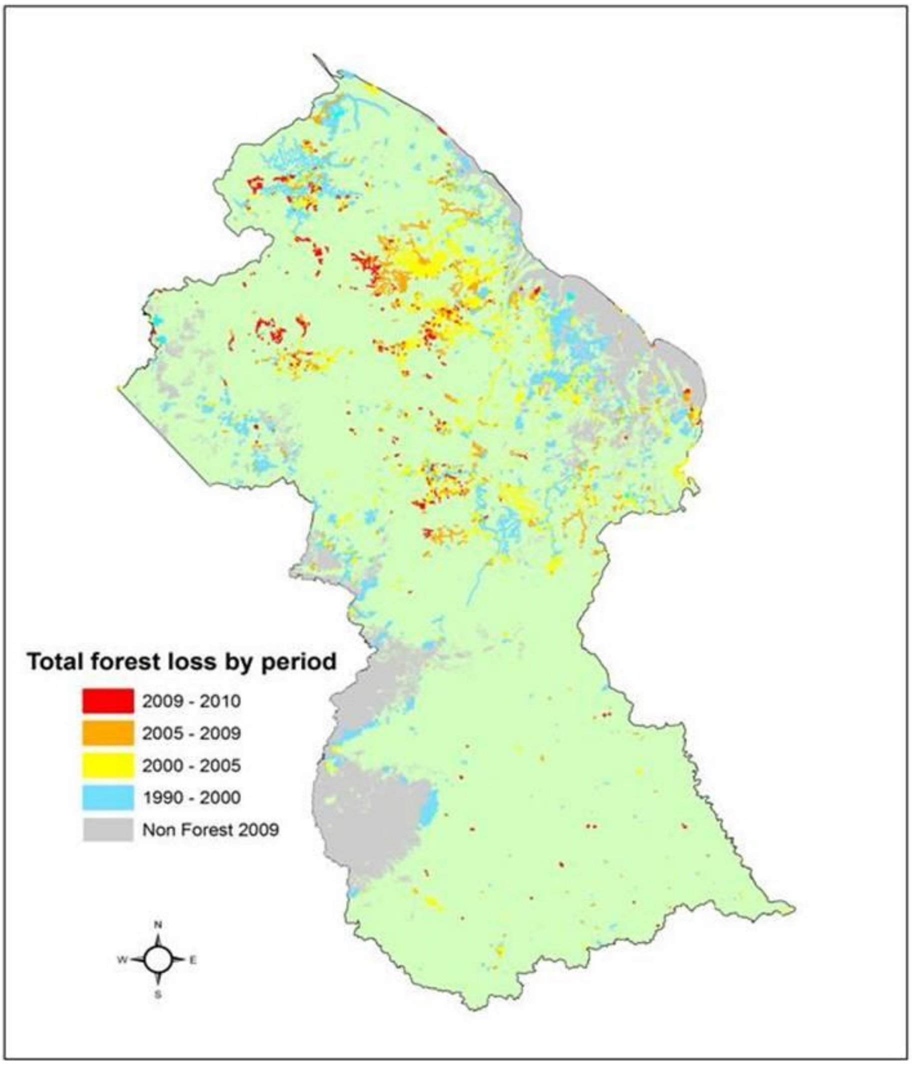
Table 8-7:
State Lands Annualised Forest Change by Driver from 1990 to 2010

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	2	156	30	3	72	264
2001-2005	5	19	513	163	14	0	709
2006-2009	4.8	6	365	40	4		415
2009-10	**1**	24	510	175	32	0	741

8.4 Deforestation Patterns

The temporal analysis of deforestation from 1990 to 2010 is presented in Map 8-1. The map shows that most of the change is clustered[40] and new areas tend to be developed in close proximity to existing activities.

Map 8-1:
Forest Change 1990 to 2010

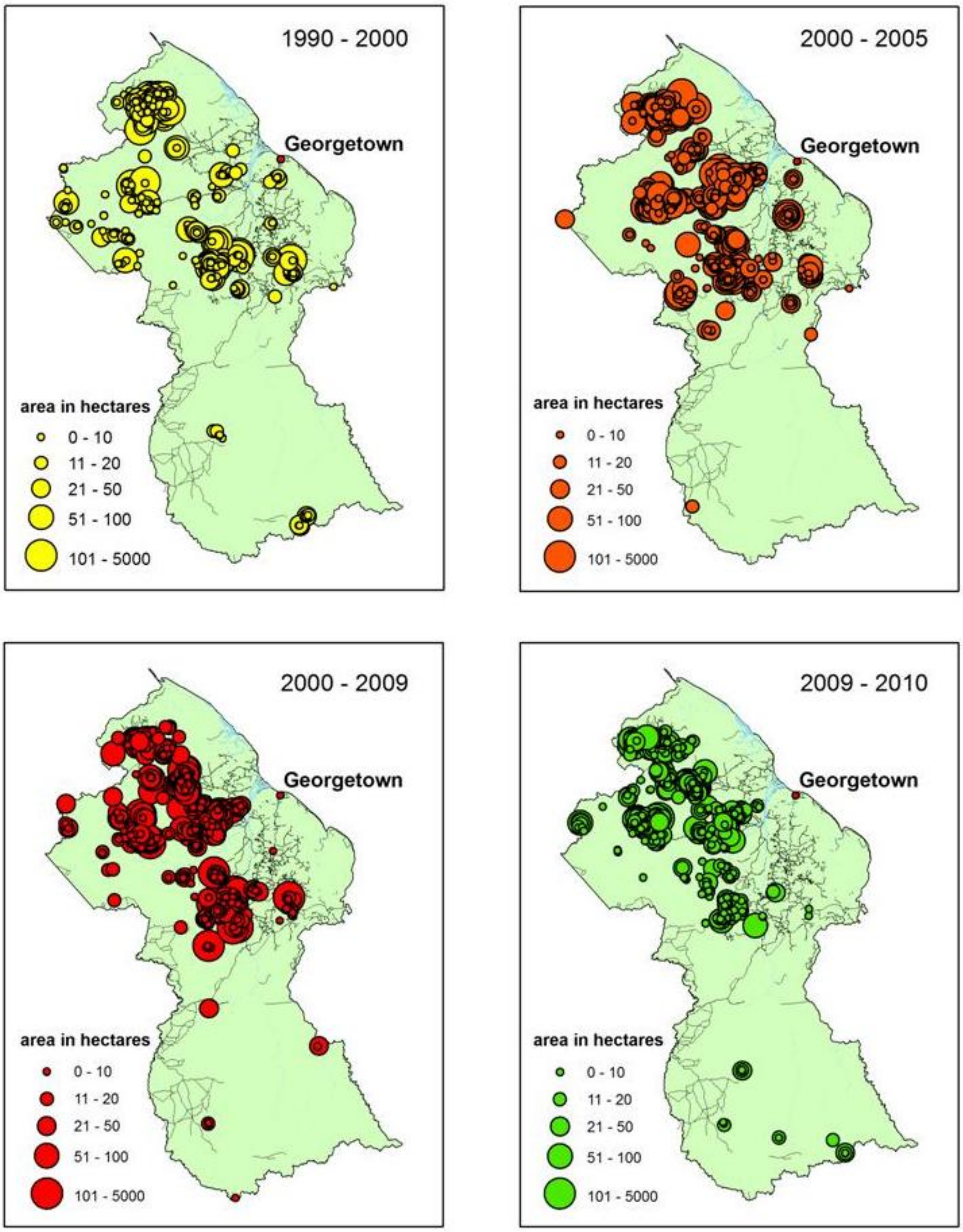


[40] For the purposes of display the area of deforestation has been buffered to make it more visible.

The distribution pattern also shows that areas of increased activity tend to be clustered around the existing road infrastructure and rivers. The following series of maps show the temporal and spatial distribution of deforestation by driver (mining, forestry and agricultural and biomass burning)

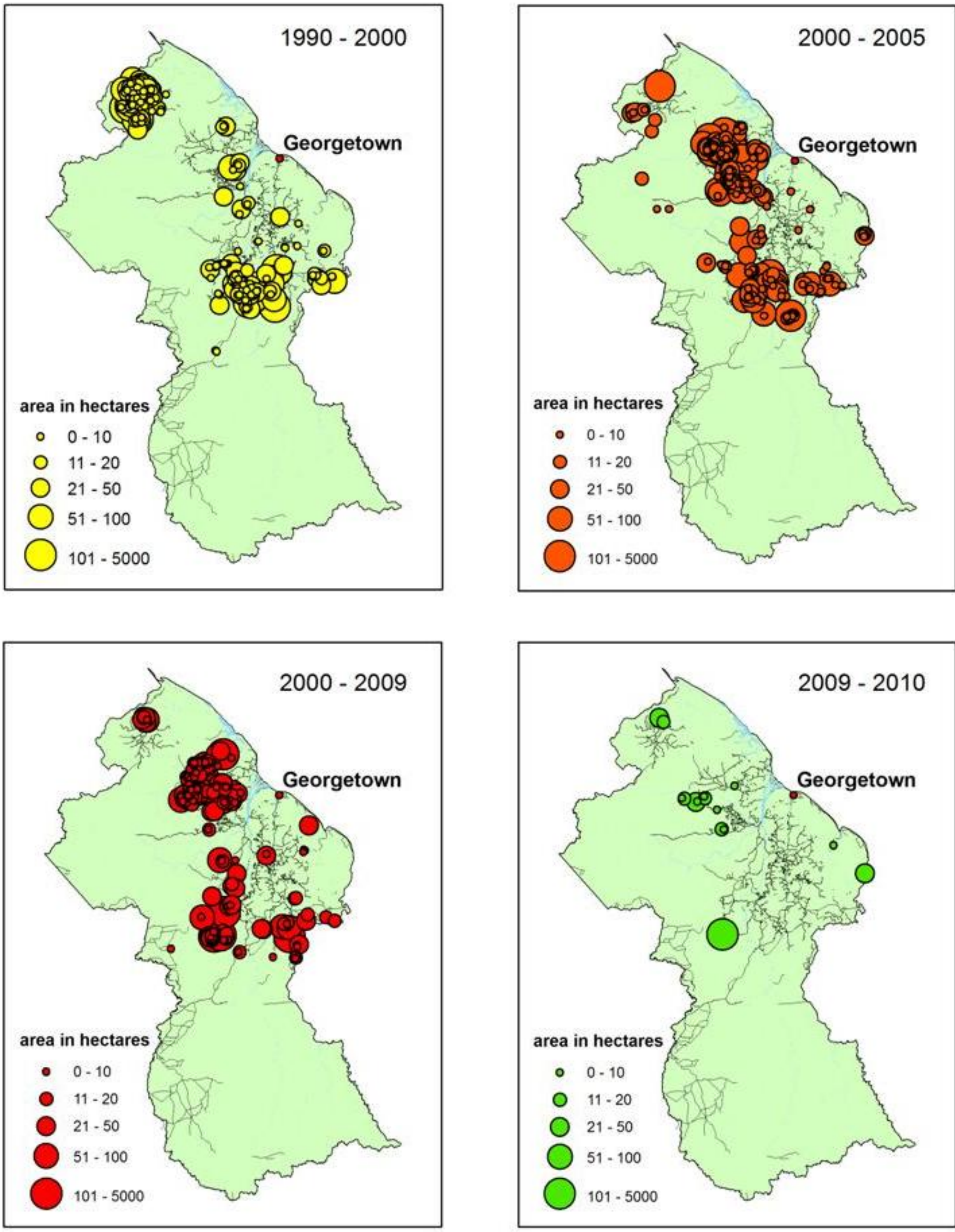
The spatial trend on Map 8-2shows that mining activities including associated road construction are concentrated in northwest of the country. Most of the activity is within the SFA with recent mining 2009-10 also observed along the Guyana/Brazil boarder.

Map 8-2:
Mining Spatial & Temporal Distribution



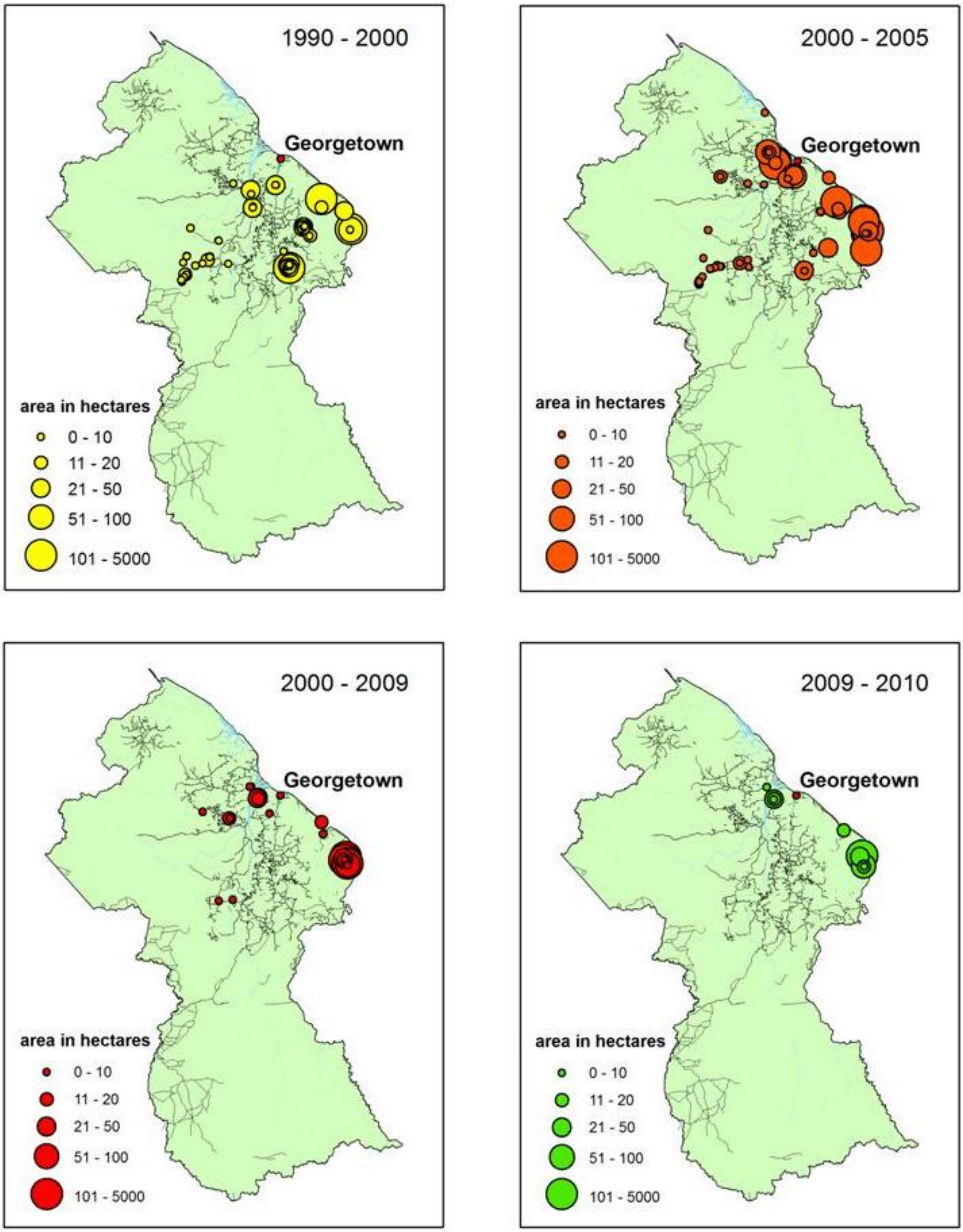
Map 8-3 shows that a majority of forestry activities are located within the SFA. The spatial and temporal trend indicates that forestry activity is focussed in the same locations.

Map 8-3:
Forestry Spatial & Temporal Distribution



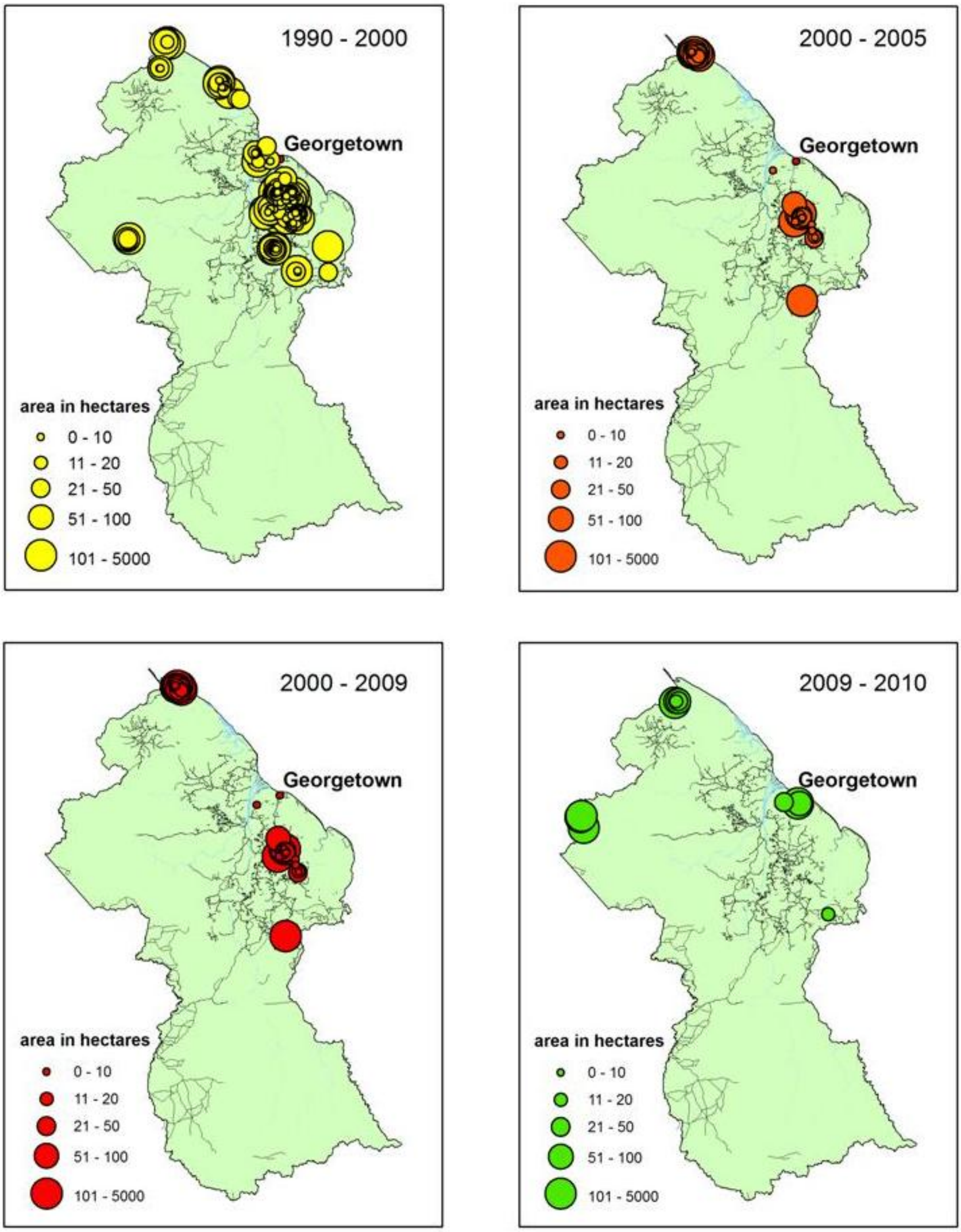
Map 8-4 shows that the largest area of agricultural development is located close to Georgetown and the coastal zone. Current deforestation activities are also focussed in this region.

Map 8-4:
Agriculture Spatial & Temporal Distribution



Map 8-5shows the distribution of fires resulting in deforestation since 1990. A majority of fire events occurred along the coastal zone in mangrove and white sand forests. Fire is also very common in the non-forest savannah areas to the south of the country (see Map 4-7).

Map 8-5:
Biomass Burning - Fire Temporal and Spatial Distribution



9 VERIFYING FOREST AND FOREST CHANGE MAPPING

An independent assessment of the estimates of forest area, area change and deforestation rates is scheduled for January 2011. The desired goal of this validation is to derive a statistically robust and quantitative assessment of the uncertainties associated with the estimates. To this end, RapidEye satellite imagery with a 5 m resolution has been tasked (October 2010 to January 2011) to increase the number and distribution of available reference images. At this stage a forest stratification map which delineates forest strata by potential carbon stocks is still being developed.

As part of the internal quality assurance process a simple verification of the forest boundary and forest change mapping was conducted to gain some understanding of the overall quality of the mapping. The verification represents "best efforts" given the limited high resolution reference data. An assessment of the accuracy of deforestation rates is precluded by the lack of historical high resolution imagery for the various time periods.

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 automated and manual procedures used to interpret the forest map category
- Cartographic and thematic standards (i.e. minimum mapping unit and land use definitions)
- The availability of field reference data for evaluation of the results.

Widely accepted approaches were used to minimize these sources of error. Pre-processing and mapping standards were applied in a consistent and transparent manner (including treatment of areas of cloud) following IPCC and GOFC GOLD good practice guidelines as appropriate.

The accepted approach in evaluating the accuracy of mapping is through a probability-based sampling design. Key considerations when considering the design as outlined by Stehman (1999) include:

- Known inclusion probabilities, ensuring the objectivity of sample selection and the validity of statistical inferences
- Small variance for estimated accuracy parameters
- Good spatial distribution of the sample to ensure adequate precision for sub-region estimates as well as precision of estimates for the full region
- Representation of all classes, including rare classes such as change areas
- Low cost (both budgetary and time), and
- Simple to implement and analyse

The objectivity of sample selection was significantly compromised by the restricted availability and, uneven distribution of high resolution reference imagery over Guyana (see Map 4-6), the limited temporal coverage of these datasets and issues with respect to cloud cover and data quality. Given that a non-probabilistic approach is used, the information presented here provides an insight into the map quality but it may not be representative of the map as a whole.

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).

9.1 Response Design

The response design refers to how reference data are collected. In this instance a set of high resolution CBERS-HRC panchromatic and Ikonos multispectral images with capture dates corresponding roughly to the 2010 currency of the map was used as the reference data source. Due to the lack of historical high resolution imagery the same dataset was used for checking the accuracy of the delineation of the 1990 forest-non-forest boundary and the subsequent forest change.

From the available images a set of six that were selected based on their suitability for validation. This decision was based on selecting images that covered a range of locations and land cover types that contained low cloud cover.

