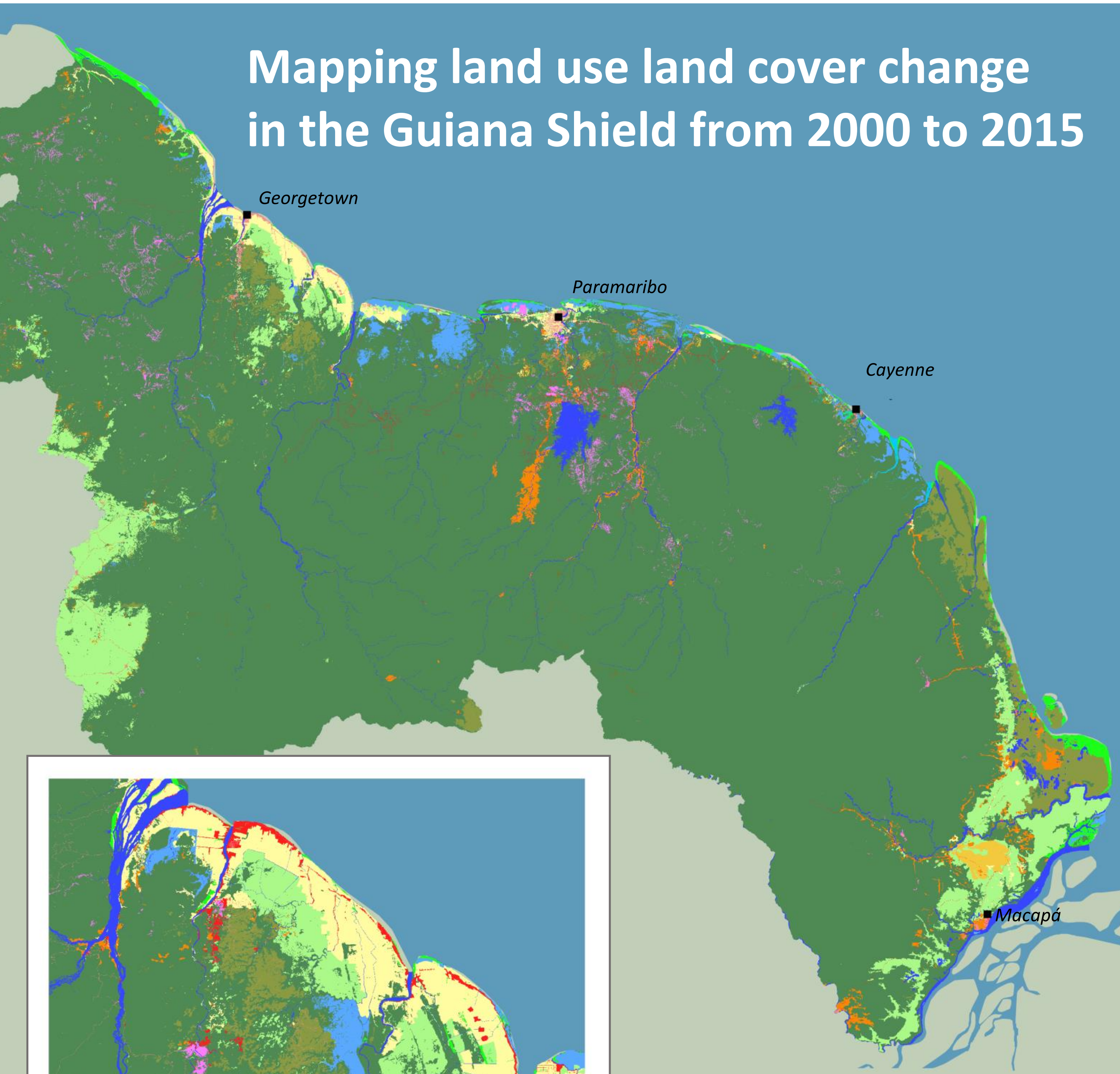
Ecosystem Services Observatory of the Guiana Shield

ECOSEO

Mapping land use land cover change in the Guiana Shield from 2000 to 2015



LAND USE AND LAND COVER CHANGE FROM 2000 TO 2015 IN THE TERRITORIES OF GUYANA, SURINAME, FRENCH GUIANA AND THE STATE OF AMAPA IN BRAZIL

ECOSEO – Ecosystem Services Observatory of the Guiana Shield

Preamble

This report has been carried out in the frame of the ECOSEO project - Regional Ecosystem Services Observatory on the Guiana Shield.

ECOSEO is a transnational cooperation project between French Guiana, Suriname, Guyana and the state of Amapá in Brazil. Led by WWF France assisted by ONF International and WWF Guianas, the project is co-funded by the Interreg Amazon Cooperation Program of the European Union, the French Guiana Water office, and the project partners, namely: the National Forest Office (ONF) of French Guiana, the Foundation for Forest Management and Production Control (SBB) in Suriname, the Guyana Forestry Commission in Guyana, the Secretariat of the Environment (SEMA) in the State of Amapá and the Gottfried Wilhelm Leibniz Universität Hannover (Germany).

The main objectives of ECOSEO are to highlight and promote the need for considering ecosystems values in decision-making and to build a transnational cooperation network to foster the sustainable development of the region.

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Recommended citation: Rahm M., Smartt T., Totaram J., Sukhu B., Thornhill-Gillis D., Amin N., Thomas R., Sookdeo C., Paloeng C., Kasanpawiro C., Moe Soe Let V., Hoepel I., Pichot C., Bedeau C., Farias P., Carvalho R., Weber JL., and Lardeux C. (2020). Mapping land use land cover change in the Guiana shield from 2000 to 2015. ECOSEO project. pp.69

Executive summary

Located in the Guiana shield ecoregion, the Guianas (Guyana, Suriname and French Guiana) and the State of Amapá (Brazil) are one of the world's last great wild places, particularly noteworthy for its endemism, unique ecosystems, and exceptionally pristine state, as well as for its cultural diversity. The forest cover rate is one of the highest in the world, playing a critical role in mitigating climate change at the South America first but also international level. In a privileged position in terms of natural resources, the region is one of the few places left on earth where all options are still available for a sustainable development.

Often overlooked and unknown internationally, the region lacks basic data to support cross-border and transnational cooperation actions essential to the preservation of this unique shared ecosystem. The objective of this study is to fill the lack of comparable data in terms of land use land cover (LULC) and its evolution in the region. This information, useful at many levels, is the cornerstone for the production of Ecosystem natural capital accounts (ENCA) endorsed by the Convention on Biological Diversity (CBD), the primary goal of the ECOSEO project.

Although some global LULC products exist, their resolution is too coarse to capture most of the changes in the region, occurring often at small-scale. Given the limited time and resources available in the project, the production was carried out in a pragmatic way, capitalizing as much as possible on existing data in the countries. Two LULC products were produced for the reference years 2000 and 2015 (+/- 1 year), for which some data were available in each territory; A "primary" product at 30m resolution, produced for the Guianas from national data and image processing. A "secondary" product at 100m resolution, covering the entire study area (including the state of Amapá) and developed earlier in the project from global and national data to serve as an input for ecosystem accounting.

This report describes the production process and the results of both LULC products with an emphasis on the primary product at higher resolution. The 2000-2015 regional LULC change maps were derived from 13 classes per date. Resulting in 156 potential combinations of change, these were eventually compiled into a matrix of 9 LULC change flows, describing the main processes of land conversion. LULC map accuracy of the primary product were assessed for 2160 stratified random sample locations. The LULC change map yielded a high level of overall accuracy (94.5%) based on the normalized confusion matrix, taking into account area proportions. Analysing the absolute sample instead of estimated area proportions, the overall accuracy drops to moderately high level (79.3%), reflecting more the accuracy of the change classes.

To analyse the trend at the scale of the entire study area, data from both LULC products were compiled. On a total area close to 600,000 km2, more than 98% of the area remained stable during the 2000-2015 period. The results show that tropical moist forest is largely dominant, covering about 87% of the territory in 2000 and 86% in 2015. In 2015, French Guiana had the highest forest cover rate of the region (94%), followed by Suriname (91%)[1], Guyana (85%) and the state of Amapá (77%). In fifteen years, nearly 1% of forest has been converted to other LULC, representing an estimated deforestation of 4,923 km2.