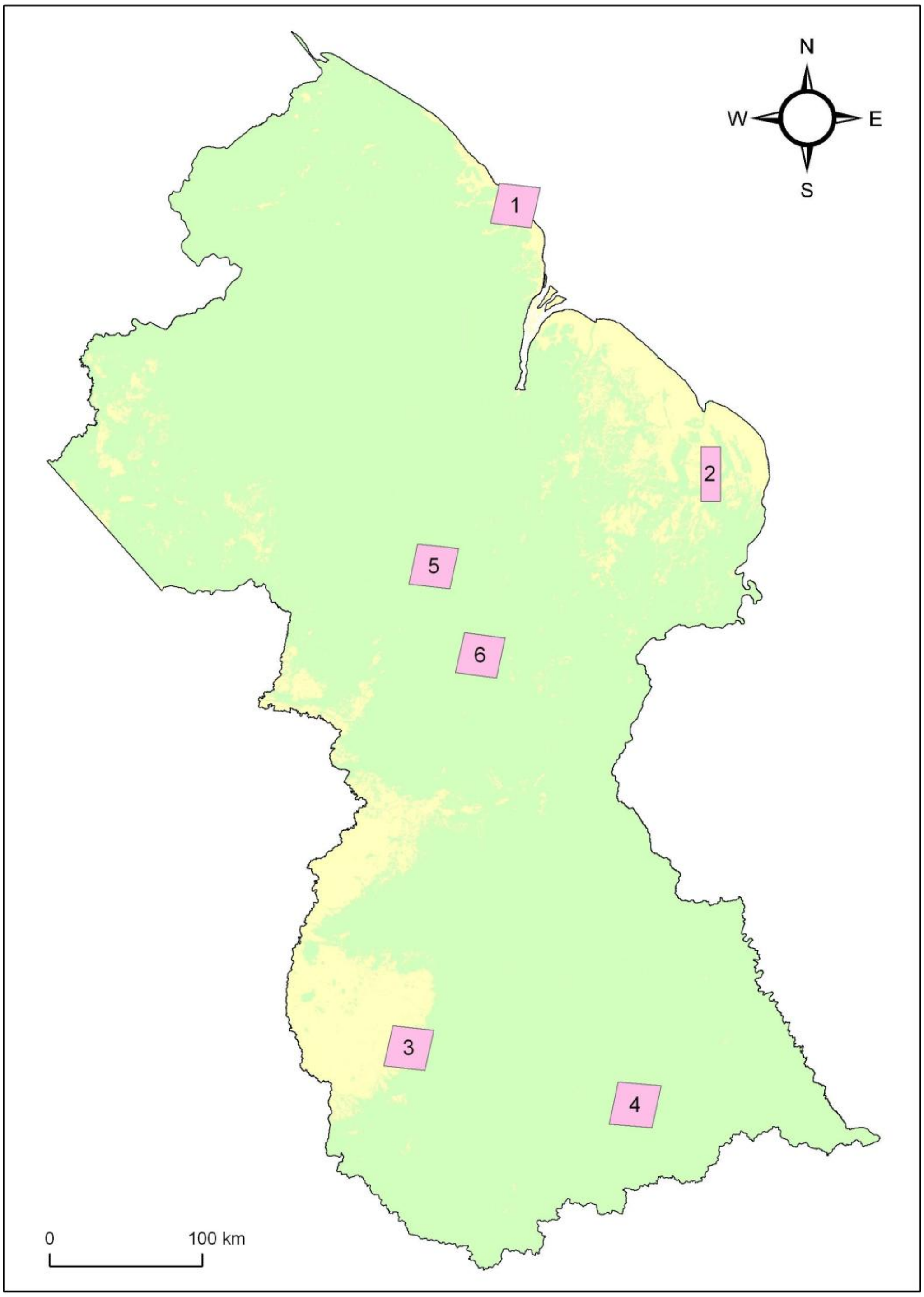
Three of the images display a high proportion of non-forest land and areas of gradual transition to complete forest cover with little evidence for post-1990 deforestation (sampling frames 1 to 3). These images were used to assess the accuracy with which the forest and non-forest categories are discriminated. One image covers a remote location with extensive forest cover and no cloud cover and was used for checking for potential omission of forest change (frame 4).

Two of the images display the best evidence for deforestation and were used to evaluate the accuracy of the forest change mapping (frames 5 & 6),

Table 9-1:
Summary of Images Sampled

Sampling Frame Ref	Application	Image Name	Data Provider	Sensor	Spectral Range	Capture Date (dd/mm/yy)	Resolution (m)	Area (ha)
1	Forest / non forest	CBERS_2b_HRC_20090814_174_D_092_1_l2_BAND1	INPE	CBERs HRC	Pan	14/08/09	2.7	72 059
2		IKP004R002_090908	GeoEye	Ikonos	MS	9/08/09	4	45 591
3		CBERS_2B_HRC_20090830_173_B_097_4_L2_BAND1	INPE	CBERs HRC	Pan	30/8/09	2.7	73 061
4		CBERS_2B_HRC_20091017_172_D_098_1_L2_BAND1	INPE	CBERs HRC	Pan	17/10/09	2.7	80 078
5	Forest change	CBERS_2B_HRC_20090814_174_D_094_3_L2_BAND1	INPE	CBERs HRC	Pan	14/08/09	2.7	72 589
6		CBERS_2B_HRC_20091209_173_A_095_1__L2_BAND1	INPE	CBERs HRC	Pan	09/12/09	2.7	72 130

Map 9-1:
Location of Samples



The registration of the selected images was checked against the location of the Landsat dataset and adjusted where necessary to ensure their relative positional accuracy.

9.2 Sampling Design

The sampling design refers to the methods used to select the locations at which the reference data are obtained.

For the assessment of forest/non-forest categories (sampling frames 1-4) a random sample of 250 points was used. A sample size of 50-100 per class is quoted in literature sources as providing an estimate of accuracy of acceptable precision Stehman (2001). A minimum distance of 500 m between points was enforced and points located over cloud, shadow, water or data gaps were omitted.

For each sample point the dominant land-cover class (forest or non-forest) within a circular area of one hectare surrounding the sample point was determined. A one hectare unit of assessment represents the minimum mapping unit used (±3 x 3 pixel block for the Landsat imagery). A stratified sampling strategy was adopted for assessing the change mapping (frames 5 and 6) because the areas of change are quite rare. A sample size of 250 points per stratum was used with no enforcement of minimum distances. A larger sample size for the 'no-change' forest class allows for assessment of the true extent of false negatives. This is in accordance with the GOFC-GOLD (2006) recommendations.

The sampling frame from which the samples were selected excludes areas that were non-forest in 1990. As the areas of non-forest may not be accurately mapped the sample points were checked against the 1990 Landsat imagery and points were omitted if they were occupied areas that were non-forested in 1990.

Areas of forest degradation were treated as 'unchanged' forest as only deforestation is being assessed. Areas of shifting cultivation were also excluded from the sampling frames as were water bodies and areas of cloud and shadow. Areas representing Year 1 change were also omitted as this change postdates the reference imagery.

As some of the mapped change occurred up to 20 years prior to the acquisition of the reference imagery early deforestation events may be masked by subsequent reforestation. Sample points selected from 'change' areas that are classed as 'no-change' (i.e. still forest) from the reference imagery were checked against the Landsat imagery time series to confirm that deforestation had in fact occurred.

For the change mapping assessment, a 'change' status was applied to a sample point if evidence for change was detected within the one hectare circular unit of assessment surrounding the point. Many of the sample points in the 'change' class lie along roads and their presence would not be detected if a dominant class was used.

9.3 Analysis and Estimation

The analysis produces a confusion or error matrix that provides the basis for describing the quality of the classification and characterizing the error. The labels assigned to sample points in the reference data are cross-tabulated against the mapped classes for each sampling frame.

The accuracy of a class is expressed in two ways, as a user's and producer's accuracies (Story and Congalton 1986).

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.

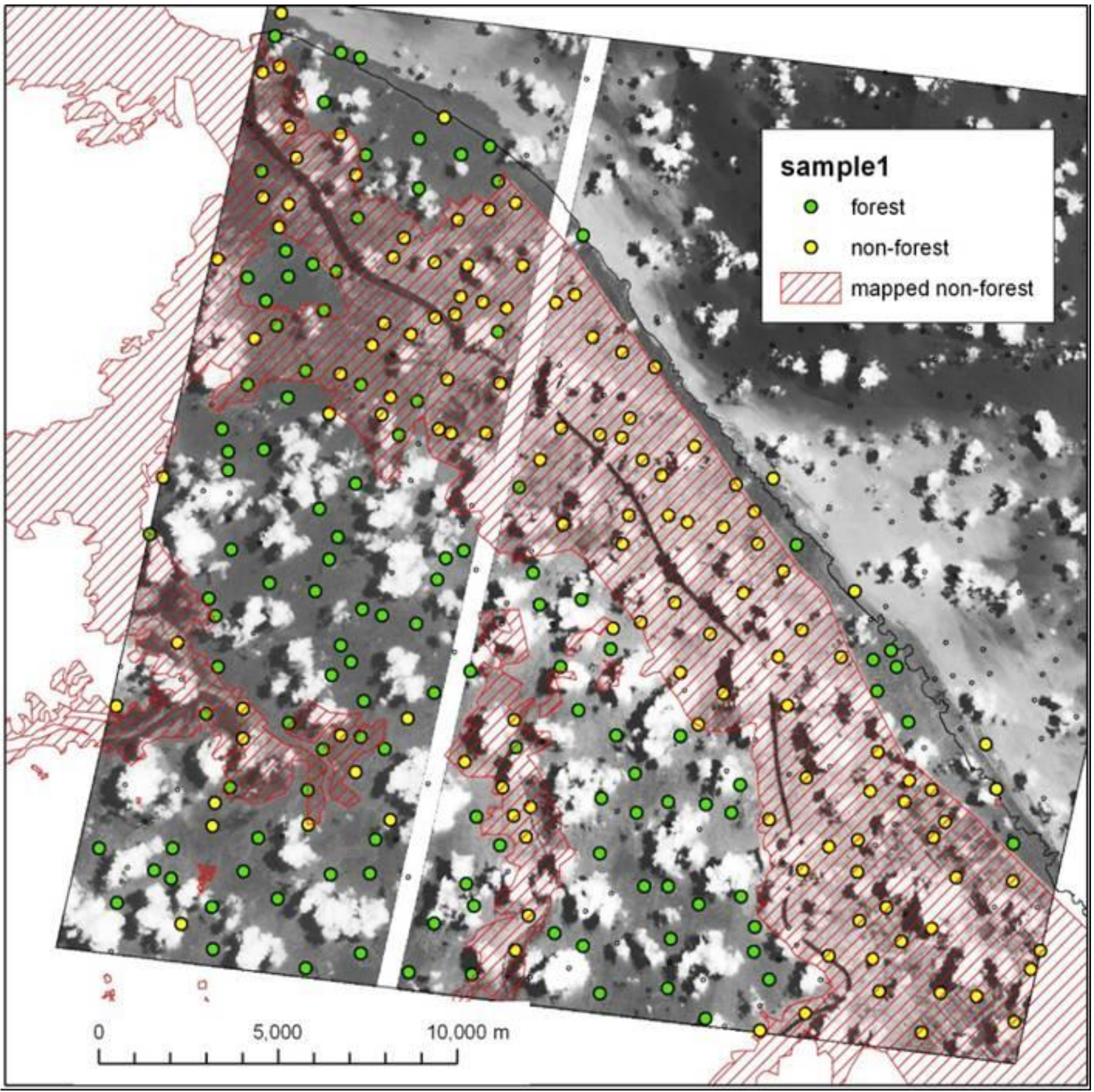
9.4 Results and Discussion for Forest and Non-forest Validations

This section describes in part, the quality of mapping and the methodology used in quality assurance and quality control (QA/QC). Estimation of uncertainties will be undertaken under a separate independent exercise using a sample of higher quality data to establish more robust quantitative traits of the uncertainty in areas being reported. Determining and undertaking a quantitative assessment of uncertainties was not in scope of this exercise as it is recognized to be a substantial exercise.

The following maps (Maps 9-2 to 9-5) show the reference images, the sample points and their assigned labels (i.e. forest or non-forest). Overlain on the image is the area classified as non-forest. The error matrices and statistics for each sample are presented in Tables 9-2 to 9-5.

The first sampling frame selected covers a coastal area that has a high proportion of non-forest (red hatched area).

Map 9-2:
Frame 1 CBERS HRC



The results for sampling frame 1 indicate that only a few points omitted or commissioned into the incorrect class. Overall mapping accuracy is estimated to be 86%.

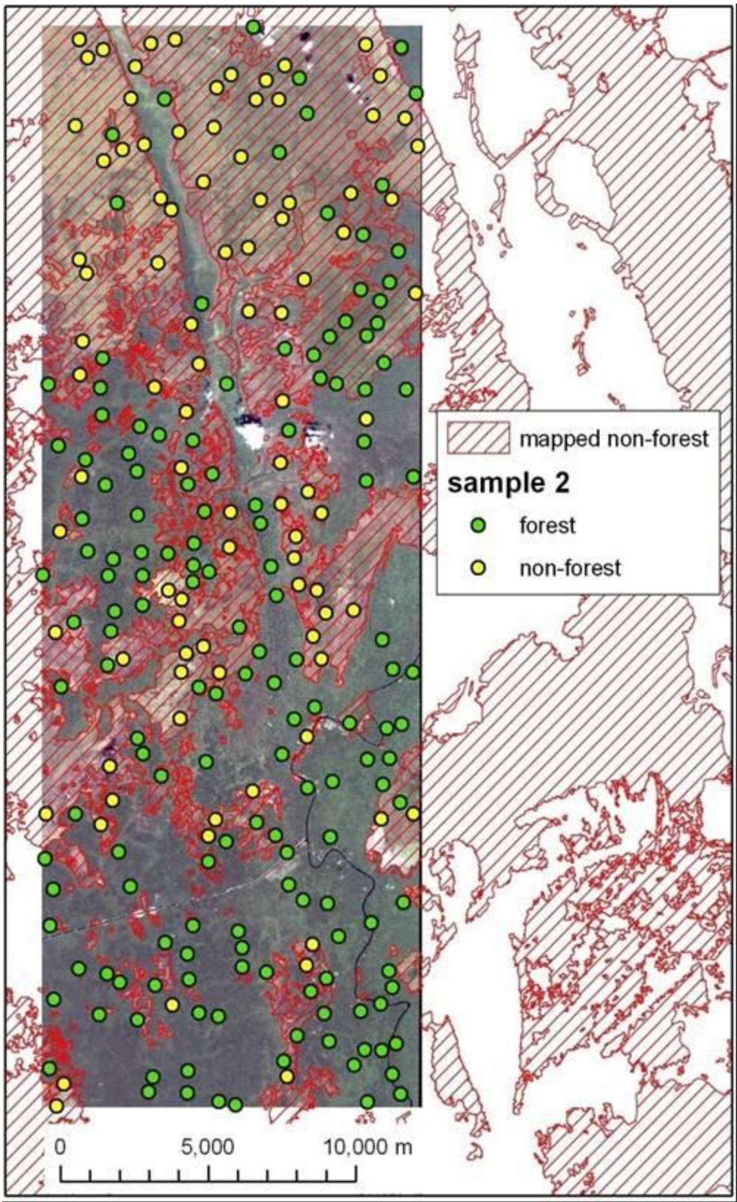
Table 9-2:
Frame 1 Error Matrix

Frame 1	Class	Reference Image			
		Forest	Non-forest	Total	User Accuracy
Map	Forest	106	19	125	84.8%
	Non-forest	16	109	125	87.2%
	Total	122	128	250	
Producer Accuracy		86.9%	85.2%		

Overall Accuracy: 86.0%

The second sampling frame used an IKONOS scene (4 m resolution). This scene covered a coastal area and also included settlements and access routes.

Map 9-3:
Frame 2 IKONOS



Similar results were achieved as frame 2 with an overall accuracy of 84% with no strong bias observed between omission and commission errors

Table 9-3:
Frame 2 Error Matrix

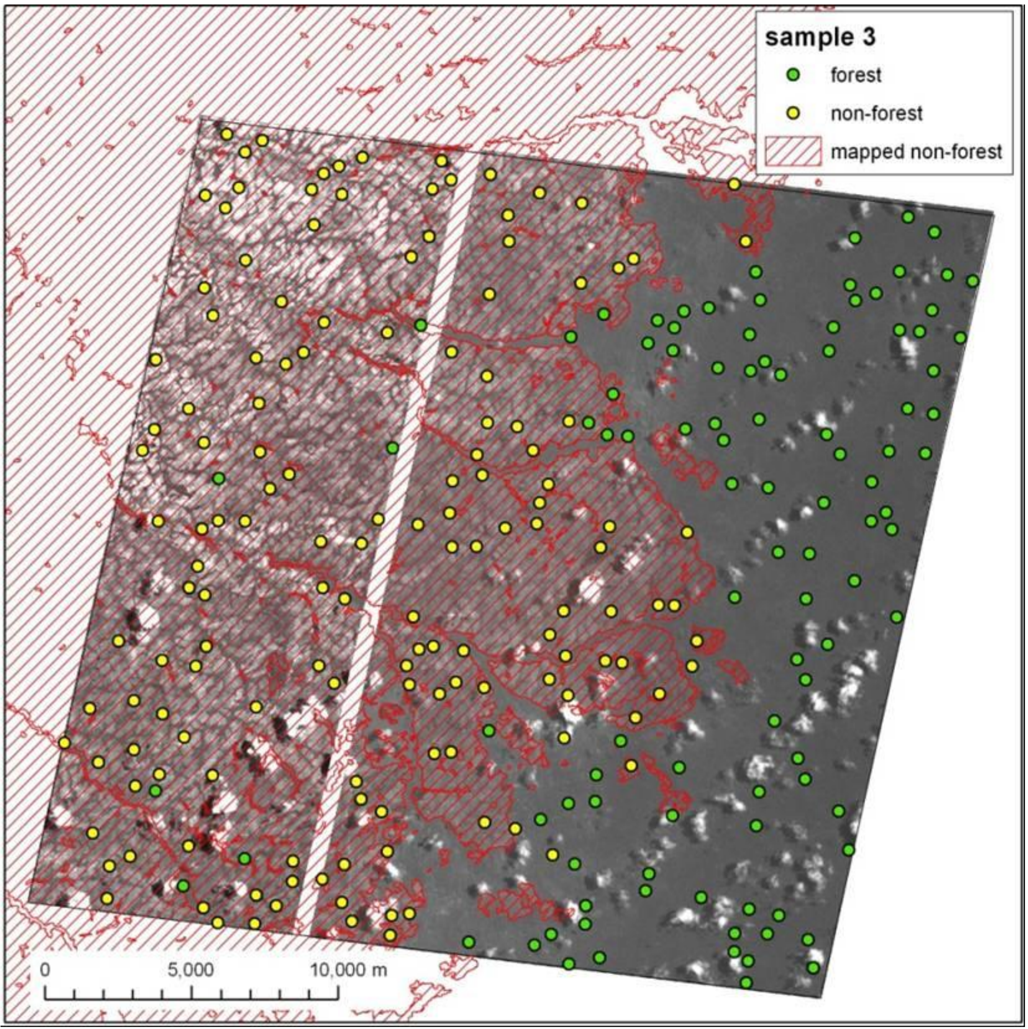
Frame 2	Class	Reference Image			
		Forest	Non-forest	Total	User Accuracy
Map	Forest	132	17	125	88.6%
	Non-forest	24	77	125	76.2%
	Total	122	128	250	
Producer Accuracy		84.6%	81.95%%		

Overall Accuracy: 83.6%

The third sampling frame was located in southern Guyana and encompasses the natural transition from forest to open savannah (non-forest). Two characteristics of the land cover pattern and land use management of this area include;

- Inside the savannah area the forest is fragmented and occurs along water courses
- A large number of fires are recorded by the FIRMs dataset over this area.

Map 9-4:
Frame 3 CBERS HRC



The results of the accuracy assessment for frame 3 indicate that both forest and non forest are mapped with a high degree of accuracy (97%).

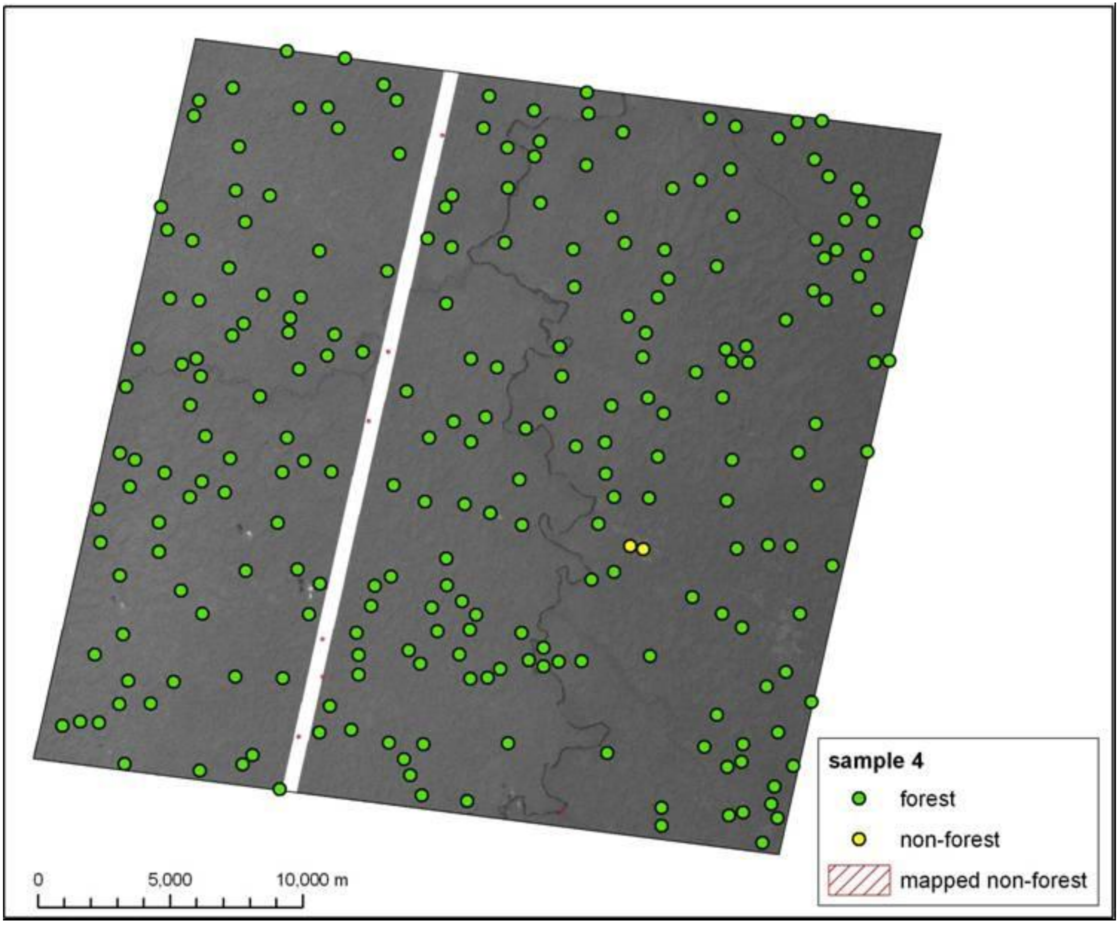
Table 9-4:
Frame 3 Error Matrix

Frame 3	Class	Reference Image			
		Forest	Non-forest	Total	User Accuracy
Map	Forest	142	2	144	98.6%
	Non-forest	6	100	106	94.3%
	Total	148	102	250	
Producer Accuracy		95.9%	98.0%		

Overall Accuracy: 96.8%

The final frame covers a remote area in south east Guyana and is dissected by a major river. This frame was expected to be forested due to the absence of any transport infrastructure.

Map 9-5
Frame 4 CBERs HRC



The results of the accuracy assessment for frame 4 indicate that the error of omission for the forest class is negligible in remote areas.

Table 9-5:
Frame 4 Error Matrix

Frame 4	Class	Reference Image			
		Forest	**Non-forest**	**Total**	**User Accuracy**
Map	Forest	248	2	250	99.2%
	Non-forest	0	0	0	-
	Total	248	2	250	
Producer Accuracy		100.0%	0%		

Overall Accuracy: 99.2%

9.5 Forest & Non-forest Combined Error Matrix

The error matrices for the four samples were used to produce a combined error matrix (Table 9-10). The overall accuracy for the combined samples 91%. The errors of commission for the forest class as measured by the user accuracies range from 0.8% to 15.2% across the four datasets with an average of 6.0% while the errors of omission for forests as measured by the producer accuracies are in the range 0% to 13.1% with an average of 6.8%.

Table 9-6:
Combined Error Matrix

Combined	Class	Reference Images			
		Forest	Non-forest	Total	User Accuracy
Map	Forest	628	40	668	94.0%
	Non-forest	46	286	332	86.1%
	Total	674	326	1000	
Producer Accuracy		93.2%	87.7%		

Overall accuracy: 91.4%

Estimates of the uncertainty for the total forest area can be derived from the combined error matrix if it is assumed that the assessment areas constitute a random sample from the entire country.

In the technical feedback to a draft version of this report, McRoberts et al., (2010) applied a model-assisted difference estimator to the dataset to derive a 95% confidence interval of 18.008 to 18.807 million ha for the 1990 forest area. A forest area of 18.3947 ± 0.4130 million ha is therefore indicated.

9.6 Results and Discussion for Forest Change Mapping Quality Control and Validation

Two image frames from areas of high deforestation activity in central Guyana were evaluated to provide an indication of the change mapping accuracy. The preliminary analysis indicate that the change estimates are conservative (over estimated) for the period assessed.

Unfortunately the limited number and the quality of the scenes restrict the conclusions that can be drawn from this analysis. Consequently, estimates of the uncertainty for the areas of change are not attempted here due to the non-probabalistic nature of the sampling and the small sample size.

A formal independent accuracy assessment scheduled for January-February 2011 should expand on the indicative results and will also provide an estimate of the accuracy and uncertainties relating to thematic land use classes and change. It is unusual for the mapping team to undertake its own accuracy assessment, hence a separate independent contractor has been contracted to undertake a full accuracy assessment exercise. The simple verification described in the IMR was only conducted as part of mapping quality control and quality assurance (QA/QC) to give an understanding of the quality of the mapping and used internally for this purpose.

Given the limited availability of high resolution datasets emphasis should be placed on field inspections and aerial over-flights. It is also worth noting that the lack of historical imagery that covers the 1990-2009 period means that it is not realistic to expect an estimate of change accuracy for this period. The most pragmatic approach would be to infer this from the validation single date year 1 map which covers the period from October 1 2009 to September 30 2010

It is envisaged that these results will be used in the future to guide the map improvement process and focus efforts in key areas undergoing change.

The following maps (9-6 and 9-7) show the reference images, sample points with assigned labels, and the mapped areas of change and non-forest. Sample points are symbolized with a green circle to represent unchanged forest and with a yellow circle to represent change from forest to non-forest since 1990. Error matrices and statistics for each sample are presented in Tables 9-6 to 9-9.

Sample frames 5 and 6 lie in an area of the northern central part of Guyana where deforestation activity related to mining and roading is prevalent.

Map 9-6:
Frame 5 CBERs HRC

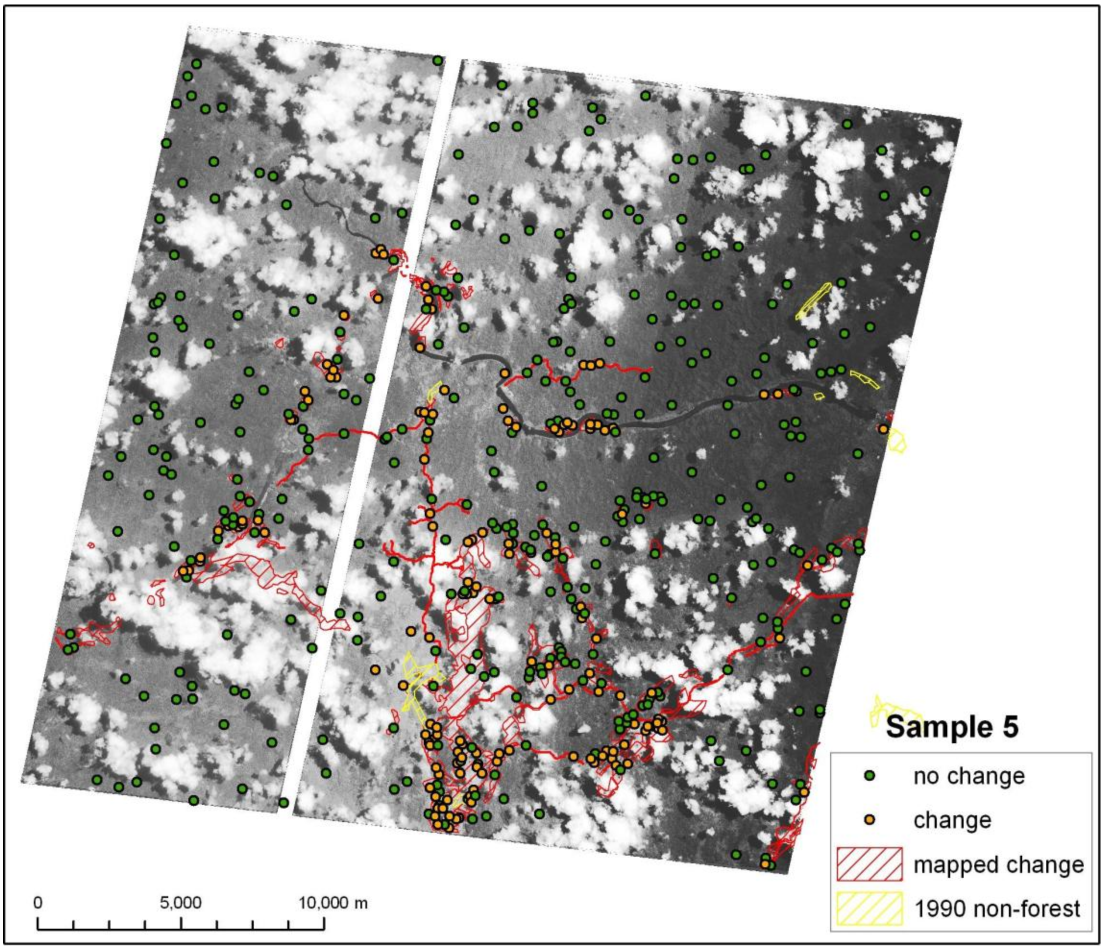


Table 9-7:
Frame 5 Error Matrix

Frame 5	Class	Reference Image			
Map		No change	Change	Total	Mapped Area (000 ha)
	No change	244	3	247	18398.48

	Change	32	217	249	74.917
	Total	276	220	496	18473.40

For a stratified sample the error matrix is converted into a joint probability error matrix using the proportional counts and class areas before calculating the statistical parameters. For example for the first no change cell in Table 9-7, the probability expressed as a percentage is obtained from (244/247)*(18398478/18473395) *100 = 98.38. The results of this conversion are shown in Table 9-8 and 9-9.

Table 9-8:
Frame 5 Error Matrix of Joint Probabilities

Frame 5	Class	Reference Image			
Map		No change	Change	% of Total Area	User Accuracy
	No change	98.38	1.210	99.594	99.79%
	Change	0.052	0.354	0.406	87.19%-
	Total	98.432	1.564	100	
Producer Accuracy		99.94	22.63%		

Overall Accuracy: 98.73%

Map 9-7:
Frame 6 CRBERs HRC

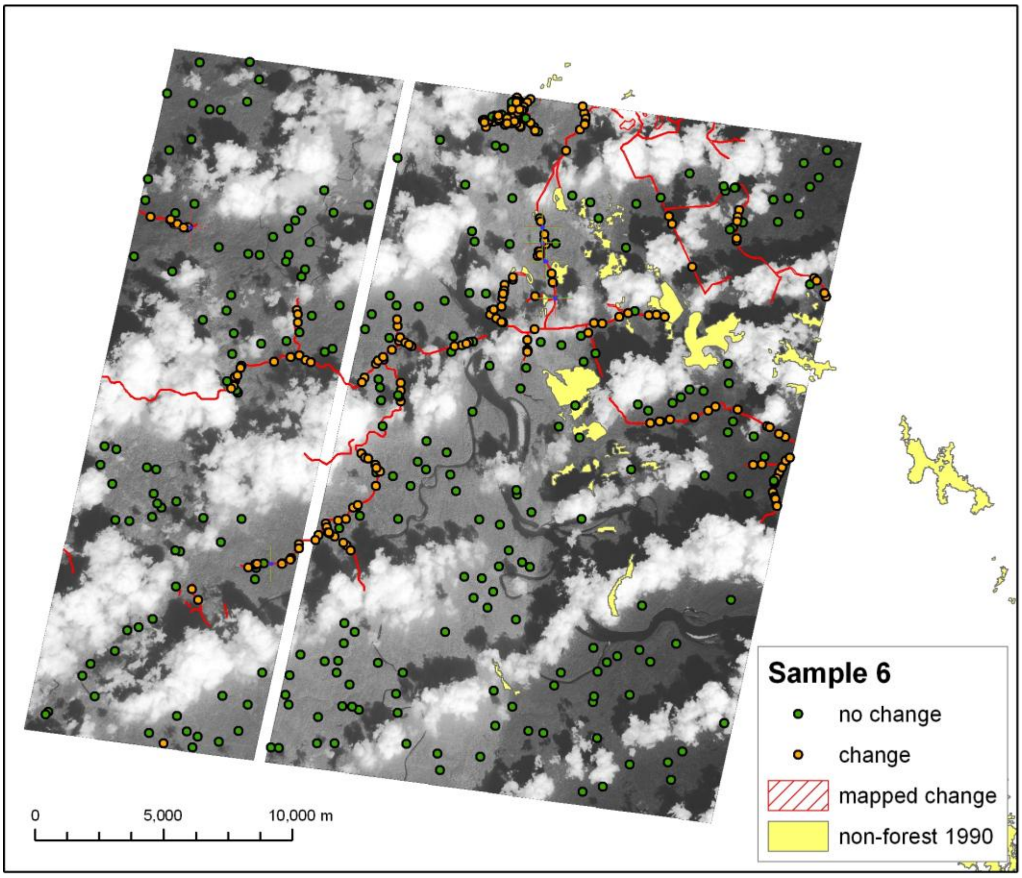


Table 9-9:
Frame 6 Error Matrix

Frame 6	**Class**	**Reference**			
Map		**No change**	**Change**	**Total**	**Mapped Area (000 ha)**
	No change	248	1	249	18398.48
	Change	5	245	250	74.917
	Total	253	246	499	18473.40

Table 9-10:
Frame 6 Error Matrix of Joint Probabilities

Frame 6	**Class**	**Reference Image**			
Map		**No change**	**Change**	**Total (%)**	**User Accuracy**
	No change	99.19	0.40	99.594	99.60%
	Change	0.01	0.40	0.406	98.52%
	Total	99.29	0.80	100.0%	
Producer Accuracy		99.99%	50.008		

Overall Accuracy: 98.79%

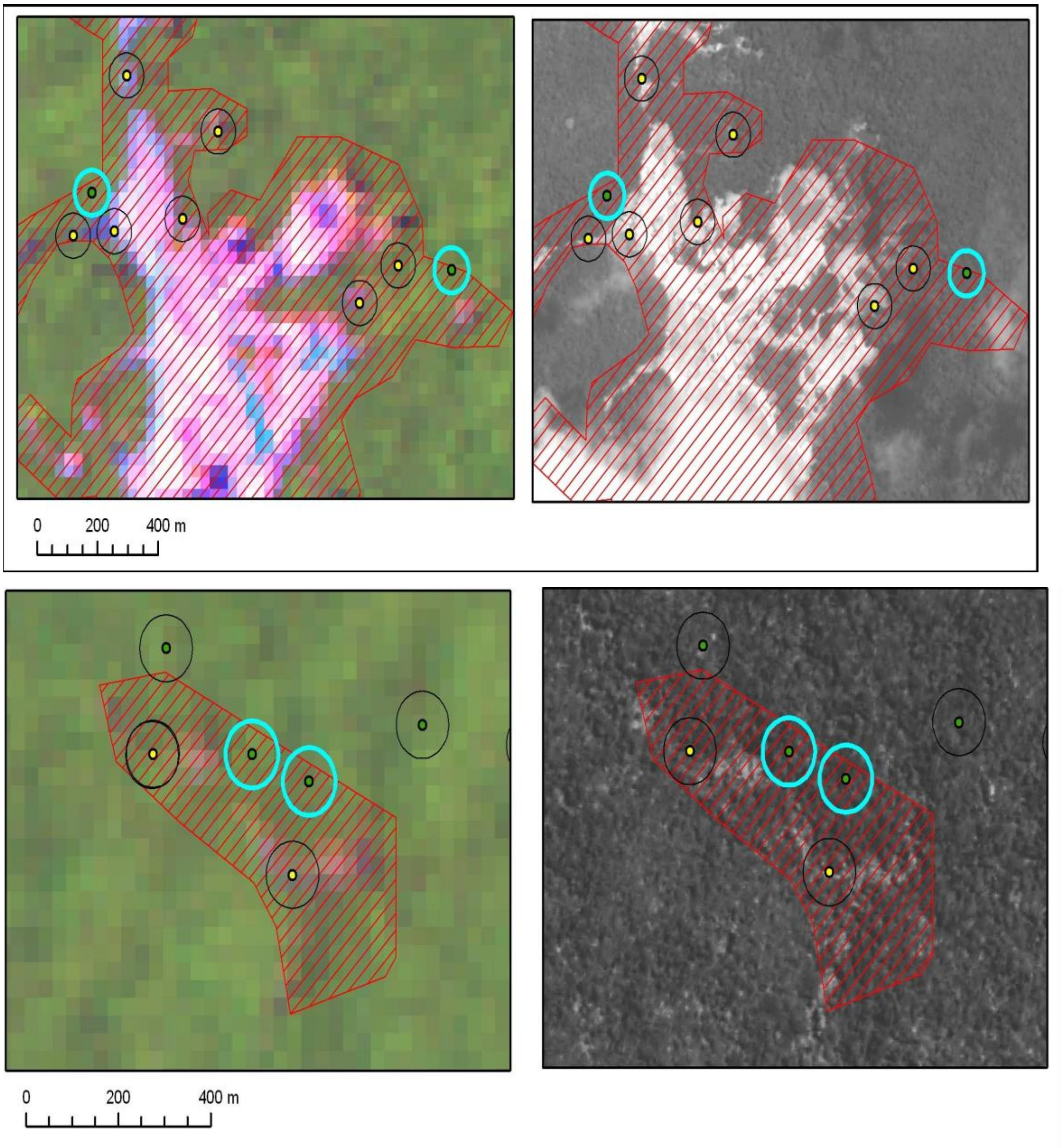
The tables show that the accuracy for the overall detection of change is in the order of 98%. This is based on using the method of assessing accuracy of the detected change within the unit of assessment. The change mapping from a user's perspective ranges from 87% to 95%, but is considerably lower (22% to 50%) from a producer's perspective.

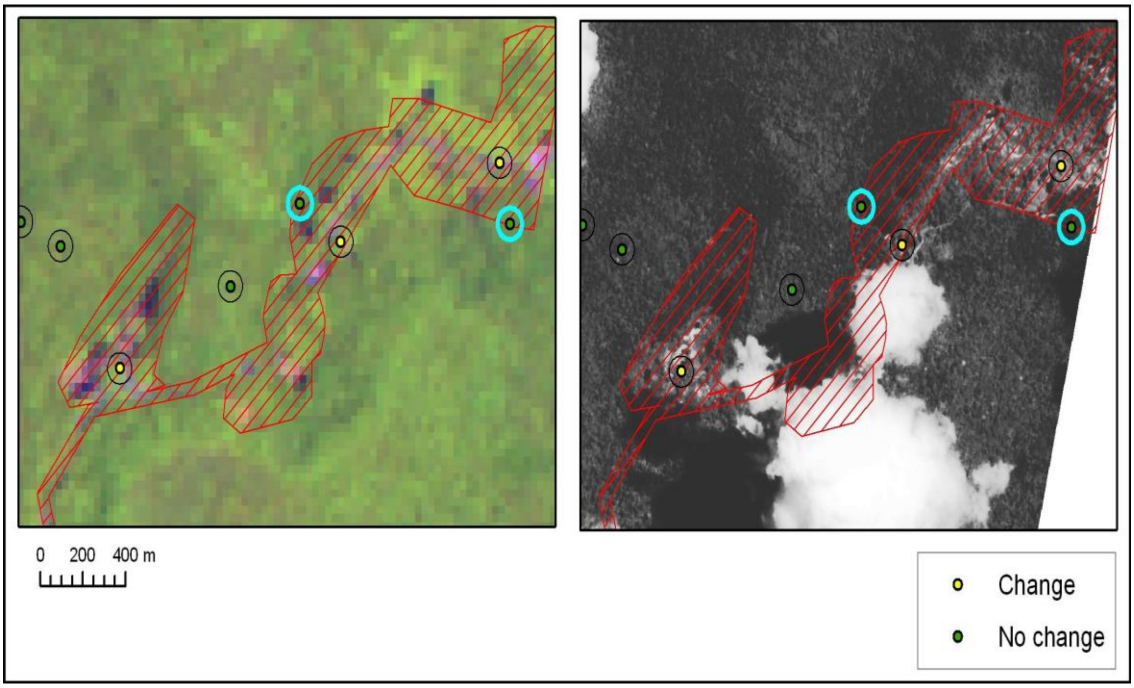
This indicates that areas have been incorrectly classified or “omitted” from the correct class. i.e. forest areas have been included as change.

The low producer's accuracy is largely attributed to generalization of the mapped boundaries of the change areas during digitization. The change areas invariably includes small forest patches (< 1 ha) and forested land along the edges, the net effect of which is an overestimation of the area of change.

The following examples show sample points near the margins of change areas are often classed as forest in the reference dataset (Figure 9-1). The left image is Landsat (30 m resolution) and right image CBERs HRC 2.7 m resolution.

Figure 9-1
Examples of Sample Points Misclassified as Forest





Estimates of the uncertainty for the areas of change are not attempted here due to the non-probabalistic nature of the sampling and the small sample size.

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. The intention is that these interim measures will be phased out as the MRVS is established[41].

The basis for comparison of a majority of the interim measures is the 30 September 2009 benchmark map[42]. 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.

A summary of the key reporting measures and brief description for these interim measures are outlined in Table 10-1. The calculations to determine the rate of deforestation (measure ref. 1) has been covered in section 8. Outputs and results are provided for the Intact Forest Landscape (measure ref. 2) and forest management indicators (measure ref. 3 and 4) in this section. Where applicable a reference measure has been included. For measures such as forest degradation this is the first time this has been calculated.

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

Table 10-1:
Interim Measures

Measure Ref.	Reporting Measure	Indicator	Reporting Unit	Reference Measure	Year 1 Period	Difference
1	Deforestation Indicator	Rate of conversion of forest area as compared to the agreed reference level	Rate of change (%)/yr^{-1}	N/A	0.06%	N/A
2	Degradation Indicators	National area of Intact Forest Landscape (IFL)	Million ha	N/A	7.60[43]	N/A
2b		Determine the extent of	ha	N/A	92,413[44]	N/A

[41] 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.

[42] 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.

[43] Note that in the January 2011 version of the Interim Measures Report (IMR), the definition of intact forests was applied with selectively logged/low intensity logged forests being included as intact forests. The definition of intact forests, taken from www.intactforests.org, outlines that these are to be treated as background influence. As part of the inclusive and participatory nature of the MRVS process, following verification activities and comments from stakeholders with specific recommendations regarding this indicator, allocated state forest areas are excluded from the intact forest landscape layer and reported as such, in this revised version of the IMR.

[44] This indicator as is required by the Joint Concept Note of the Agreement between Guyana and Norway, includes a buffering of 500 m 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 agriculture, 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

Measure Ref.	Reporting Measure	Indicator	Reporting Unit	Reference Measure	Year 1 Period	Difference
		degradation associated with new infrastructure such as mining, roads, settlements post the benchmark period				
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	000'm^3/yr^{-1}	705.347[45]	695.043[46]	-10.304
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)	000'm^3/yr^{-1}	105.802[47]	6.796[48]	99.006
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[49]	N/A
6	Emissions resulting from subsistence	Emissions resulting from communities to meet their local needs may increase	Not considered relevant in the interim period.	N/A	N/A	N/A

degradation in the interim. Note: in the January 2011 version of the IMR, 77,766 ha were recorded for this indicator. This total was since updated to record additional areas for Year 1 that were not included in the eligible areas for buffer for this indicator. This change in no way affects the gross deforestation indicator or any other indicator. The updating is specific to this indicator.

[45] Includes production volume and includes additional volume accounted for by Default Expansion factor of 25% as collateral damage. Production volumes are recorded in a custom designed database which is updated monthly by the GFC, subject to internal verification, and is backed up and stored monthly, offsite.

[46] Computed for the period October 1, 2009 to September 30, 2010 and includes collateral damage. 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. Note that in accordance with the Forest Legislation, production for the purpose of royalty is computed using what is termed a ‘hoppus/quarter girth’ measurement which assumes a factor of 78.25% of the “true” volume. Since this is a legislative requirement, the GFC had previously reported, in the January 2011 version of the IMR, this production level. One recommendation of the verification process was to record the harvested volume for this indicator. As a means of addressing this recommendation, the GFC has increased the previously reported production volumes, for both the historic and current year, by a factor of 1.278 in the case of logs and doubling the total lumber volume to account for the conversion process. This therefore represents the volume harvested. Total production in year 1 was also adjusted for minor changes in procedural and illegal logging databases.

[47] Assumes a level of 15% on harvested production of that total that includes collateral damage of: 705,347 m^3. 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. Note that in keeping with the recommendation from the verification process to report on “true” volume and not “hoppus” volume, this total was re calculated to take account of collateral damage in both historic and year 1 totals. Additionally, minor adjustments were made to the total of illegal logging and procedural breaches volumes and incorporated in year 1 total (in all cases less than 5% materiality).

[48] Rate of illegal logging for the forest year October 2009 to Sept 2010 is informed by a custom designed database that is updated monthly, and subject to routine internal audits.

[49] Degradation from forest fires are taken from an average over the past 19.75 years. In the January 2011 version of the IMR, a total of 1,700 ha were used as a result of rounding to one decimal point. Following the verification process, recommendation was made to use two decimal points thus resulting in the change from the use of 19.8 years to 19.75 years in the average tally.

Measure Ref.	Reporting Measure	Indicator	Reporting Unit	Reference Measure	Year 1 Period	Difference
	forestry, land use and shifting cultivation lands (i.e. slash and burn agriculture).	as result of inter alia shorter fallow cycle or area expansion.				
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

10.1 Interim Reporting Indicators

The following provides as 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

Emissions from the loss of forests are identified as among the largest per unit emissions from terrestrial carbon loss in tropical forests. Above ground biomass and below ground biomass combined represent approximately 75% of total carbon[50.]

Interim Performance Indicators

- Rate of conversion of forest area as compared to agreed reference level as set out in the joint concept note.
- 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.

[50] Indicative figures C/ha for tropical low land forest in Boliva (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 biomass.

Monitoring Approach

The approach uses medium resolution images to identify new areas of development at a one hectare scale. All areas identified during the creation of the benchmark will be revisited to monitor the transition of these areas.

10.3 Degradation Indicators

There are a series of indicators that were monitored for forest degradation. These are examined below.

10.3.1 Intact Forest Landscape

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

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

Using the above definition the extent of Intact Forest has been determined at the end of the year 1 period (September 2010).

A set of replicable criteria by Potapov et al. (2008) were used to locate areas that satisfy the IFL definition. The criteria are separated into two groups to be applied in sequence.

The first group of criteria were used to eliminate developed area, namely:

- 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;
- Industrial activities during the last 30-70 years, such as logging, mining, oil and gas exploration and extraction, peat extraction, etc

The second group of criteria were used to delineate the patches of IFL:

- larger than 50 000 hectares
- at least 10 km wide at the broadest place (measured as the diameter of the largest circle that can be fitted inside the patch)
- at least 2 km wide in corridors or appendages to areas that meet the above criteria.

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

Note that in the January 2011 version of the Interim Measures Report (IMR), the definition of intact forests was applied with selectively logged/low intensity logged forests being included as intact forests. The definition of intact forests, taken from www.intactforests.org, outlines that these are to be treated as background influence. As part of the inclusive and participatory nature of the MRVS process, following verification activities and comments from stakeholders with specific recommendations regarding this indicator, allocated state forest areas are excluded from the intact forest landscape layer and reported as such, in this revised version of the IMR.

Degradation Monitoring Datasets & Approach

The monitoring approach adopted uses medium resolution satellite images and supplementary GIS layers to map and identify the extent of the following features at 30 September 2009. 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 (http://en.wikipedia.org/wiki/Guyana).

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 including allocated concessions and the associated infrastructure from 1990 to 30 September 2010 are subtracted from the IFL. Mining concessions and dredge locations were provided by GGMC in a GIS format. New and historical mining activities were mapped from medium resolution satellite imagery.

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

Industrial-scale Exploitation of Resources

Industrial-scale exploitation of timber, peat extraction and oil exploration is 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 are not subtracted from the IFL. Shifting cultivation areas have been defined from medium resolution satellite imagery and areas under SFM are held by GFC in GIS format.

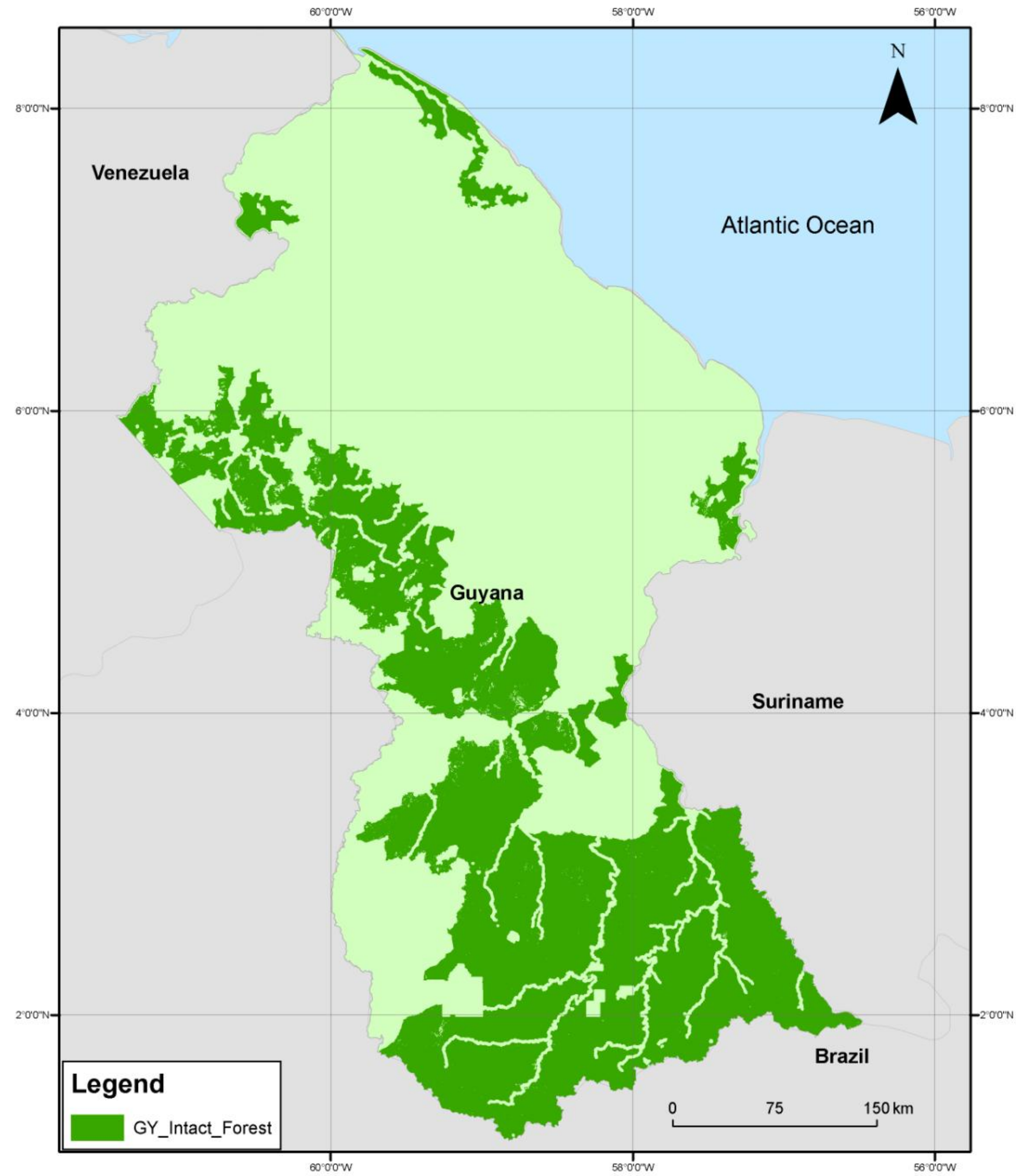
Benchmark Intact Forest Landscape

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.

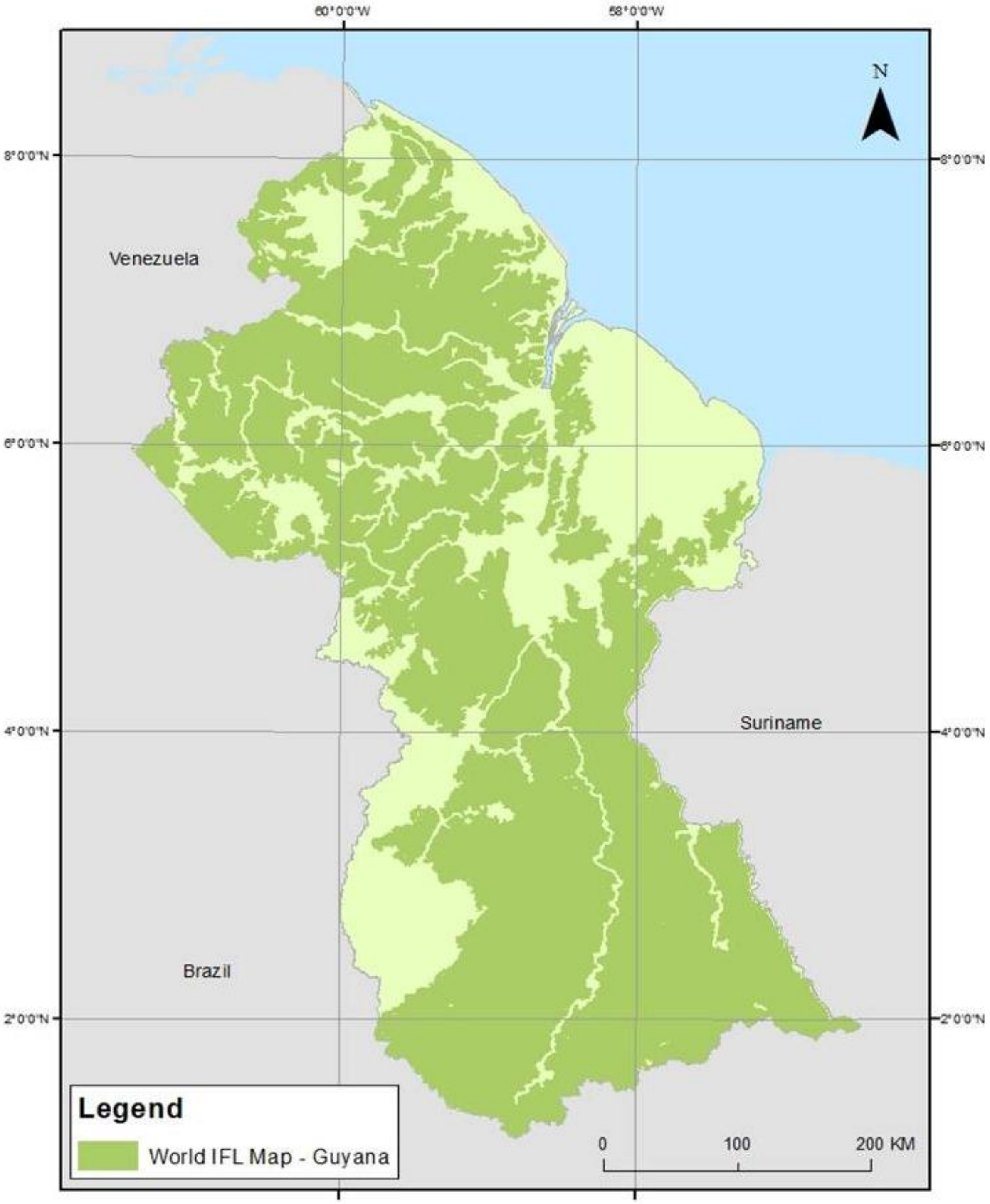
The following map shows the extent of the first IFL as created for the Year 1 period. At this point in time the total intact forest landscape area in Guyana is estimated at 7.60 million ha. This area excludes any areas within the SFE that are subject to selective or allocated for selective logging as at 30 September 2009.

This is less than the 14.5 million ha as calculated from the Global Intact Forest Layer (www.intactforests.org). This is because the global product (created in 2000) was developed from 2000 era satellite imagery and regional-scale GIS datasets. It will not reflect changes such as the increase in mining activity that has occurred post 2000.

Map 10-1:
Guyana Year 1 Intact Forest Landscape Map



Map 10-2:
Global Intact Forest Map 2000



10.3.2 Carbon Loss as Indirect Effect of New Infrastructure

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 is the case as there are a very limited number of high resolution scenes available over Guyana. It is anticipated that future mapping and field efforts will concentrate on evaluating the extent of degradation associated with deforestation activities.

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 then a buffer of 500 m is applied from the external edge of the feature. A 50% loss in biomass is assumed.

The area of degradation 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 but it is a provision as required by the interim indicator of the Joint Concept Note. Degradation will be comprehensively mapped when the full MRVS is operational. This is therefore a conservative measure of degradation in the interim. It should be noted that in the January 2011 version of the IMR, 77,766 ha were recorded for this indicator. This total was since updated to record additional areas for Year 1 that were not included in the eligible areas for buffer for this indicator. This change in no way affects the gross deforestation indicator or any other indicator. The updating is specific to this indicator.

A sensitivity analysis was performed to provided an understanding of the area of degradation using various buffer widths for the year 1 period and historically from 2000-2009. The year 1 results are presented in Table 10-2 and historical results are presented in

Table 10-3

Table 10-2
Year 1 Degradation Based on Buffer Width

	500m	300m	200m	150m	100m
	(ha)				
Total area	92,413	51,663	32,950	24,094	15,590
Mining	72,361	39,613	24,895	18,046	11,558
Roads	21,256	12,407	8,194	6,120	4,060
Area overlap	1,205	357	140	72	28

Table 10-3
Annualised Historical Degradation Based on Buffer Width

	500m	300m	200m	150m	100m
	(ha)				
Total area	53,675	33,040	22,319	16,837	11,280
Mining	19,194	11,494	7,652	5,726	3,803
Roads	36,148	22,136	14,917	11,244	7,530

10.3.3 Forest 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 and timber imports and exports. The following information is documented by the GFC and available for review for the period 1 October 2009 to 30 September 2010:

1. Production by forest concession
2. Export by company/individual
3. Total production

The reporting requirements include data on extracted timber volumes post 2008 and will be verified in the next reporting period by independent forest monitoring (IFM). 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 (to be established) 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 station level, at concession level and supplemented by random monitoring by the GFC's Internal Audit Unit and supervisory staff. At all active large concessions, resident forest officers perform the function of ensuring that all monitoring and legality procedures are strictly complied with. In instances of breach, investigation is conducted and based on the outcome, action is instituted based on the 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 office 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 for 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 programatic 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 authorise 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 (Chainsawn 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. The total of harvested volume is 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.

Note that in accordance with the Forest Legislation, production for the purpose of royalty is computed using what is termed a 'hoppus/quarter girth' measurement which assumes a factor of 78.25% of the "true" volume. Since this is a legislative requirement, the GFC had previously reported, in the January 2011 version of the IMR, this production level. One recommendation of the verification process was to record the harvested volume for this indicator. As a means of addressing this recommendation, the GFC has increased the previously reported production volumes, for both the historic and current year, by a factor of 1.278 in the case of logs and doubling the total lumber volume to account for the conversion process. This therefore represents the volume harvested. Total production in year 1 was also adjusted for minor changes in procedural and illegal logging databases.

Logging Damage– Default Factor

There are basically two types of logging damage: canopy damage and ground damage.

Canopy loss results mainly from tree felling activities, with trees with large crowns creating relatively more damage. Tree felling also occurs for road construction, skid trail construction and construction of log markets (or log decks). Felling causes mainly crown injuries or stem breakage. Road and skid trail construction and skidding cause damage to bark and uprooted trees.

Ground damage, defined as the ground area subject to mechanical disturbance, also occurs from road works, skidding and log deck operations. Most authors however used the number of trees damaged or gap size to quantify logging damage.

According to Van der Hout (2000) felling trees creates more than one opening, at the place where the crown of the tree was removed and the place where the crown of the tree landed.

There is a strong link between logging intensity and the amount of damage created (Sist, 2000). Sist (2000) relates that generally for Latin America a logging intensity of 5-7 trees/hectare (equivalent to volume of 30-50m^3) leads to damage of 25-40% of the original population of trees (in terms of trees injured or killed).

Based on the Latin American Study, logging damage/collateral damage for Guyana's current logging intensity (at a maximum of 10 m^3/ha), is estimated to be 25%. This default factor of logging/collateral damage is applied to the total production to result in an additional volume accounted for.

In every case researched, reduced impact logging causes about half the logging damage as conventional logging.

The table below summarises the mean volume of timber, fuelwood and plywood for the period 2003-2008 and the annual extracted volume for the reporting period October 1, 2009 to September 30, 2010.

The application of this factor has as a shortcoming, the use of the extracted volume instead of the original population. Winrock International is currently in the process of scientifically establishing a rate of logging damage to be applied to the MRVS aspect of forest degradation. Issues such as total forest carbon stock per forest strata, forest carbon stock per extracted stem, and the relationship between extracted volume and damage to original population are being established by work that is being done by Winrock International at this present moment. Whilst this is ongoing and will be completed by end of 2011, the GFC has applied an expansion factor of 25% for collateral damage and has applied this to extracted volume. It is the intention that as part of the continuous improvement process, the logging damage factor scientifically established for Guyana, will be used in upcoming annual assessments.

The reported difference between the annual mean for the period 2003-2008 and the assessment year of October 1, 2009 to September 30, 2010 is shown in Table 10-4. For this period the reported volume extracted has reduced by 14 700 m^3.

Table 10-4:
Timber Harvesting Statistics

Period	**Description**	**Volume ('000 m^3)**
October 1, 2009 - September 30, 2010	Annual volume extracted	556.034
2003-2008	Mean volume 2003-08	564.278
Difference		-8.244

Table 10-5:
Timber Harvesting Statistics including Collateral Damage[51]

Period	**Description**	**Volume ('000 m^3)**
October 1, 2009 - September 30, 2010	Annual volume extracted	695.043
2003-2008	Mean volume 2003-08	705.347
Difference		-10.304

10.3.4 Emissions resulting from Illegal Logging Activities

It is required for areas and processes of illegal logging to 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 historic reporting, the default level of 15% of harvested production of 705,347m^3 is used in the absence of a complete database of illegal activities being in place. 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 historic total assumes a level of 15% on harvested average annual production over the period 2003-2008 that includes collateral damage of 705,347m^3. 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. In keeping with the recommendation from the verification process to report on “true” volume and not “hoppus” volume, this total was re calculated to take account of collateral damage in both historic and year 1 totals. Additionally, minor adjustments were made to the total of illegal logging and procedural breaches volumes and incorporated in year 1 total (in all cases less than 5% materiality).

The rate of illegal logging for the forest year October 2009 to Sept 2010 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.

[51] Default expansion factor of 25% as collateral damage used.

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.

10.3.5 Emissions from Anthropogenic Forest Fires

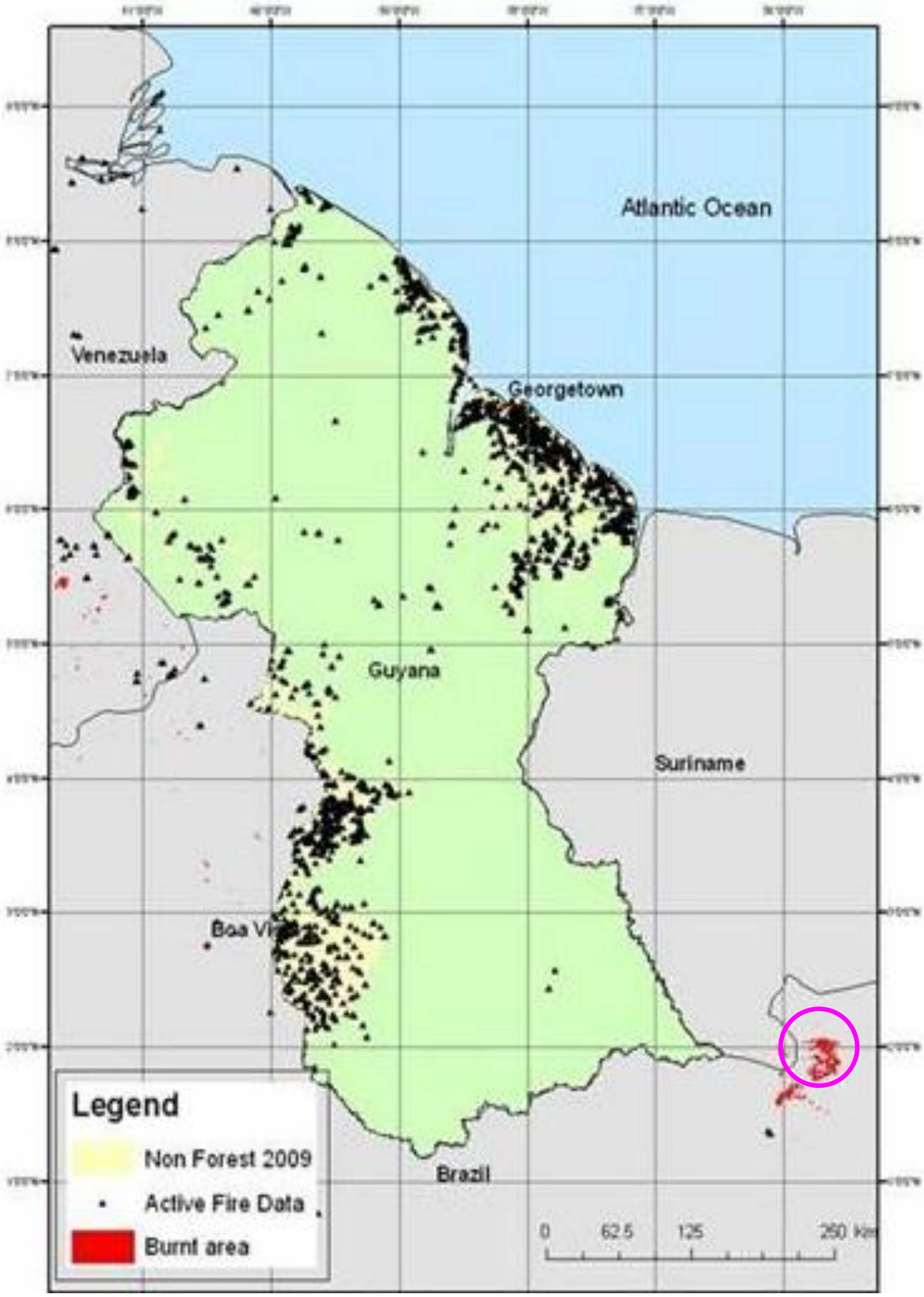
The FIRMS fire point data from MODIS was the main dataset used to assess changes in the burnt area (Map 10-3). Any points were checked against the Landsat imagery to validate the presence of fire and establish the extent. Only a few small fires located on the coast, were detected by the MODIS (500 m) burnt area dataset. Consequently, this dataset was not used extensively. Larger-scale fires are observed on Brazil/Suriname border (circled on Map 10-3).

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[52]. This equated to a mean annual area of 1 706 ha. This area has been used as the Year 1 value. The largest area burnt occurred between 1990 and 2000. This trend coincides with a prolonged dry period caused by the El Niño weather pattern.

In the January 2011 version of the IMR, a total of 1,700 ha were used as a result of rounding to one decimal point. Following the verification process, recommendation was made to use two decimal points thus resulting in the change from the use of 19.8 years to 19.75 years in the average tally.

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

Map 10-3
FIRMS Fire & Burnt Area Data 2009-2010



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APPENDIX 1

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[53], 7.1, 7.2. 8.1	Class 6
	Plantations	Locations in GFC's GIS	Area insignificant
Grassland	Savannah <30% cover	Non forest classes still to be mapped	
	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.

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

[53] This class (1.7) has also been identified as potentially threatened by fire.

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[54]. However, as the vegetation map appeared to be correct in most instances no further changes were made.

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

The map was finally produced in three sizes, A4 (letter), A3 (tabloid) and A0 (1: 1 000 000). TIFF & JPG versions for the GFC web page were also produced (See The Map in Appendix 4).

[54] The rivers base layer has subsequently been improved as part of the MRVS implementation

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

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).

1.2 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.

1.3 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.

1.4 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.

1.8 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;

2.1 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.

2.2 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.

2.3 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. *Eperua falcata* 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, Ormosia coutinhoi, Eschweilera corrugata, Aspidosperma excelsum, Terminalia amazonia, Chamaecrista adiantifolia, Chamaecrista apocouita, Swartzia* spp., *Dicymbe altsonii* (west Guyana only), *D. corymbosa* (ibid.), *Manilkara bidentata* (Pomeroon-Waini waterdivide) and *Pouteria*.

2.4 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.

2.5 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*.

2.6 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

3.1 Open swamps

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

3.2 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, Macrolobium acaciifolium, 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.

3.3 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

4.1 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

5.1 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, Palicourea rigida*, *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

6.1 Xeromorphic scrub

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

6.2 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.*

6.3 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.

6.4 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

8.1 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.

1.5 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.

1.6 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).

1.7 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: *Cereus hexagonus, Melocactus smithii, Cnidoscolus urens, Cyrtopodium glutiniferum* and *Portulaca sedifolia*.

7.1 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.

7.2 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 2

Joint Concept Note

Joint Concept Note on REDD+ cooperation between Guyana and Norway

Section 1: 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[1]), the protection of biodiversity, and enhancement of sustainable, low carbon development. This Joint Concept Note constitutes the framework for taking this cooperation forward. Specifically, this concept note addresses Paragraphs 2 (c), 3 and 4 of the MoU signed between Guyana and Norway, to enable the acceleration of Guyana's REDD-plus efforts, based on the results of which Norway will start providing financial support. Being aware that REDD-plus is a new concept, and that this partnership is in the forefront of developments, Guyana and Norway – while considering that this Joint Concept Note clearly lays out their agreed positions as of November 2009 – will also be open to revising and further developing its content to reflect increased insights as the Partnership, and other related efforts, moves forward and lessons are learned.

The Norwegian financial support will be channeled through a multi-contributor financial mechanism (the Guyana REDD-plus Investment Fund, GRIF) which will be run by a reputable international organisation. The support will finance 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. This is described in Section 4.

The level of support will depend on Guyana's delivery of results as measured against two sets of indicators:

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1 As defined in the Bali Action Plan (2/CP.13).

- *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 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. A timeframe for when and how this will happen will be established in 2010.

The contents of this concept note, including both sets of indicators above, 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 developments in negotiations under the UNFCCC. The Government of Guyana is responsible for providing the necessary data for assessing performance against the given indicators.

Section 2: Indicators of Enabling Activities

The Governments of Guyana and Norway have decided that the commencement and annual continuity of result-based financial support from Norway will depend on agreed progress, as described below, regarding the following seven 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 in 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.

- **Continuous multi-stakeholder consultation process:**

The LCDS, including the REDD-plus strategy and prioritized LCDS funding needs, will continue to be 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. Guyana's policy is to enable indigenous communities to choose whether and how to opt in to the REDD-plus/LCDS process only when communities wish to do so, in accordance with Guyana's policy of respecting the free, prior and informed consent of these 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:**

The independent assessments of current forest governance and logging practices in Guyana, as performed by the Center for International Forestry Research (CIFOR) and the Food and Agriculture Organization of the United Nations (FAO), in addition to relevant legislation, policies and processes in Guyana, should form the basis for the continued development of a transparent, rules-based, inclusive forest governance, accountability and enforcement system. The development and implementation of this governance model will be integrated with the LCDS. Where appropriate, experiences from REDD-plus-relevant initiatives and projects nationally and internationally should be applied.

An outline of Guyana's REDD-plus governance development plan will be prepared by the end of 2009. A more detailed plan will be developed by October 2010, with clear requirements and timelines for its implementation. The development plan will be subject to review by an independent institution, jointly designated by the two Participants, and should include the points set out in Table 1. These points will be further developed over time, and the two Participants will adjust the Indicators of Enabling Activities annually for the subsequent year, based on the detailed REDD-plus governance development plan (RGDP).

- **Financial mechanism:**

The Guyana REDD-plus Investment Fund (GRIF) will be a multi-donor financial mechanism managed by a reputable international organization. The organization will be jointly selected by the Participants. The GRIF must be operational before any contributions can be disbursed
from Norway.

The GRIF will channel REDD-plus financial support from Norway and other potential donors to the implementation of Guyana's LCDS. Safeguards – including social, economic and environmental safeguards – as well as the fiduciary and operational policies of the organization selected, will apply, as appropriate, to all activities to be financed by the GRIF.

The Ministry of Finance of Guyana will be responsible for the execution of the GRIF's operations, with the selected international organization acting as manager. The manager will be responsible for ensuring full oversight of the GRIF's operations, including fiduciary obligation as trustee, and providing technical support as agreed with Guyana. One additional element which might have to be added to these safeguards is for the fund manager to ensure where appropriate that environmental impact assessments of LCDS initiatives under consideration for funding include estimates of greenhouse gas emissions impact.

Guyana and Norway believe that the fund administrator will need to apply innovative and modern capabilities to ensuring that safeguard compliance is done in an efficient and expeditious manner – a mechanism for pre-screening of thematic areas should contribute to this. The capability to enable this will be one of the criteria by which Guyana and Norway will determine who is to be the administrator of GRIF. GRIF could, if appropriate under a future UNFCCC climate change regime, over time evolve into a comprehensive climate change mitigation and adaptation fund.

- **MRV:**

A needs assessment for a national system to monitor, report and verify (MRV) emissions or removals of carbon from Guyana's forest sector shall be developed. The MRV-system must provide the basis for reporting in accordance with the principles and procedures of estimation and reporting of carbon emissions and removals at the national level as specified by the IPCC Good Practice Guidelines and Guidance for reporting on the international level, as well as meeting the particular data needs of the national RGDP.

A road map for the national MRV-system will be developed. The plan will describe the process towards establishing the system, including timelines, milestones and cost estimates.

The needs assessment and roadmap will be used as basis for dialogue and negotiations with potential providers of support and services to the national MRV system (including capacity building, methodologies for carbon estimation, technical infrastructure, etc). Where relevant, open tender processes will be applied.

Establishing a status quo/baseline database on the Guyanese forest sector, including assessments of historical and current deforestation rates at the latest by October 2010, will be a first priority.

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

The Constitution of Guyana guarantees the rights of indigenous peoples and other Guyanese to participation, engagement and decisionmaking in all matters affecting their well-being. These rights will be respected and protected throughout Guyana's REDD-plus and LCDS efforts, and 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.

- **Annual assessment and verification:**

Annual independent overall assessments will be conducted by one or more neutral expert organizations, to be appointed jointly by the Participants in consultation with the international financial institution managing the GRIF, on whether or not the REDD-plus enablers have been met; and what results Guyana has delivered according to the established indicators for REDD-plus performance. A neutral expert organization will also provide an annual status report for the Governments of Norway and Guyana. In this status report, the organization will outline its independent assessment of all Participants in the REDD+ process, and make recommendations for process and capability improvements. This will include an assessment of whoever is selected as the administrator of GRIF.

Section 3: REDD-plus performance Indicators

In the absence of an operational MRV-system for emissions or removals of carbon from Guyana's forest sector, a set of basic interim indicators will be used to assess Guyana's performance, see table 2. 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.

Until a UNFCCC methodology (or other agreed multilateral methodology) is established, the maximum sum of results-based financial support from Norway (and others) to the GRIF will be determined utilizing five elements:

- Subtracting Guyana's observed deforestation rate from an agreed interim reference level of 0.45 %.[2] ;

[2] The Conference of the Parties of the UNFCCC will set the reference levels – or the methodologies for calculating these - for a global REDD-plus arrangement. When that work is completed, Guyana's reference level will be adjusted accordingly. To set Guyana's interim reference level as a basis for Norwegian 2010 contributions to the GRIF, a methodology has been used giving equal weight to national (estimated to 0,3%* for Guyana) and collective tropical

- Calculating the carbon emission reductions achieved through reduced 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;

- 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 below. In calculating the carbon effects of forest degradation, an interim and conservatively set carbon density of 400 tC/ha[3] will be applied. Upon agreement under the UNFCCC on how to estimate and account for emissions from degradation, this approach will be adjusted accordingly;

- Applying an interim carbon price of US$5/ton CO2, as established in Brazil's Amazon Fund.

The maximum level of support for results achieved in 2009 will be calculated based on historical data as estimated by FAO and for indicators of enabling activities for 2009. Subsequent annual assessments will cover the period from 1 October until 30 September in the two years preceeding the relevant budget year, unless otherwise agreed by the Participants.

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forest countries deforestation rates (estimated to 0,6%**). Such an approach would both ensure global additionality and incentives to all significant categories of forest countries if applied overall to a global REDD-plus arrangement.

* Guyanas RPP indicates a current deforestation rate of 0.1 – 0.3%. A report by the UN REDD programme (Cedergren 2009) indicates that the figure may be 0.4% based on data on historical forest area in Guyana, but also underlines that this figure needs to be investigated further. Cedergren also makes reference to an EarthTrend study indicating 0.3% forest loss between 1990 and 2001.

** Annual percentage cover change in all tropical developing countries with positive deforestation (based on FAO FRA 2005 data on forest area and annual forest cover change 2000 – 2005).

3 The figure 400 tC/ha is based on a study by Ter Seege 2001, as refered in Cedergren, 2009. Ter Seege found a typical Guyanese forest to have an average carbon stock of 351 tC/ha. To be conservative we use 400 tC/ha.

For the sake of illustration, the maximum level of financial support based on results achieved in 2009 could be calculated as follows:

1. If Guyana's deforestation rate in 2009 is assessed to be 0.3% (of a forest area of 15 million hectares, which would be the case if indigenous groups opt in to REDD-plus and the Guyana-Norway partnership – if they do not the forest area will be lower), this is 0.15% below the reference level of 0.45%, so corresponds to 22,500 hectares of avoided deforestation;

2. Using the interim carbon stock value of 367 tCO_2 per hectare, this represents 8,257,500 t CO2;

3. At an interim carbon price of US$5/t CO2, this would translate to a maximum level of financial support of US$41,287,500.

4. Each ton of estimated increase of emissions from forest degradation– as based on the methodology described above – would lead to a decrease in level of maximum financial support of US$5.

All the above described variables will be revisited by the Participants based on improved data on deforestation rates, improved MRV capabilities, and developments under the UNFCCC and other possible international cooperation arrangements.

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 a goal of the Participants to get other Participants to join the partnership in order to make it sustainable in the long term, as it is unlikely that Norwegian support will ever equal this sum. This will enable Norwegian contributions to vary directly with performance, i.e. a reduction in estimated emissions will lead to relatively higher contributions, increases to relatively lower contributions.

The question of self-financing 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.

The Participants agree that the financial support seeks to provide incentives to avoid future deforestation, and the interim reference level has been established accordingly. While financial support will continue to be based on this reference level, 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. This level will be set through a mutually agreed process by no later than October 2010.

Section 4: Accelerating REDD+ Efforts in 2009 and 2010:

Norway's financial support to Guyana will be result-based, as set out in Sections 2 and 3. During the first years of cooperation, a portion of this support will finance specific REDD-plus capacity building activities (what the IWG-IFR refers to as "policy and participation enablers" as set out in the LCDS and FCPF documents (including Guyana's R-PP). The activities to be covered in 2009 and 2010 include:

- MRV system;
- Project Management Office and Office of Climate Change (operational costs);
- Multi-stakeholder consultation process;
- Annual verification by neutral experts that the REDD-plus enabling activities have been completed as appropriate;

- Annual verification by neutral expert(s) of the maximum amount due to Guyana according to the indicators for REDD-plus performance; and
- The establishment of a system for Independent Forest Monitoring (IFM).

The contributions to capacity building will decrease over time, resulting in a gradually larger emphasis on financing implementation of activities under the LCDS. The funding of some of the above activities could be done in partnership with donors and other international partners and the Government of Guyana. To ensure consistency and avoid overlap, Guyana will transparently communicate how each element of the LCDS is being supported by various contributors.

- The Participants agree that the following steps – in addition to other elements – would constitute positive contributions to Guyana's forest governance, and should thus be in place before financial support commences:
    - first formal steps taken by Guyana to establish independent forest monitoring by a credible, independent entity;
    - an outline of the REDD-plus governance development plan, which includes the issues listed below.
- The Participants also agree that as well as independent forest monitoring, Guyana's engagement with other forest-related international processes could assist in building better mechanisms for ensuring high national and international standards for trade in forestry products. In line with its declared intention to engage with the European Union Forest Law Enforcement, Governance and Trade (FLEGT) processes, and the Extractive Industries Transparency Initiative, the Government of Guyana will by the end of 2009:

- start a formal dialogue with the European Union with the intent of joining its Forest Law Enforcement, Governance and Trade (FLEGT) processes towards a Voluntary Partnership Agreement (VPA);
- start a formal dialogue with the Extractive Industries Transparency Initiative (EITI) or an alternative mechanism agreed by the Participants to further the same aim as EITI.

Table 1: Contents of REDD+ Governance Plan

The REDD-plus governance development plan should include the following points:

- Transparency and accountability are key to success in any REDD-plus effort. REDD-plus-relevant decisions and data should be publicly available. Guyana recognizes the need to demonstrate international standards, and therefore aims to implement IFM. Data generated through IFM and EITI (or an alternative mechanism agreed by the Participants to further the same aim as EITI) could also serve as input and/or verifiers to the forest carbon accounting system. Guyana has also decided to enter into a dialogue with the European Union with the purpose of entering the FLEGT program; through a Voluntary Partnership Agreement;

- The development of a system for reporting on the multiple benefits of REDD-plus, including on measures to protect biological diversity, improved livelihoods, good governance, and how the Constitutional protection of the rights of indigenous peoples and local communities are facilitated within the framework of Guyana's REDD-plus efforts.

- The development of a national[4], inter-sectoral, land use planning system in order to avoid national leakage, with REDD-plus as the overarching goal and with specific emphasis on managing the impacts of infrastructure development and agricultural expansion on forests;

- The development of valuation systems for determining the costs and benefits of different alternatives and courses of action on the forest resource, related to environmental benefits and new alternative uses of forests, and also more classical uses and standing timber values;

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[4] Although the land use planning system will be developed on a national level, that does not imply opt-in of indigenous lands until their free, prior, and informed consent has been gathered.

- A strengthened forest monitoring and control system, focusing on all significant drivers of deforestation and degradation, including logging, mining and agriculture activities on forest lands. Monitoring and control activities must be intensified in areas identified as or assumed to be of high risk of deforestation and forest degradation, for example in border areas or adjacent to infra-structure developments;

- Establishment of criteria for identifying priority areas for biodiversity within Guyana's forests, to inform the overall land use planning system and especially the REDD-plus component of the LCDS. Policies should be put in place for concession holders in the different REDD-plus-relevant areas, such as logging, mining and agriculture, to adopt best practice, including with regards to protecting biodiversity. Indicators to monitor progress should be put in place, e.g., increases in areas with certified REDD-plus-relevant concessions; and over time company compliance with EITI or equivalent commitments if appropriate. Identified forest biodiversity priority areas should also be targeted for expanded conservation/protection efforts;

- The development of a multi-year plan to continue the process of titling, demarcation, and extension of Amerindian lands when requested to do so by Amerindian communities, with the aim of completing the process for outstanding requests. The Government of Guyana has expressed the urgency of accelerating this process, and sees REDD-plus as an opportunity to achieve this;

- The development of the mechanisms by which distribution of REDD-plus funds will occur, as set out in the LCDS. The distribution system will be publicly available and will be reported on annually. The Government of Guyana has stated that all REDD-plus funds that accrue for indigenous peoples will be allocated to indigenous communities. The RGDP will set out more detail about how this will work. The system will recognize the stewardship role of indigenous peoples protecting forest on their traditional lands.

- An overview of all funding directed to activities relevant to REDD-plus/LCDS efforts in Guyana shall be made public and be updated on the LCDS website, in order to ensure maximum effectiveness of the funds and to provide transparency concerning contributors to Guyana's REDD-plus/LCDS efforts; and

- The mandating and where appropriate establishment of operational institutions tasked with and given authority to implement and coordinate strategic activities of the LCDS as well as Guyana's REDD-plus plans as part of the LCDS, as prioritized by Guyana through its multi-stakeholder consultation process. These institutions will also coordinate national and international actors involved in efforts relevant to REDD-plus and be responsible for identifying human resources needs in the various entities involved in the REDD-plus governance process.

- The continuation of the institutionalized, transparent, multi-stakeholder processes to ensure that grievances can be addressed as an intrinsic part of Guyana's ongoing REDD-plus efforts.

Table 2: Interim Indicators for REDD+ performance in Guyana[5]

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. 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 on 3 February 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 (eg. new roads, settlements, pipelines, mining/agriculture activities etc.)	Activity data on change in forest land

5 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.

Degradation indicators:				
Loss of intact forest landscapes[6]	Degradation of intact forest through human 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 total area of intact forest landscapes within the country should remain constant. Any loss of intact forest landscapes area shall be accounted as deforestation with full carbon loss.	Using similar methods as for forest area change estimation.	Changes in carbon stocks in 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-	All areas under forest management should be rigorously monitored and activities documented (i.e. concession activities, harvest estimates, timber imports/exports).	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

[6] **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)

	term.	Increases in total extracted volume (as compared to mean volume 2003 – 2008) will be accounted as increased forest carbon emissions[7] 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.		

[7] 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.

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, reservoirs) shall be accounted with a 50% annual carbon loss through forest degradation.	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
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	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	Changes in carbon stocks in forests remaining as forests

	international climate change mitigation policies		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.	
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	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		Activity data on change to forest land and changes in carbon stocks in forests remaining as forests

	increase the sequestration of atmospheric carbon.	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.		

APPENDIX 3

Image Data

Temporal Coverage

The following maps (Figure 11-1 and Figure 1-2) show the temporal distribution of images up to the end of the each analysis period. The objective was to capture all changes belonging to a specific period. Figure 11-1 shows images acquired for the end of the benchmark period (Sept 30 2009). The latest images available for this period over Guyana span from August 2009 to first week of October 2009. A majority of land area was covered in September 2009. The cloud cover map for this period is provided in section 7.1. Only 1.8% of the land area was obscured by persistent cloud. These areas were assessed using MODIS and radar images.

Figure 11-1:
Temporal Distribution of Benchmark Period Images

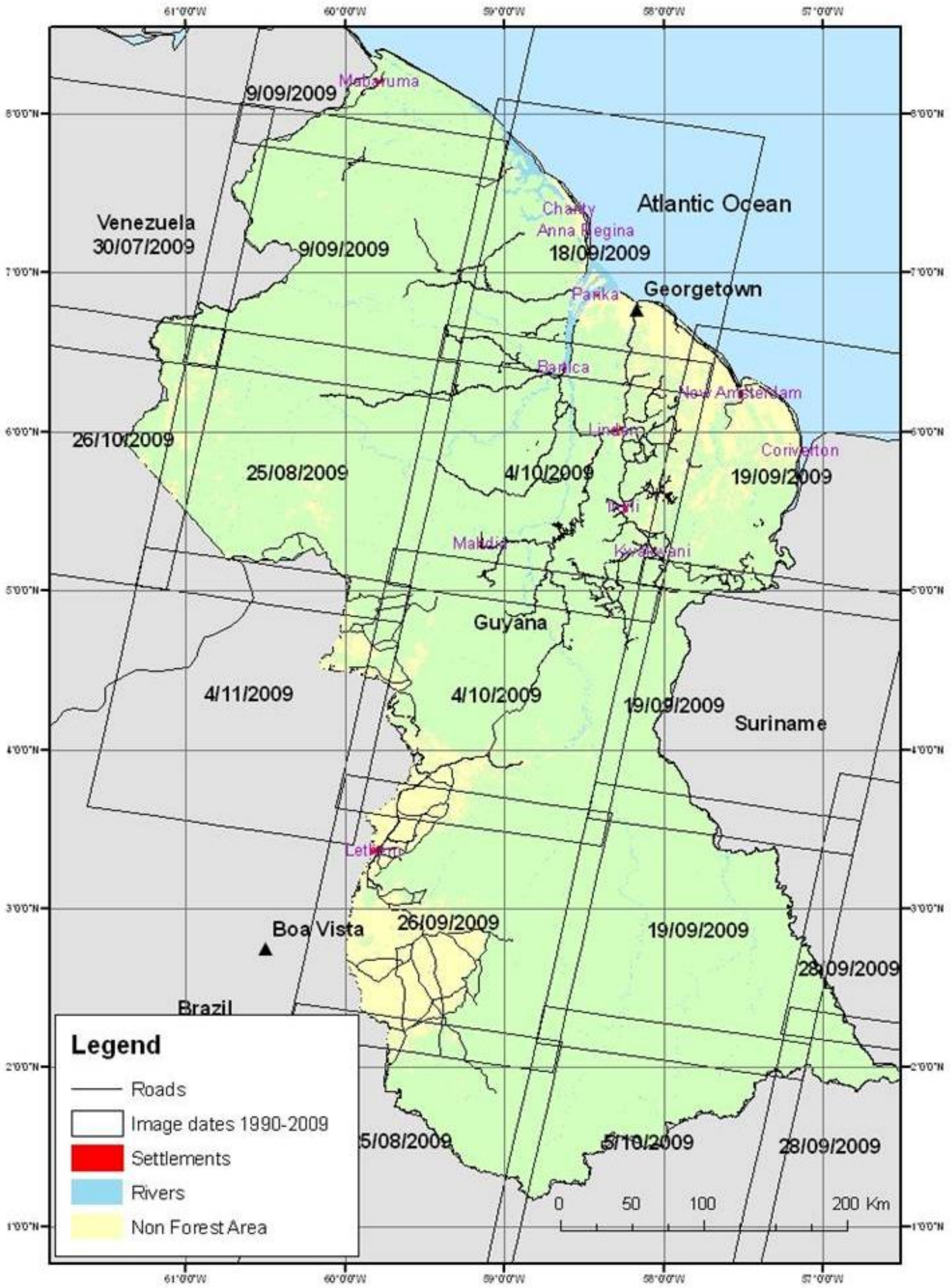
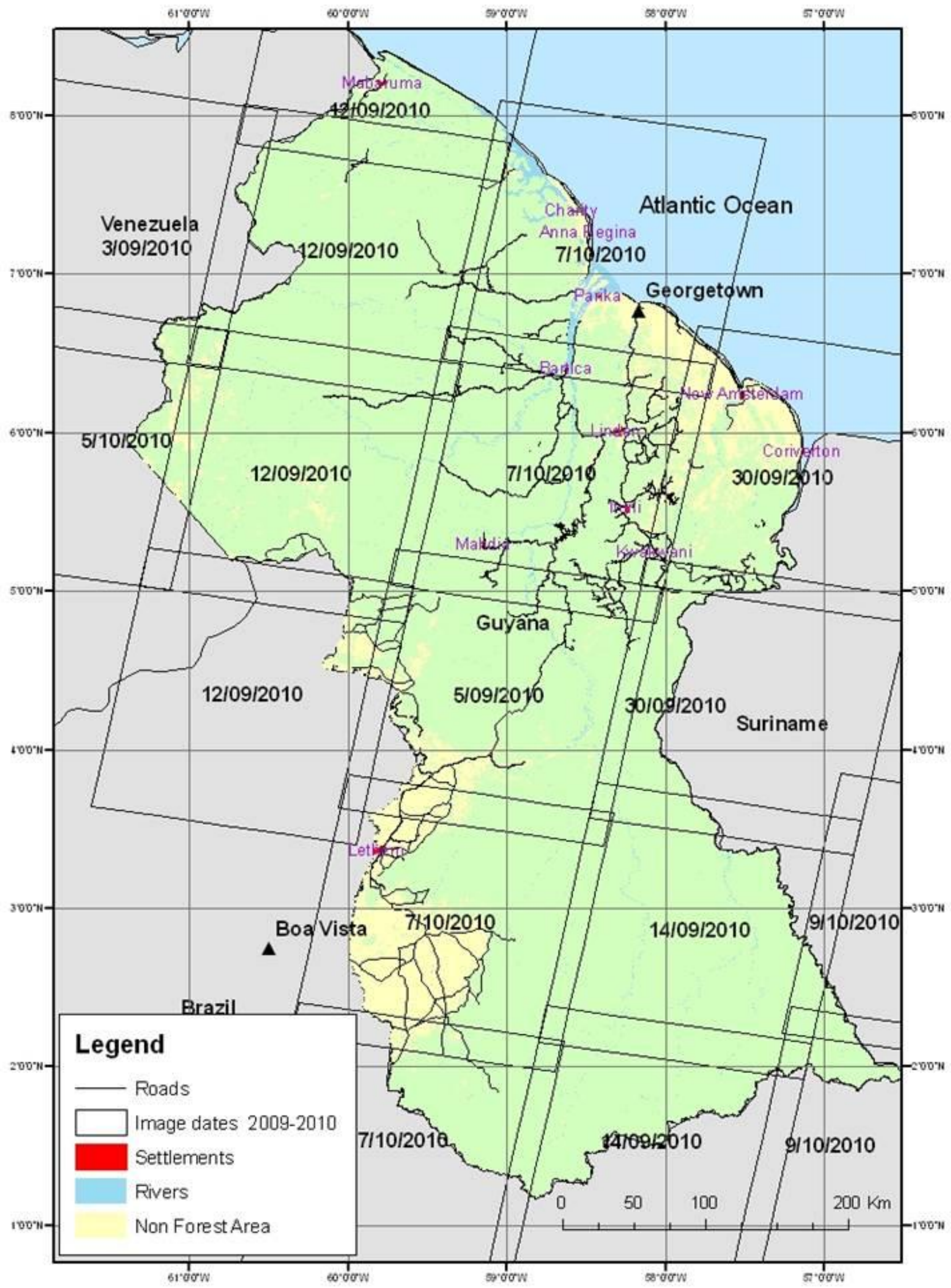


Figure 1-2 shows images acquired at the end of the Year 1 period (Sept 30 2010). The latest images available for this period over Guyana span a two month period from September 2010 to first week of October 2010. A majority of land area was covered in September 2010. The cloud cover map for this period is provided in section 7.1. Only 2.9% of the land area was obscured by persistent cloud. These areas were assessed using MODIS and radar images.

Figure 1-2:
Temporal Distribution of Year 1 Images



The following table describes the naming conventions and column headings for the image catalogue shown in Table 2. This is a dynamic archive and will be updated as more imagery is acquired. A few images used to support the analysis including MODIS, CBERS, ASTER and ALOS are still to be added to the image catalogue. All of the imagery listed in the following table has been archived.

Table 1:
Catalogue Key

Image Stack Name	Image name in the following format: Satellite (2-3), Path (4), Row (1-3) _ Image Date (YYMMDD)
Mapping Stream	The change detection period the image falls into (Benchmark or Year 1)
Data Provider	The name of the data provider.
Cloud cover	A cloud cover percentage estimate for the scene.

Table 2:
Image Catalog

Stack name	Mapping Stream	Data Type	Data Provider	Cloud Cover
L5P229R58_870815.tif	1990	Landsat 5	USGS	2
L4P229R58_871026.tif	1990	Landsat 4	USGS	30
L7P229R58_991128.tif	2000	Landsat 7	USGS	5
L5P229R58_000903.tif	2000	Landsat 5	INPE	15
L5P229R58_010914.tif	2000	Landsat 5	USGS	15
L5P229R58_051019.tif	2005	Landsat 5	USGS	5
L5P229R58_090928.tif	Benchmark	Landsat 5	INPE	1
L7P229R58_101009.tif	Year 1	Landsat 7	USGS	15
L7P229R58_100603.tif	Year 1	Landsat 7	USGS	90
L5P229R59_860913.tif	1990	Landsat 5	USGS	10
L4P229R59_871127.tif	1990	Landsat 4	USGS	0
L5P229R59_000911.tif	2000	Landsat 5	USGS	1
L5P229R59_041219.tif	2005	Landsat 5	USGS	1
L5P229R59_051019.tif	2005	Landsat 5	INPE	1
L5P229R59_090928.tif	Benchmark	Landsat 5	INPE	1
L7P229R59_100603.tif	Year 1	Landsat 7	USGS	90
L5P230R56_870806.tif	1990	Landsat 5	USGS	20
L5P230R56_890912.tif	1990	Landsat 5	INPE	1
L5P230R56_990706.tif	2000	Landsat 5	INPE	10
L7P230R56_010905.tif	2000	Landsat 7	USGS	10
L5P230R56_040804.tif	2005	Landsat 5	INPE	1
L5P230R56_090903.tif	Benchmark	Landsat 5	INPE	5
L5P230R56_090919.tif	Benchmark	Landsat 5	INPE	5
L7P230R56_100728.tif	Year 1	Landsat 7	USGS	85
L5P230R57_890912.tif	1990	Landsat 5	USGS	1
L5P230R57_000910.tif	2000	Landsat 5	INPE	40
L7P230R57_020908.tif	2000	Landsat 7	USGS	15
L5P230R57_040820.tif	2005	Landsat 5	USGS	5
L5P230R57_060927.tif	2005	Landsat 5	USGS	1
L5P230R57_090903.tif	Benchmark	Landsat 5	INPE	10

L5P230R57_090919.tif	Benchmark	Landsat 5	INPE	10
L7P230R56_100813.tif	Year 1	Landsat 7	USGS	40
L7P230R57_100930.tif	Year 1	Landsat 7	USGS	40
L7P230R57_100728.tif	Year 1	Landsat 7	USGS	85
L5P230R58_870907.tif	1990	Landsat 5	USGS	2
L5P230R58_980905.tif	2000	Landsat 5	INPE	1
L5P230R58_050924.tif	2005	Landsat 5	USGS	11
L5P230R58_060927.tif	2005	Landsat 5	INPE	10
L5P230R58_090903.tif	Benchmark	Landsat 5	INPE	1
L5P230R58_090919.tif	Benchmark	Landsat 5	INPE	4
L7P230R58_100914.tif	Year 1	Landsat 7	USGS	10
L7P230R58_100728.tif	Year 1	Landsat 7	USGS	95
L5P230R59_870907.tif	1990	Landsat 5	USGS	1
L5P230R59_980905.tif	2000	Landsat 5	INPE	5
L5P230R59_040820.tif	2005	Landsat 5	USGS	25
L5P230R59_050924.tif	2005	Landsat 5	USGS	16
L5P230R59_060927.tif	2005	Landsat 5	INPE	10
L5P230R59_090802.tif	Benchmark	Landsat 5	INPE	10
L5P230R59_090903.tif	Benchmark	Landsat 5	INPE	8
L5P230R59_090919.tif	Benchmark	Landsat 5	INPE	15
L7P230R59_100914.tif	Year 1	Landsat 7	USGS	15
L7P230R59_100728.tif	Year 1	Landsat 7	USGS	95
L5P231R55_870813.tif	1990	Landsat 5	USGS	60
L4P231R55_920717.tif	1990	Landsat 4	USGS	60
L4P231R55_920919.tif	1990	Landsat 4	USGS	10
L5P231R55_980928.tif	2000	Landsat 5	INPE	70
L7P231R55_021001.tif	2000	Landsat 7	INPE	60
L7P231R55_020713.tif	2000	Landsat 7	USGS	70
L5P231R55_051001.tif	2005	Landsat 5	INPE	60
L5P231R55_080331.tif	Benchmark	Landsat 5	INPE	45
L7P231R55_090222.tif	Benchmark	Landsat 7	USGS	3
L7P231R55_100719.tif	Year 1	Landsat 7	USGS	40
L5P231R56_870813.tif	1990	Landsat 5	USGS	35
L5P231R56_870914.tif	1990	Landsat 5	INPE	30
L4P231R56_920919.tif	1990	Landsat 4	USGS	20
L5P231R56_950803.tif	1990	Landsat 5	INPE	20
L5P231R56_980912.tif	2000	Landsat 5	INPE	20
L7P231R56_010912.tif	2000	Landsat 7	INPE	30
L5P231R56_051001.tif	2005	Landsat 5	INPE	10
L5P231R56_080907.tif	Benchmark	Landsat 5	INPE	30
L5P231R56_090825.tif	Benchmark	Landsat 5	INPE	50
L7P231R56_090902.tif	Benchmark	Landsat 7	USGS	20
L5P231R57_870626.tif	1990	Landsat 5	USGS	50
L5P231R57_900906.tif	1990	Landsat 5	INPE	35
L5P231R57_920919.tif	1990	Landsat 5	USGS	40
L5P231R57_980928.tif	2000	Landsat 5	INPE	10
L5P231R57_051001.tif	2005	Landsat 5	INPE	1
L5P231R57_080907.tif	Benchmark	Landsat 5	INPE	15

L7P231R57_090902.tif	Benchmark	Landsat 7	USGS	20
L5P231R57_090926.tif	Benchmark	Landsat 5	INPE	40
L7P231R55_100905.tif	Year 1	Landsat 7	USGS	50
L7P231R56_100719.tif	Year 1	Landsat 7	USGS	60
L7P231R56_100905.tif	Year 1	Landsat 7	USGS	50
L7P231R57_100601.tif	Year 1	Landsat 7	USGS	85
L5P231R58_910909.tif	1990	Landsat 5	USGS	2
L5P231R58_910925.tif	1990	Landsat 5	USGS	10
L5P231R58_980928.tif	2000	Landsat 5	INPE	4
L7P231R58_021001.tif	2000	Landsat 7	USGS	2
L5P231R58_051001.tif	2005	Landsat 5	INPE	4
L5P231R58_080907.tif	Benchmark	Landsat 5	INPE	5
L5P231R58_090926.tif	Benchmark	Landsat 5	INPE	10
L7P231R57_100905.tif	Year 1	Landsat 7	USGS	35
L7P231R58_100601.tif	Year 1	Landsat 7	USGS	90
L5P231R59_870712.tif	1990	Landsat 5	USGS	4
L5P231R59_910909.tif	1990	Landsat 5	INPE	2
L4P231R59_920919.tif	1990	Landsat 4	USGS	20
L5P231R59_940917.tif	1990	Landsat 5	INPE	2
L5P231R59_990713.tif	2000	Landsat 5	INPE	15
L5P231R59_000917.tif	2000	Landsat 5	INPE	35
L5P231R59_031012.tif	2005	Landsat 5	INPE	10
L5P231R59_041014.tif	2005	Landsat 5	USGS	1
L5P231R59_090825.tif	Benchmark	Landsat 5	INPE	40
L7P231R58_101007.tif	Year 1	Landsat 7	USGS	20
L7P231R59_100601.tif	Year 1	Landsat 7	USGS	85
L4P232R54_871031.tif	1990	Landsat 4	USGS	30
L5P232R54_900913.tif	1990	Landsat 5	USGS	50
L5P232R54_910119.tif	1990	Landsat 5	USGS	50
L5P232R54_000815.tif	2000	Landsat 5	USGS	7
L7P232R54_030128.tif	2005	Landsat 7	USGS	30
L7P232R54_051016.tif	2005	Landsat 7	USGS	30
L7P232R54_090909.tif	Benchmark	Landsat 7	USGS	35
L7P231R59_101007.tif	Year 1	Landsat 7	USGS	5
L7P231R59_100905.tif	Year 1	Landsat 7	USGS	15
L7P232R54_100624.tif	Year 1	Landsat 7	USGS	40
L4P232R55_871031.tif	1990	Landsat 4	USGS	30
L5P232R55_881009.tif	1990	Landsat 5	INPE	25
L5P232R55_990720.tif	2000	Landsat 5	INPE	50
L5P232R55_010420.tif	2000	Landsat 5	INPE	60
L7P232R55_010717.tif	2000	Landsat 7	USGS	50
L7P232R55_020125.tif	2000	Landsat 7	USGS	50
L5P232R55_060925.tif	2005	Landsat 5	INPE	25
L5P232R55_080407.tif	Benchmark	Landsat 5	INPE	90
L5P232R55_090731.tif	Benchmark	Landsat 5	USGS	80
L7P232R55_090909.tif	Benchmark	Landsat 7	USGS	75
L5P232R56_890809.tif	1990	Landsat 5	USGS	10
L7P232R56_991016.tif	2000	Landsat 7	USGS	30

L5P232R56_050922.tif	2005	Landsat 5	USGS	70
L5P232R56_060925.tif	2005	Landsat 5	USGS	40
L5P232R56_080813.tif	Benchmark	Landsat 5	INPE	25
L5P232R56_090731.tif	Benchmark	Landsat 5	USGS	95
L7P232R54_100912.tif	Year 1	Landsat 7	USGS	30
L7P232R55_100624.tif	Year 1	Landsat 7	USGS	70
L7P232R55_100912.tif	Year 1	Landsat 7	USGS	40
L5P232R57_900913.tif	1990	Landsat 5	INPE	1
L4P232R57_920910.tif	1990	Landsat 4	USGS	15
L5P232R57_990517.tif	2000	Landsat 5	INPE	1
L5P232R57_050922.tif	Benchmark	Landsat 5	USGS	4
L4P233R55_871123.tif	1990	Landsat 4	USGS	45
L5P233R55_991015.tif	2000	Landsat 5	INPE	85
L5P233R55_050828.tif	2005	Landsat 5	INPE	15
L5P233R55_051031.tif	2005	Landsat 5	USGS	20
L5P233R55_080905.tif	Benchmark	Landsat 5	INPE	40
L7P233R55_090730.tif	Benchmark	Landsat 7	USGS	20
L7P232R56_100811.tif	Year 1	Landsat 7	USGS	90
L7P232R56_100912.tif	Year 1	Landsat 7	USGS	35
L7P232R57_100624.tif	Year 1	Landsat 7	USGS	50
L7P232R57_100912.tif	Year 1	Landsat 7	USGS	25
L7P233R55_100428.tif	Year 1	Landsat 7	USGS	85
L7P233R55_100903.tif	Year 1	Landsat 7	USGS	60
L7P233R56_100428.tif	Year 1	Landsat 7	USGS	95
L7P233R56_101005.tif	Year 1	Landsat 7	USGS	40
L5P233R56_870304.tif	1990	Landsat 5	USGS	30
L5P233R56_870405.tif	1990	Landsat 5	USGS	80
L5P233R56_991015.tif	2000	Landsat 5	INPE	20
L5P233R56_040825.tif	2005	Landsat 5	USGS	4
S4P672R337_060925.tif	2005	SPOT 4	SPOT	10
S2P673R334_081004.tif	Benchmark	SPOT 2	SPOT	50
S2P673R335_081004.tif	Benchmark	SPOT 2	SPOT	5
S2P673R336_081004.tif	Benchmark	SPOT 2	SPOT	1
S4P673R336_081023.tif	Benchmark	SPOT 4	SPOT	30
S2P673R337_081004.tif	Benchmark	SPOT 2	SPOT	5
S2P673R339_081004.tif	Benchmark	SPOT 2	SPOT	15
S4P673R339_080217.tif	Benchmark	SPOT 4	SPOT	30
S5P674R333_080323.tif	Benchmark	SPOT 5	SPOT	25
S5P674R335_081006.tif	Benchmark	SPOT 5	SPOT	60
S4P674R336_061016.tif	2005	SPOT 4	SPOT	85
S4P674R337_061016.tif	2005	SPOT 4	SPOT	3
S4P674R338_070310.tif	Benchmark	SPOT 4	SPOT	50
S2P674R339_081030.tif	Benchmark	SPOT 2	SPOT	30
S5P675R334_070314.tif	Benchmark	SPOT 5	SPOT	50
S4P675R335_070202.tif	Benchmark	SPOT 4	SPOT	40
S5P675R337_070314.tif	Benchmark	SPOT 5	SPOT	50
S4P675R337_070202.tif	Benchmark	SPOT 4	SPOT	45
S5P675R338_070314.tif	Benchmark	SPOT 5	SPOT	75

S2P675R338_080320.tif	Benchmark	SPOT 2	SPOT	30
S2P675R338_081221.tif	Benchmark	SPOT 2	SPOT	40
S2P675R339_070830.tif	Benchmark	SPOT 2	SPOT	30
S5P676R334_070802.tif	Benchmark	SPOT 5	SPOT	15
S2P676R336_061113.tif	2005	SPOT 2	SPOT	20
S2P676R336_071011.tif	Benchmark	SPOT 2	SPOT	20
S2P676R337_071011.tif	Benchmark	SPOT 2	SPOT	25
S2P676R338_071011.tif	Benchmark	SPOT 2	SPOT	40
S5P676R340_081022.tif	Benchmark	SPOT 5	SPOT	20
S4P676R340_081129.tif	Benchmark	SPOT 4	SPOT	35
S2P676R341_080320.tif	Benchmark	SPOT 2	SPOT	15
S2P676R342_080320.tif	Benchmark	SPOT 2	SPOT	3
S2P676R343_080320.tif	Benchmark	SPOT 2	SPOT	2
S5P676R343_081022.tif	Benchmark	SPOT 5	SPOT	2
S4P677R338_070426.tif	Benchmark	SPOT 4	SPOT	30
S2P677R339_061017.tif	2005	SPOT 2	SPOT	10
S2P677R340_061017.tif	2005	SPOT 2	SPOT	15
S4P677R340_080928.tif	Benchmark	SPOT 4	SPOT	20
S2P677R341_081014.tif	Benchmark	SPOT 2	SPOT	15
S4P677R342_080807.tif	Benchmark	SPOT 4	SPOT	10
S2P677R342_081014.tif	Benchmark	SPOT 2	SPOT	10
S2P677R344_061017.tif	2005	SPOT 2	SPOT	4
S2P677R344_080315.tif	Benchmark	SPOT 2	SPOT	2
S5P677R345_060908.tif	2005	SPOT 5	SPOT	15
S5P677R346_060908.tif	2005	SPOT 5	SPOT	10
S2P677R346_081014.tif	Benchmark	SPOT 2	SPOT	5
S4P678R337_081108.tif	Benchmark	SPOT 4	SPOT	30
S5P678R339_071019.tif	Benchmark	SPOT 5	SPOT	40
S5P678R340_071019.tif	Benchmark	SPOT 5	SPOT	25
S5P678R341_071019.tif	Benchmark	SPOT 5	SPOT	35
S5P678R342_060908.tif	2005	SPOT 5	SPOT	25
S2P678R343_070915.tif	Benchmark	SPOT 2	SPOT	40
S5P678R345_081001.tif	Benchmark	SPOT 5	SPOT	15
S5P678R346_081001.tif	Benchmark	SPOT 5	SPOT	40
S2P679R337_081130.tif	Benchmark	SPOT 2	SPOT	10
S2P679R337_090206.tif	Benchmark	SPOT 2	SPOT	7
S2P679R340_081130.tif	Benchmark	SPOT 2	SPOT	35
S2P679R340_090206.tif	Benchmark	SPOT 2	SPOT	25
S2P679R341_080506.tif	Benchmark	SPOT 2	SPOT	10
S2P679R341_090409.tif	Benchmark	SPOT 2	SPOT	20
S2P679R342_060925.tif	2005	SPOT 2	SPOT	7
S4P679R342_070219.tif	Benchmark	SPOT 4	SPOT	12
S4P679R343_060925.tif	2005	SPOT 4	SPOT	7
S2P679R343_070219.tif	Benchmark	SPOT 2	SPOT	25
S2P679R344_070219.tif	2005	SPOT 2	SPOT	5
S5P679R345_070217.tif	Benchmark	SPOT 5	SPOT	50
S2P679R345_061203.tif	2005	SPOT 2	SPOT	55
S2P679R346_061203.tif	2005	SPOT 2	SPOT	40

S5P680R338_080731.tif	Benchmark	SPOT 5	SPOT	25
S5P680R338_060908.tif	2005	SPOT 5	SPOT	6
S5P680R340_060908.tif	2005	SPOT 5	SPOT	12
S4P680R340_060925.tif	2005	SPOT 4	SPOT	8
S2P680R341_071011.tif	Benchmark	SPOT 2	SPOT	3
S2P680R341_060616.tif	2005	SPOT 2	SPOT	25
S5P680R342_060903.tif	2005	SPOT 5	SPOT	6
S2P680R342_070910.tif	Benchmark	SPOT 2	SPOT	8
S2P680R342_060616.tif	2005	SPOT 2	SPOT	25
S5P680R343_071115.tif	Benchmark	SPOT 5	SPOT	15
S5P680R343_060903.tif	2005	SPOT 5	SPOT	5
S5P680R344_071115.tif	Benchmark	SPOT 5	SPOT	20
S5P680R344_060903.tif	2005	SPOT 5	SPOT	80
S5P680R345_071115.tif	Benchmark	SPOT 5	SPOT	15
S4P680R345_060926.tif	2005	SPOT 4	SPOT	40
S4P680R346_060926.tif	2005	SPOT 4	SPOT	60
S4P680R346_060830.tif	2005	SPOT 4	SPOT	45
S2P680R347_060902.tif	2005	SPOT 2	SPOT	10
S4P680R347_060926.tif	2005	SPOT 4	SPOT	15
S4P681R340_060825.tif	2005	SPOT 4	SPOT	50
S4P681R340_070909.tif	Benchmark	SPOT 4	SPOT	40
S2P681R341_060927.tif	2005	SPOT 2	SPOT	15
S4P681R341_070909.tif	Benchmark	SPOT 4	SPOT	15
S5P681R342_060903.tif	2005	SPOT 5	SPOT	20
S4P681R342_060831.tif	2005	SPOT 4	SPOT	25
S5P681R343_060831.tif	2005	SPOT 5	SPOT	70
S4P681R343_060903.tif	2005	SPOT 4	SPOT	75
S2P681R344_070905.tif	Benchmark	SPOT 2	SPOT	20
S4P681R346_080928.tif	Benchmark	SPOT 4	SPOT	10
S2P682R339_080808.tif	Benchmark	SPOT 2	SPOT	50
S2P682R340_080808.tif	Benchmark	SPOT 2	SPOT	70
S2P682R340_060806.tif	2005	SPOT 2	SPOT	40
S4P682R341_070914.tif	Benchmark	SPOT 4	SPOT	50
S4P682R341_070724.tif	Benchmark	SPOT 4	SPOT	75
S4P682R342_070724.tif	Benchmark	SPOT 4	SPOT	65
S4P682R342_070914.tif	Benchmark	SPOT 4	SPOT	50
S4P682R343_060810.tif	2005	SPOT 4	SPOT	50
S4P682R344_060629.tif	2005	SPOT 4	SPOT	65
S4P682R344_060810.tif	2005	SPOT 4	SPOT	70
S4P682R345_070724.tif	Benchmark	SPOT 4	SPOT	25
S4P682R345_060629.tif	2005	SPOT 4	SPOT	10
S4P682R345_060810.tif	2005	SPOT 4	SPOT	15
S4P682R346_070724.tif	Benchmark	SPOT 4	SPOT	5
S4P682R346_060629.tif	2005	SPOT 4	SPOT	25
R1P314R74_100413.tif	Year 1	ResourceSat 1	INPE	20
R1P313R71_100806.tif	Year 1	ResourceSat 1	INPE	30
IKP005R000_090919.tif	Benchmark	Ikonos	IKONOS	29
IKP005R001_090919.tif	Benchmark	Ikonos	IKONOS	1

IKP005R002_090919.tif	Benchmark	Ikonos	IKONOS	4
IKP005R003_090919.tif	Benchmark	Ikonos	IKONOS	9
IKP005R004_090919.tif	Benchmark	Ikonos	IKONOS	15
IKP007R000_090919.tif	Benchmark	Ikonos	IKONOS	17
IKP007R001_090919.tif	Benchmark	Ikonos	IKONOS	16
IKP007R002_090919.tif	Benchmark	Ikonos	IKONOS	39
IKP007R003_090919.tif	Benchmark	Ikonos	IKONOS	12
IKP007R004_090919.tif	Benchmark	Ikonos	IKONOS	5
IKP006R000_090919.tif	Benchmark	Ikonos	IKONOS	12
IKP006R001_090919.tif	Benchmark	Ikonos	IKONOS	5
IKP006R002_090919.tif	Benchmark	Ikonos	IKONOS	21
IKP006R003_090919.tif	Benchmark	Ikonos	IKONOS	13
IKP006R004_090919.tif	Benchmark	Ikonos	IKONOS	7
IKP008R000_091006.tif	Year 1	Ikonos	IKONOS	66
IKP008R001_091006.tif	Year 1	Ikonos	IKONOS	16
IKP008R002_091006.tif	Year 1	Ikonos	IKONOS	36
IKP008R003_091006.tif	Year 1	Ikonos	IKONOS	1
IKP008R004_091006.tif	Year 1	Ikonos	IKONOS	0
IKP008R000_091124.tif	Year 1	Ikonos	IKONOS	4
IKP008R001_091124.tif	Year 1	Ikonos	IKONOS	34
IKP008R002_091124.tif	Year 1	Ikonos	IKONOS	45
IKP007R000_090629.tif	Benchmark	Ikonos	IKONOS	15
IKP007R001_090629.tif	Benchmark	Ikonos	IKONOS	50
IKP007R002_090629.tif	Benchmark	Ikonos	IKONOS	73
IKP007R003_090629.tif	Benchmark	Ikonos	IKONOS	78
IKP389R28_090629.tif	Benchmark	Ikonos	IKONOS	53
IKP389R29_090831.tif	Benchmark	Ikonos	IKONOS	18
IKP389R30_090831.tif	Benchmark	Ikonos	IKONOS	33
IKP389R31_090831.tif	Benchmark	Ikonos	IKONOS	15
IKP389R32_090831.tif	Benchmark	Ikonos	IKONOS	35
IKP001R000_090718.tif	Benchmark	Ikonos	IKONOS	8
IKP001R001_090718.tif	Benchmark	Ikonos	IKONOS	18
IKP004R000_090908.tif	Benchmark	Ikonos	IKONOS	0
IKP004R001_090908.tif	Benchmark	Ikonos	IKONOS	2
IKP004R002_090908.tif	Benchmark	Ikonos	IKONOS	1
IKP003R000_090908.tif	Benchmark	Ikonos	IKONOS	0
IKP003R001_090908.tif	Benchmark	Ikonos	IKONOS	0
IKP003R002_090908.tif	Benchmark	Ikonos	IKONOS	1
IKP002R000_090908.tif	Benchmark	Ikonos	IKONOS	0
IKP002R001_090908.tif	Benchmark	Ikonos	IKONOS	0
IKP002R002_090908.tif	Benchmark	Ikonos	IKONOS	4
DBP010R499_100830.tif	Year 1	DMC Beijing	DMC	25
DBP020R499_100830.tif	Year 1	DMC Beijing	DMC	20

APPENDIX 4

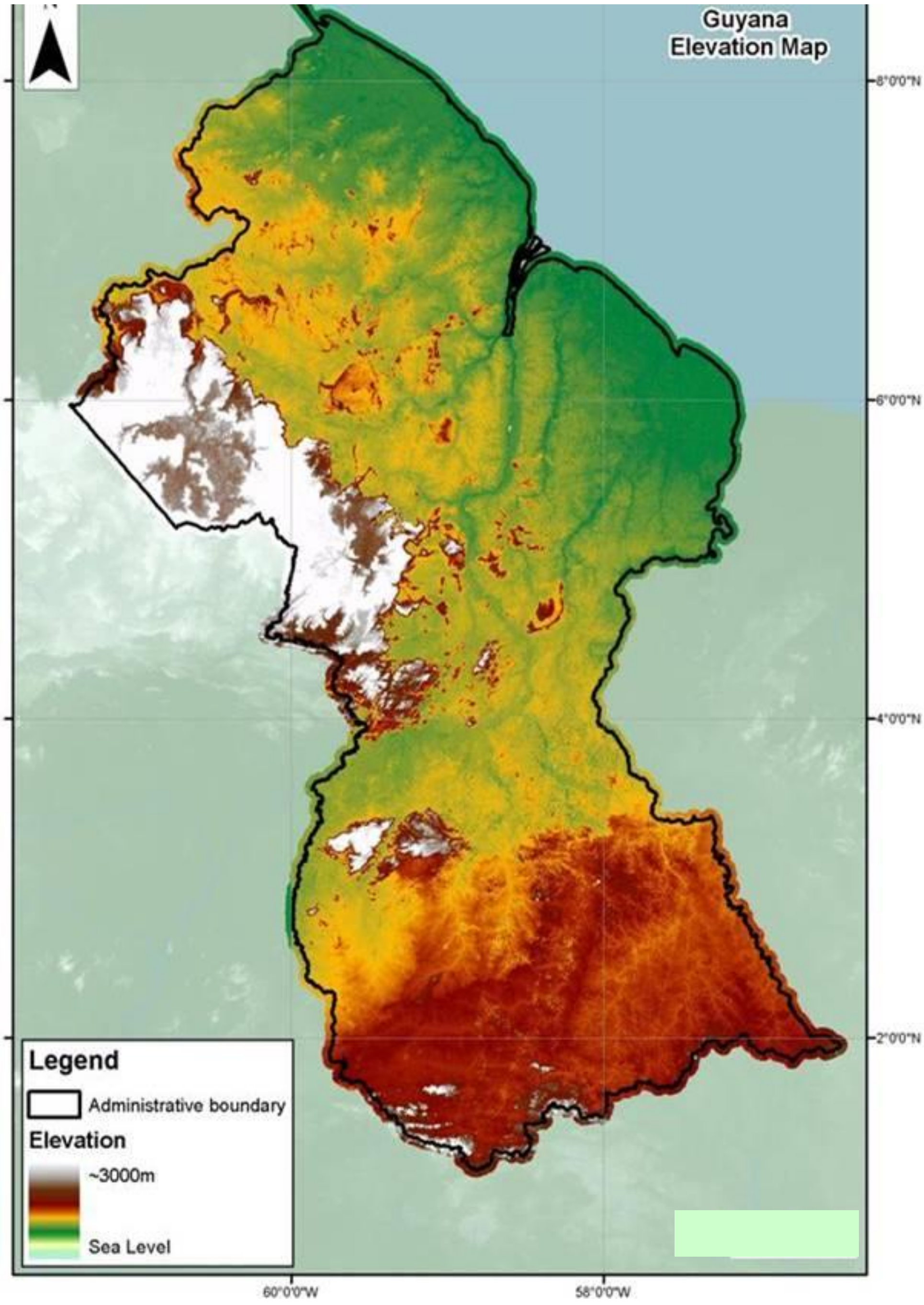
Maps of Available Datasets

The following series of maps provides an overview of the datasets available and assembled by GFC.

Elevation Data

A digital elevation model has been derived from the freely available Advanced Spaceborne Thermal Emission and Reflection Radiometer dataset (ASTER). This dataset is 30m in resolution. There are some issues with small amounts of scattered cloud which misrepresent elevation in places; however, these regions can be in-filled with Shuttle Radar Topography Mission (SRTM) data which is 90 m in resolution. Figure 1 shows the ASTER DEM mosaic.

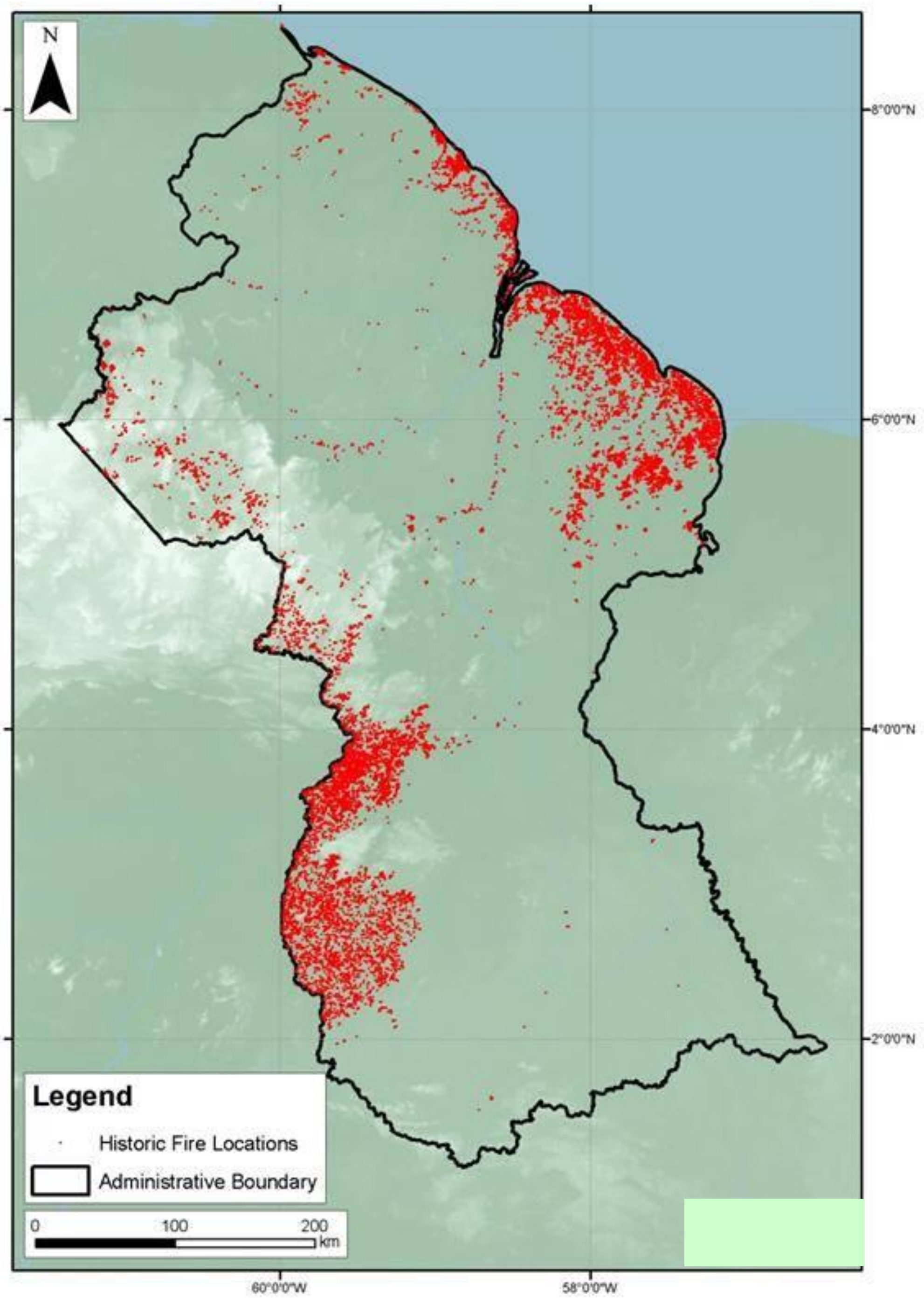
Guyana Elevation Map



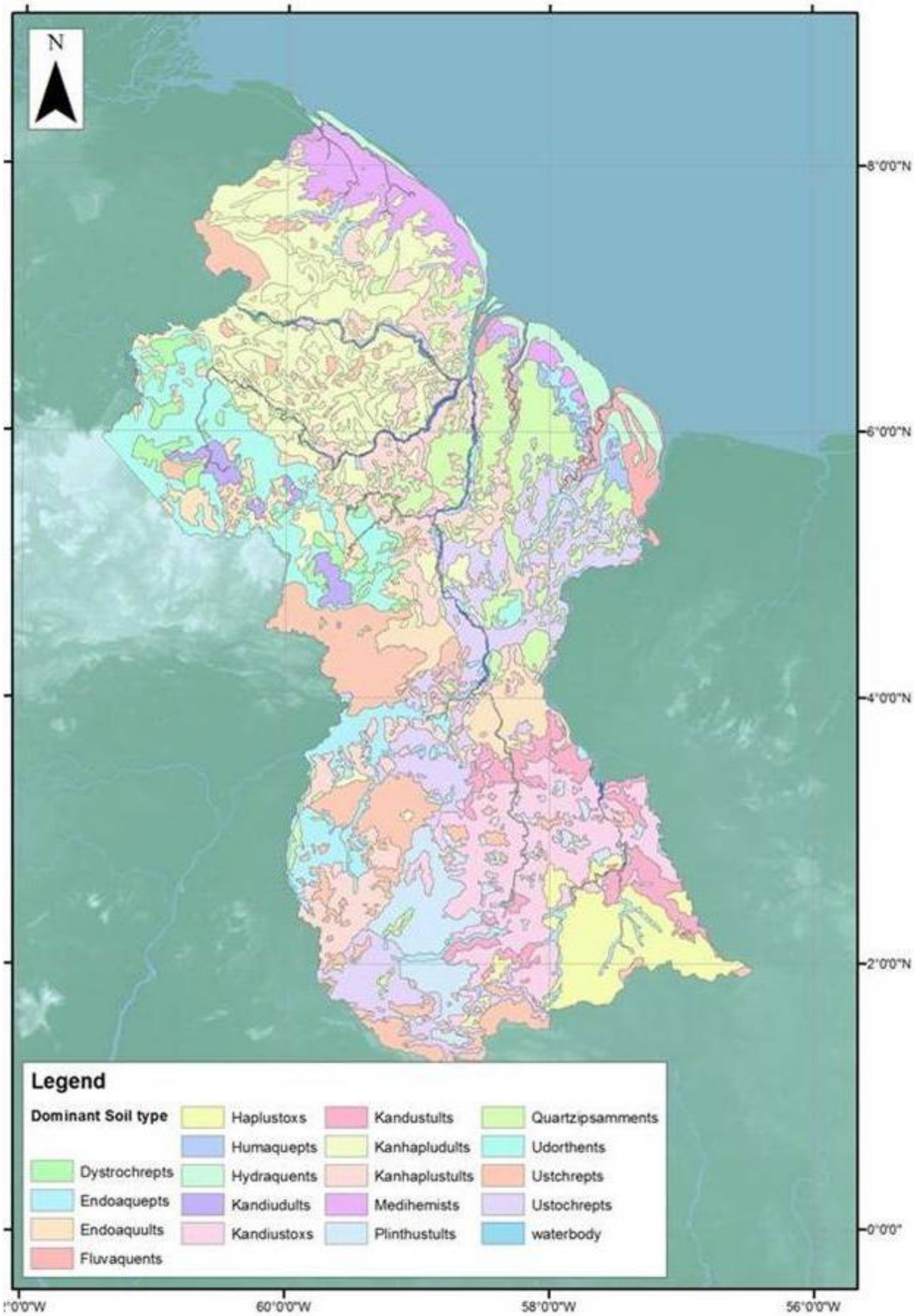
FIRMS MODIS Fire/Hotspot Dataset

The Fire Information for Resource Management System (FIRMS) data provide information about historic and present day fire locations using the Moderate Resolution Imaging Spectroradiometer (MODIS). This dataset will be used to identify land which has been impacted by past fires. Figure 2 shows the identified fire locations from 2000-2010.

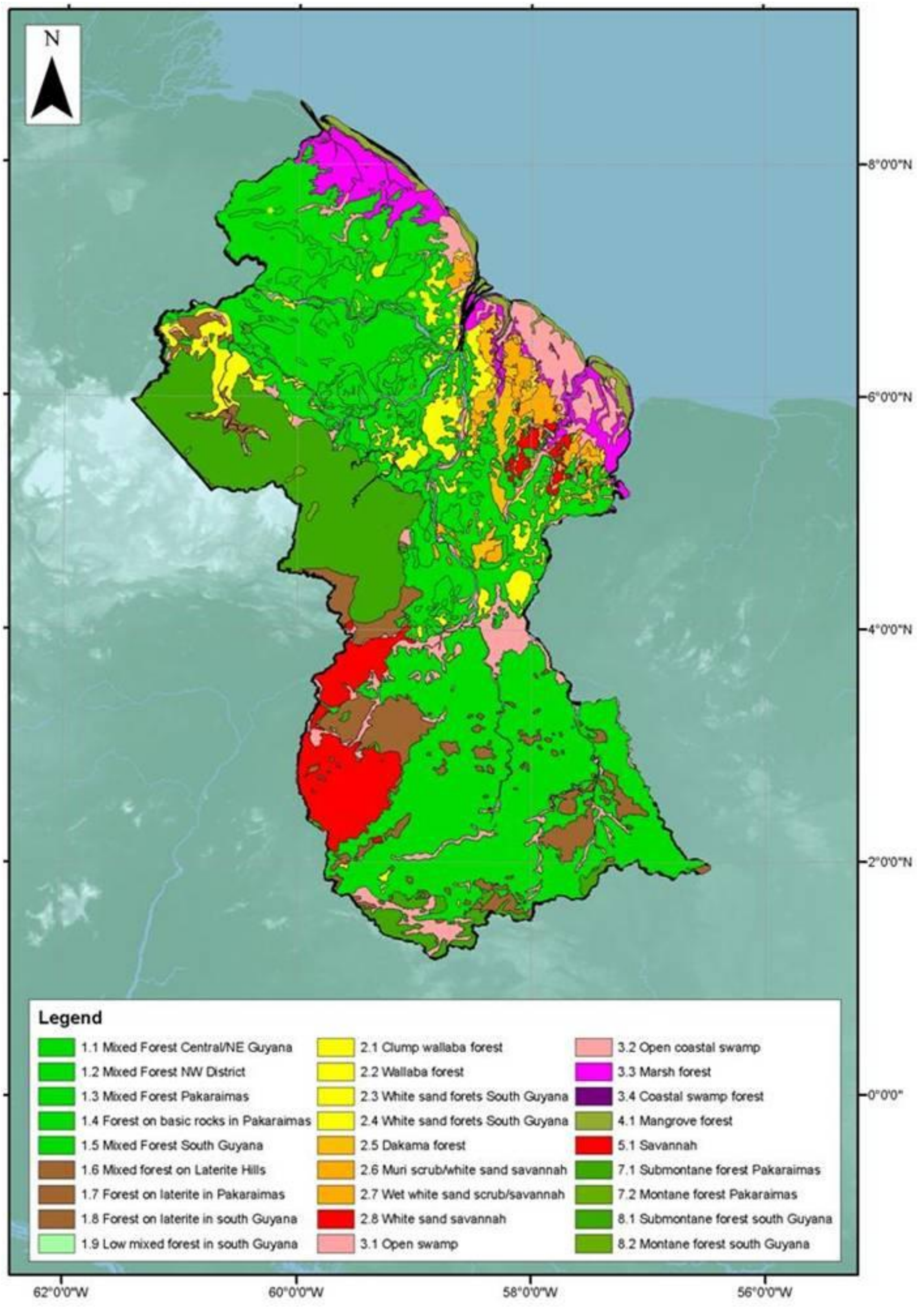
Fire Locations



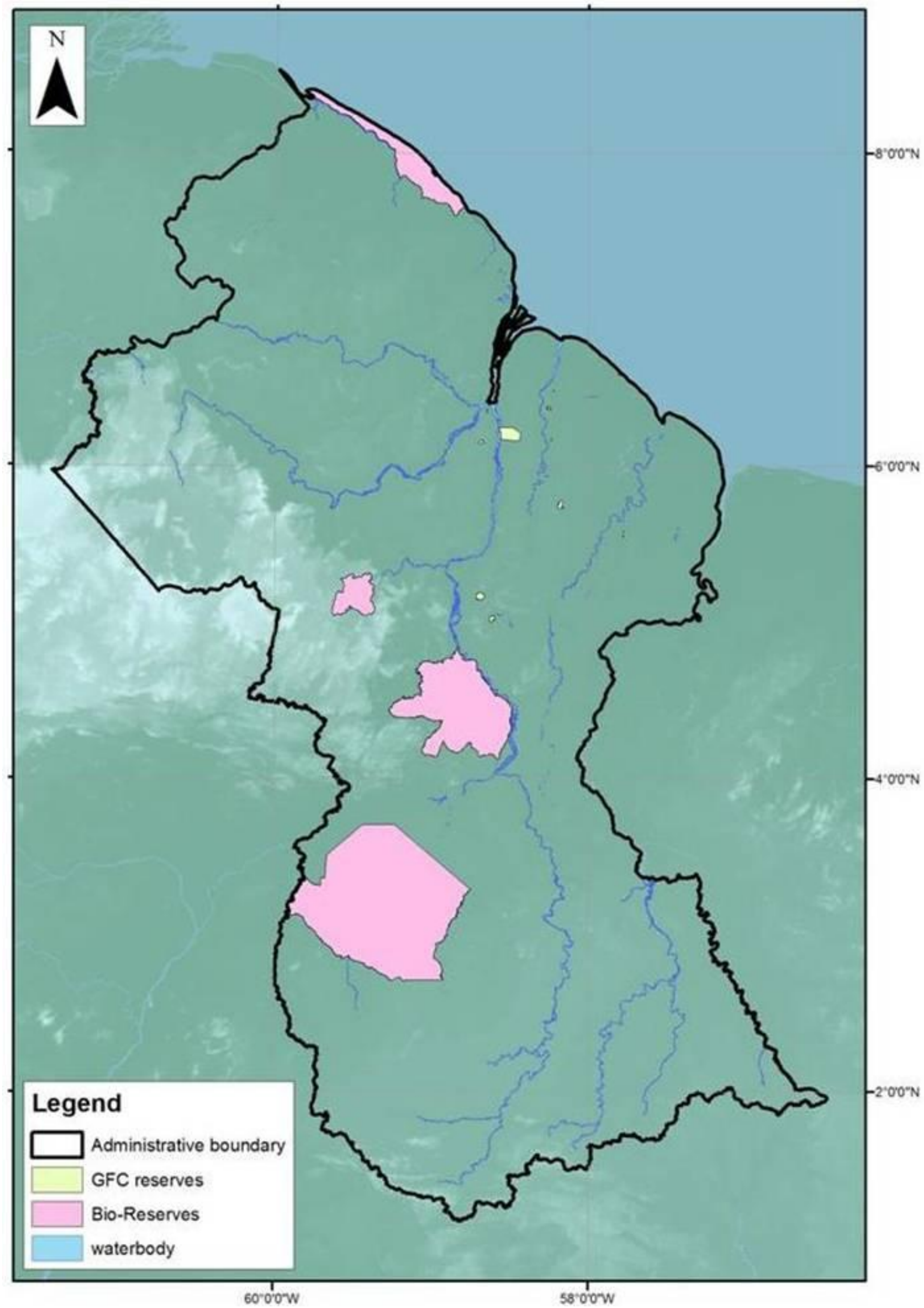
Guyana Soil Types



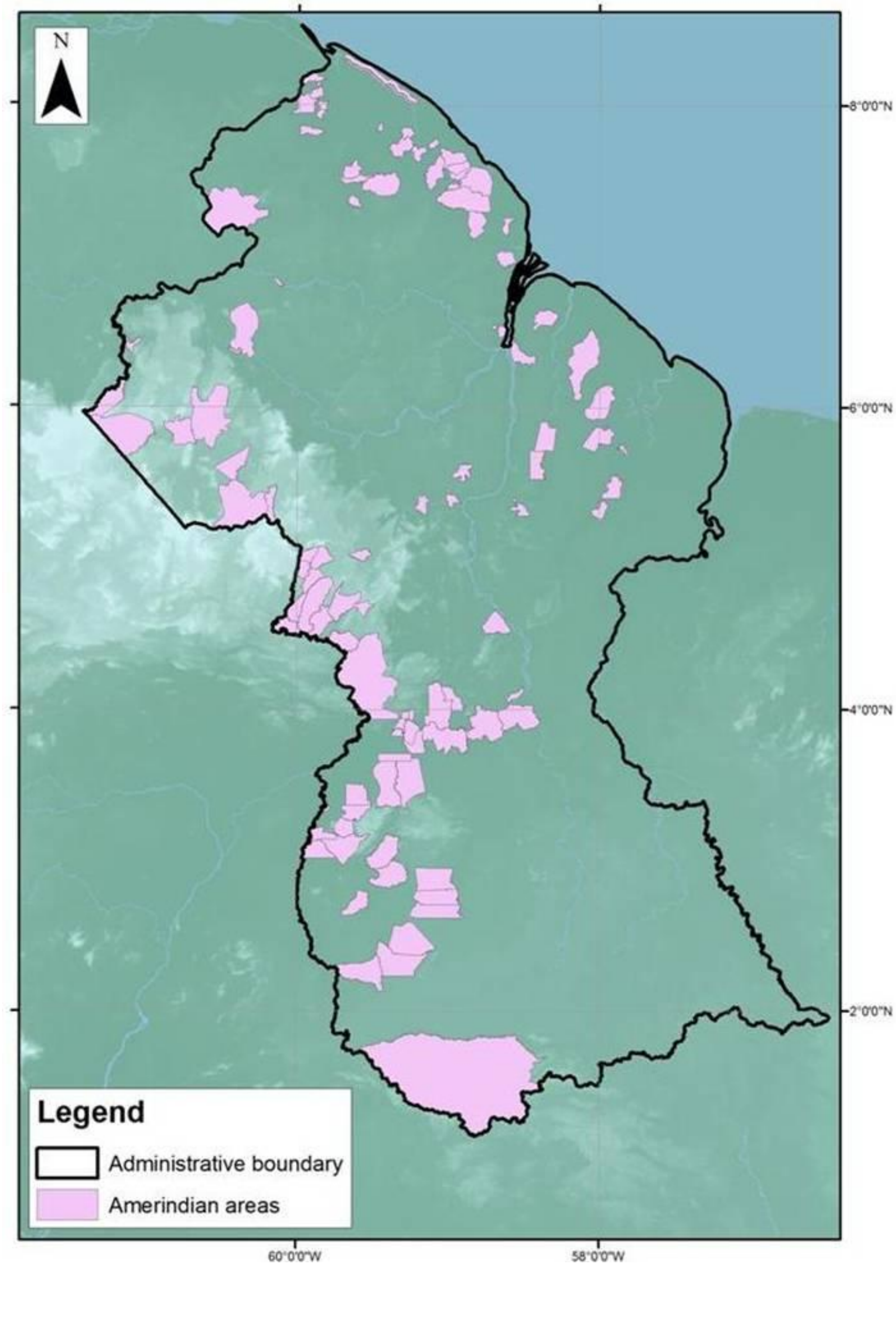
Guyana 1: 1000 000 Scale Vegetation Map



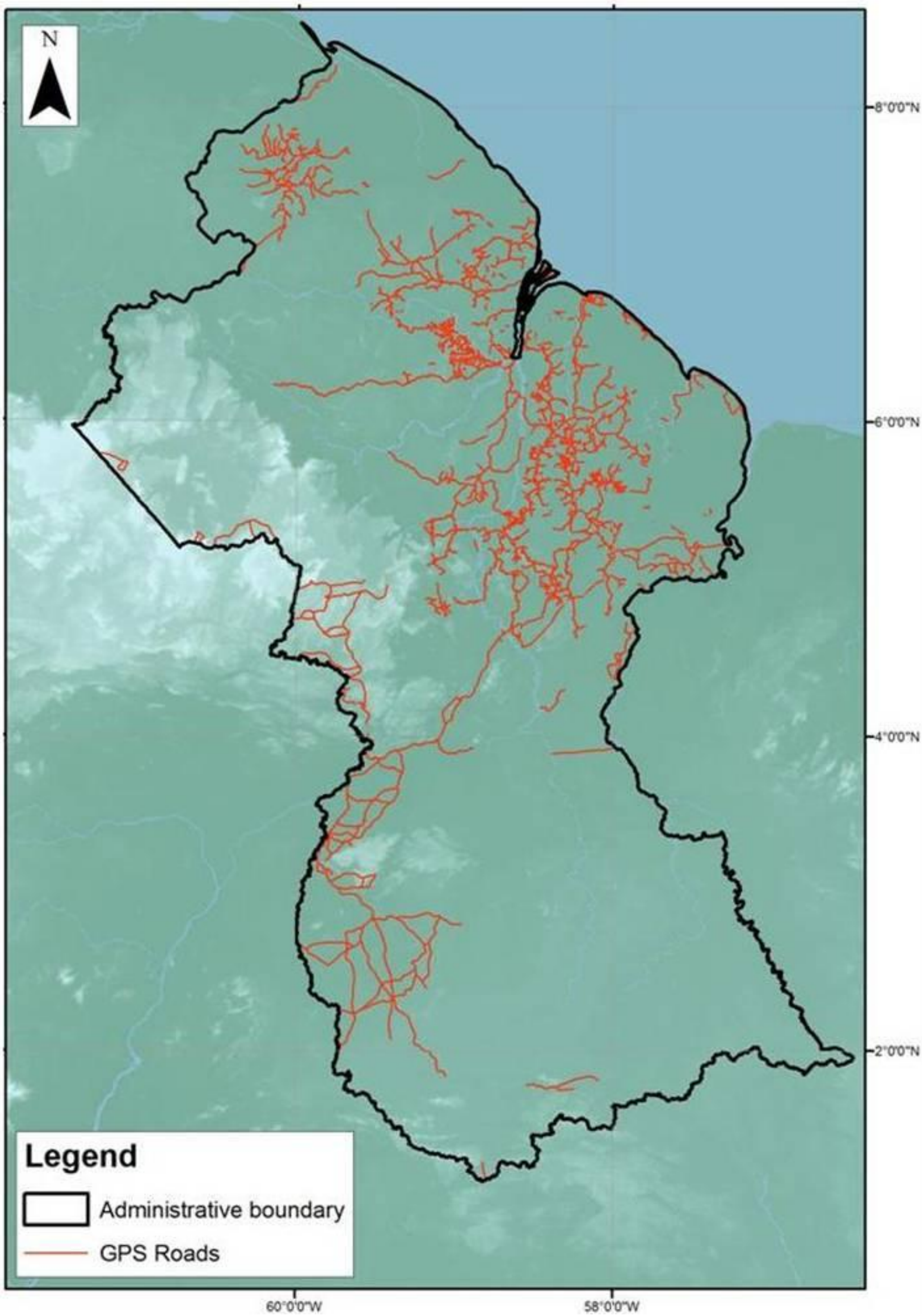
Forest Reserves



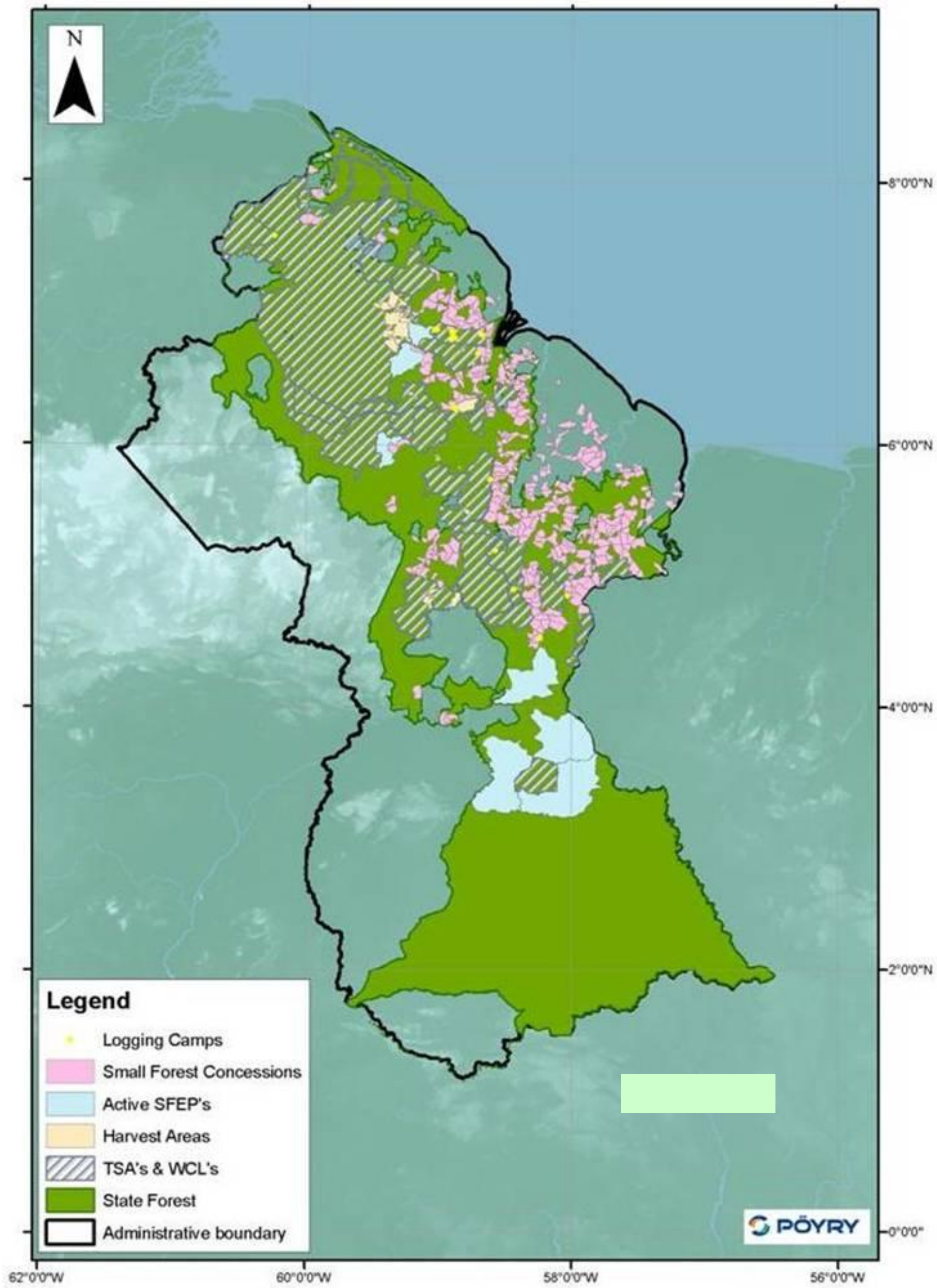
Titled Amerindian Areas



GPS Roads


N
8°0'0"N
6°0'0"N
4°0'0"N
2°0'0"N
60°0'0"W
58°0'0"W
Legend
Administrative boundary
GPS Roads

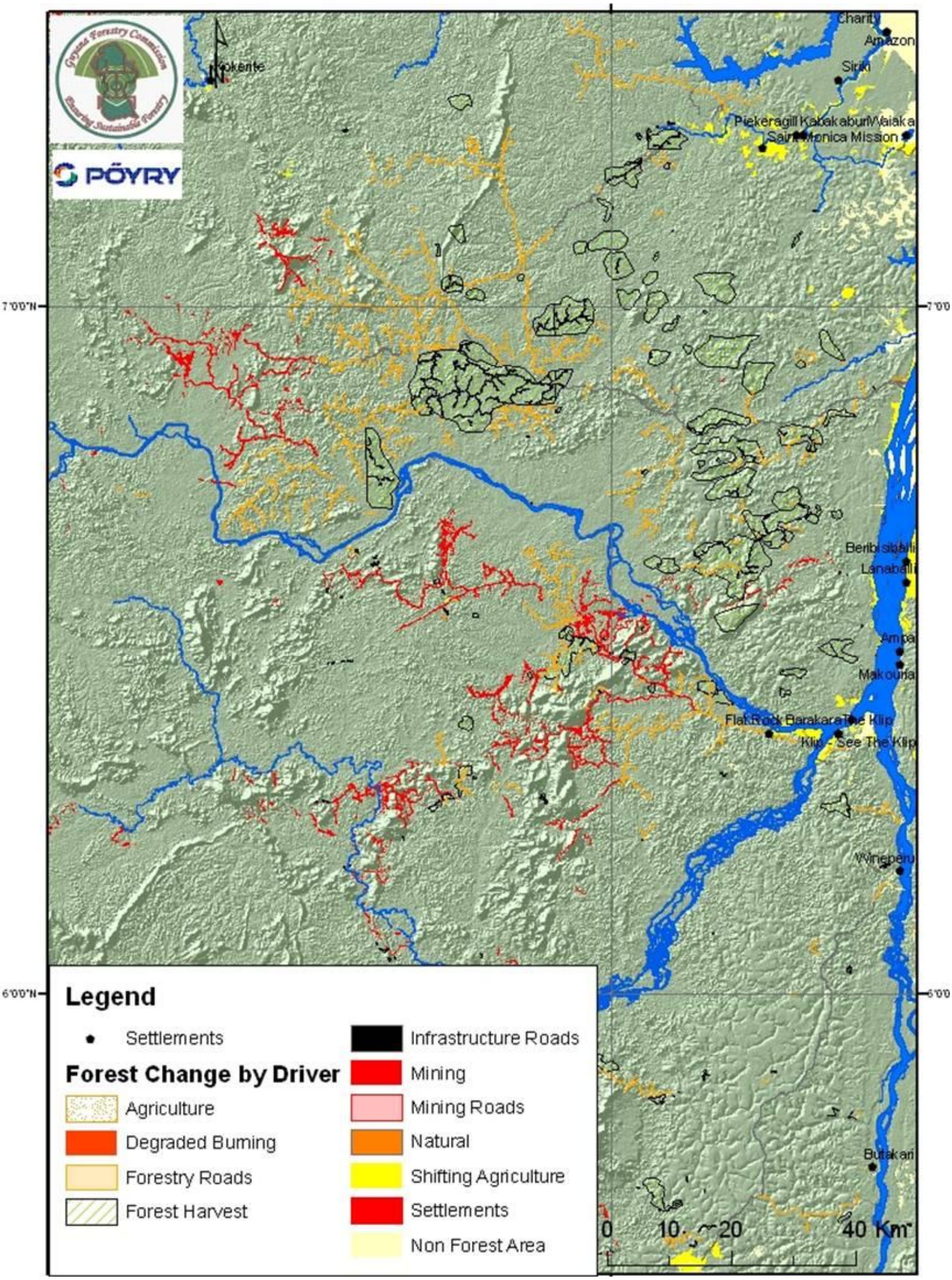
Managed Forest Areas

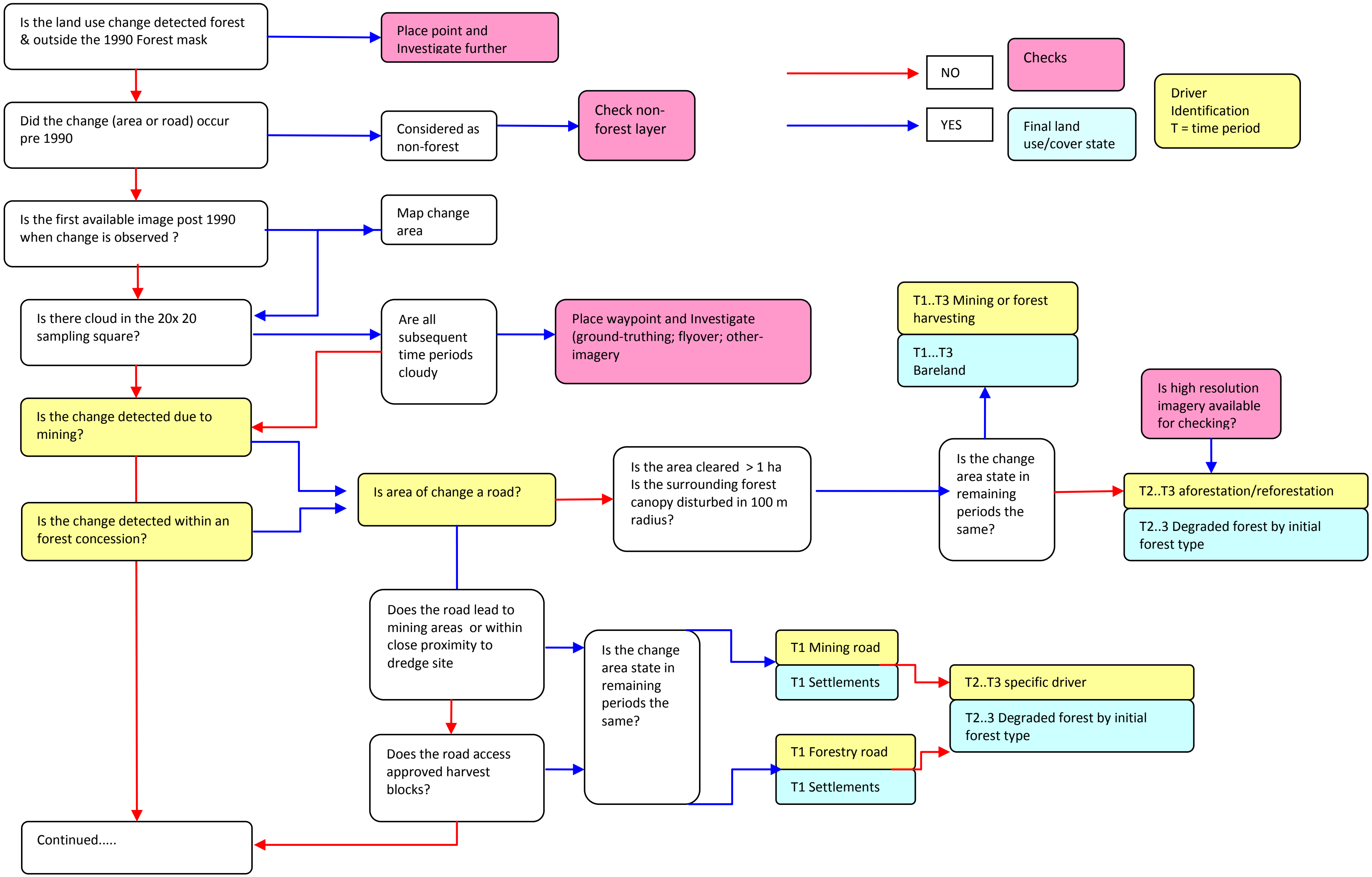


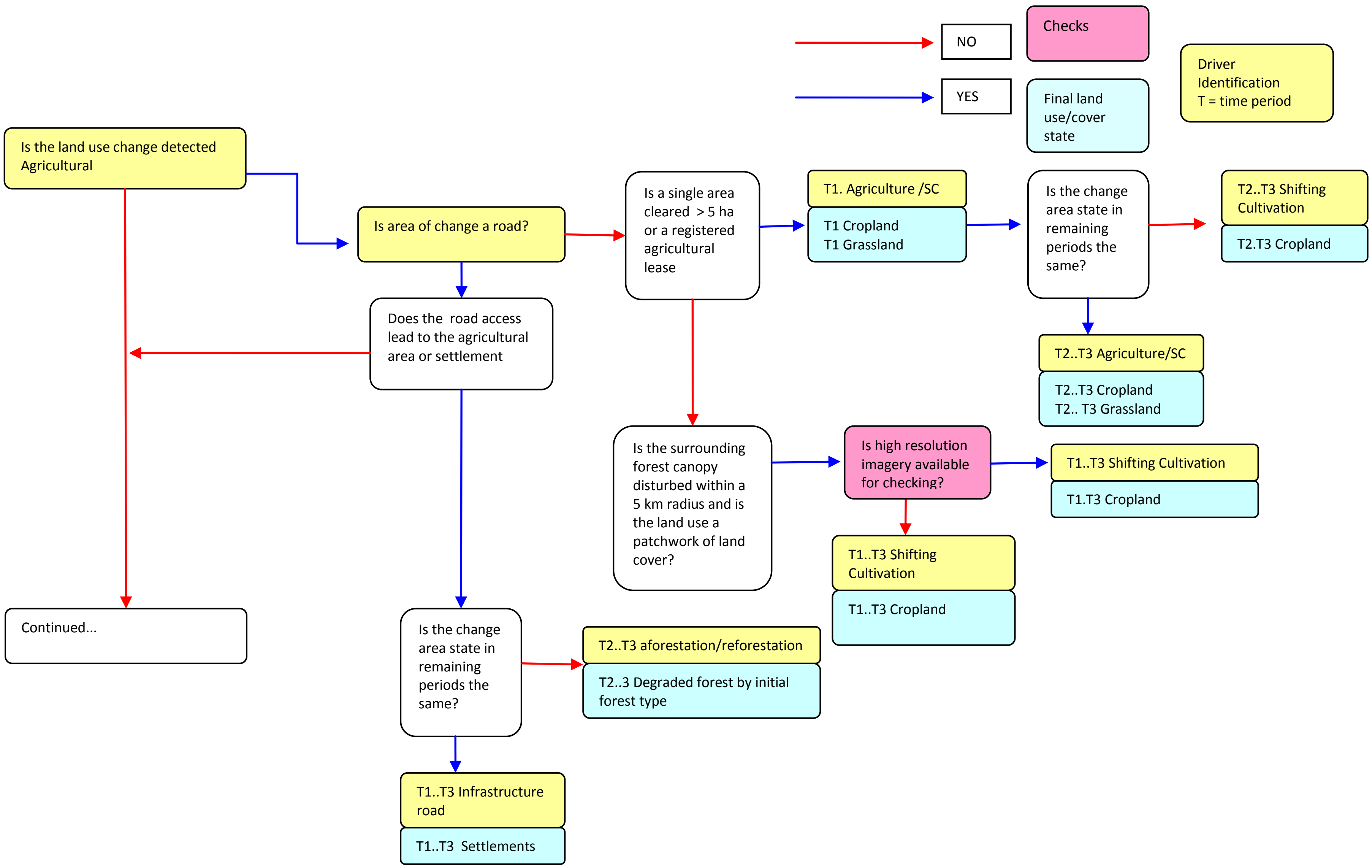
APPENDIX 5

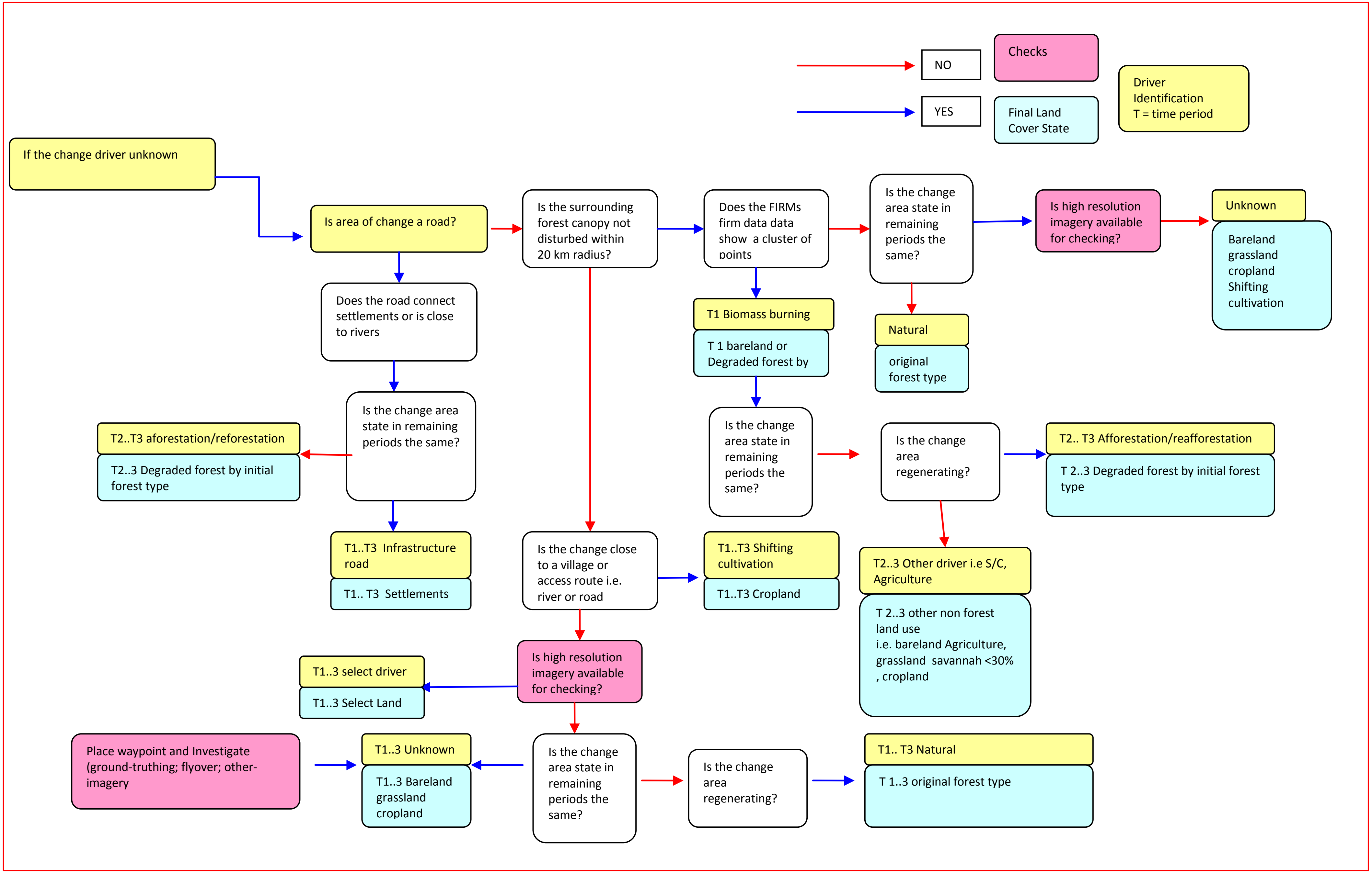
Mapping Decision Tree & GIS Output

Map 11-1:
MRVS GIS Output




Is the land use change detected forest & outside the 1990 Forest mask
Place point and Investigate further
NO
YES
Checks
Final land use/cover state
Driver Identification
T = time period
Did the change (area or road) occur pre 1990
Considered as non-forest
Check non-forest layer
Is the first available image post 1990 when change is observed ?
Map change area
Is there cloud in the 20x 20 sampling square?
Are all subsequent time periods cloudy
Place waypoint and Investigate (ground-truthing; flyover; other-imagery
T1..T3 Mining or forest harvesting
T1...T3 Bareland
Is high resolution imagery available for checking?
Is the change detected due to mining?
Is the change detected within an forest concession?
Is area of change a road?
Is the area cleared > 1 ha
Is the surrounding forest canopy disturbed in 100 m radius?
Is the change area state in remaining periods the same?
T2..T3 aforestation/reforestation
T2..3 Degraded forest by initial forest type
Does the road lead to mining areas or within close proximity to dredge site
Is the change area state in remaining periods the same?
T1 Mining road
T1 Settlements
T2..T3 specific driver
T2..3 Degraded forest by initial forest type
Does the road access approved harvest blocks?
T1 Forestry road
T1 Settlements
Continued.....


NO
YES
Checks
Final land use/cover state
Driver Identification
T = time period
Is the land use change detected Agricultural
Is area of change a road?
Does the road access lead to the agricultural area or settlement
Continued...
Is the change area state in remaining periods the same?
T1..T3 Infrastructure road
T1..T3 Settlements
T2..T3 aforestation/reforestation
T2..3 Degraded forest by initial forest type
Is a single area cleared > 5 ha or a registered agricultural lease
Is the surrounding forest canopy disturbed within a 5 km radius and is the land use a patchwork of land cover?
T1. Agriculture /SC
T1 Cropland
T1 Grassland
Is high resolution imagery available for checking?
T1..T3 Shifting Cultivation
T1..T3 Cropland
T1..T3 Shifting Cultivation
T1.T3 Cropland
Is the change area state in remaining periods the same?
T2..T3 Shifting Cultivation
T2.T3 Cropland
T2..T3 Agriculture/SC
T2..T3 Cropland
T2.. T3 Grassland



NO
YES
Checks
Final Land Cover State
Driver Identification
T = time period
If the change driver unknown
Is area of change a road?
Is the surrounding forest canopy not disturbed within 20 km radius?
Does the FIRMs firm data data show a cluster of points
Is the change area state in remaining periods the same?
Is high resolution imagery available for checking?
Unknown
Bareland
grassland
cropland
Shifting
cultivation
Does the road connect settlements or is close to rivers
T1 Biomass burning
T 1 bareland or Degraded forest by
Natural
original forest type
Is the change area state in remaining periods the same?
T2..T3 aforestation/reforestation
T2..3 Degraded forest by initial forest type
Is the change area state in remaining periods the same?
Is the change area regenerating?
T2.. T3 Afforestation/reafforestation
T 2..3 Degraded forest by initial forest type
T1..T3 Infrastructure road
T1.. T3 Settlements
Is the change close to a village or access route i.e. river or road
T1..T3 Shifting cultivation
T1..T3 Cropland
T2..3 Other driver i.e S/C, Agriculture
T 2..3 other non forest land use
i.e. bareland Agriculture, grassland savannah <30%
, cropland
T1..3 select driver
T1..3 Select Land
Is high resolution imagery available for checking?
Place waypoint and Investigate (ground-truthing; flyover; other-imagery
T1..3 Unknown
T1..3 Bareland
grassland
cropland
Is the change area state in remaining periods the same?
Is the change area regenerating?
T1.. T3 Natural
T 1..3 original forest type