[1] The 91% forest cover rate excludes shifting cultivation. According to Suriname's national definition of forest, shifting cultivation is included in the forest class, resulting in 93% forest cover for Suriname in 2015 (Source: Government of Suriname (2018). Forest Reference Emission Level for Suriname's REDD+ Programme. Modified May 2018. Paramaribo, Suriname.)

Linked to deforestation, agricultural development appears by far as the first driver of land conversion with 3,055 km^2, concerning mostly shifting cultivation in terms of agricultural practices[2]. More than two-thirds of these changes are located in the state of Amapá, where agricultural development accounts for 84% of LULC changes between 2000 and 2015. The remaining third is distributed within the Guianas, where agriculture development is the second driver of change behind mining. Mostly distributed in the west of the study area, mining accounts for 1,539 km^2 of land conversion. Since 2000, driven by the increase in gold price, legal and illegal gold mining has experienced a significant boom in the region, especially in Guyana and Suriname where it represents the first cause of forest loss. Although important in the local economy, gold mining is a scourge in the region in terms of social and ecosystem's impact. The third cause of LULC change, ahead of artificial development (infrastructure and settlements) in terms of surface, is more positive for ecosystems as it is habitat restoration. Essentially concentrated in Suriname (~70%), it results mainly from the conversion of old agricultural land into fallow areas.

The project yielded LULC map data sets that are now available for aiding any additional national, transboundary or transnational studies that assess LULC change in the region and the impacts such change may pose to water, agriculture, forestry, and disaster management efforts. In this regard, it offers in particular the possibility of updating with more detail and precision the first ecosystem natural capital accounts of the region, produced in the framework of the ECOSEO project.

[2] In Suriname, according to the national definition of deforestation, shifting cultivation is not considered as deforestation due to the agricultural patches smaller than 1ha. Shifting cultivation is included in forest, when reporting nationally and internationally.

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Equations

Acronyms

CBD	Convention on Biological Diversity
EAA	European Environment Agency
ENCA-QSP	Ecosystem Natural Capital Accounts - Quick Start Package
ESA CCI	European Space Agency Climate Change Initiative
FAO	Food and Agriculture Organization
FCMU	Forest Cover Monitoring Unit
FIRMS	Fire Information for Resource Management System
GFC	Guyana Forestry Commission
IBGE	Brazilian Institute of Geography and Statistics
IGNFI	Private Subsidiary of the French national geographic institute
INPE	Brazilian National Institute for Space Research
IPCC	Intergovernmental Panel on Climate Change
LCEFU	Land Cover Ecosystem Functional Units
LCCS	Land Cover Classification System
LEAC	Land and Ecosystem Accounting
LULC	Land Use Land Cover
MMU	Minimum mapping unit
MRVS	Measurement, Reporting and Verification system
NFMS	National Forest Monitoring System
OAM	Observatory of mining activity (French Guiana)
ONF-French Guiana	National Forest Office of French Guiana
ONFI	ONF International
PRODES	Program for Monitoring Deforestation of the Amazon by Satellite
QA/QC	Quality assessment/ Quality control
REDD+	Reducing Emissions from Deforestation and forest Degradation, plus the sustainable management of forests, and the conservation and enhancement of forest carbon stocks
SBB	Forest Management and Production Control (Suriname)
SEEA-EEA	System of Environmental Economic Accounting - Experimental Ecosystem Accounts
SEEA-CF	System of Environmental Economic Accounting - Central Framework
SEMA	Secretariat of the Environment (State of Amapá)
SVM	Support Vector Machine
WWF	World Wide Fund for Nature

I | Introduction

Land use land cover (LULC) is an observable image of the many processes taking place on the land surface. It reflects land occupation by various natural, modified or artificial systems, and, to some extent, the way land is used by such systems. LULC cartographic and statistical information therefore plays a central role in the description and quantification of the interactions between the economy and nature. The change of LULC provides basic information about what has actually happened, giving a fair and robust description of major processes such as urban development, extension of agriculture over marginal land, and change in forest tree-cover.

Within the Guiana Shield, the spatialization of information on LULC has been the subject of more or less in-depth studies at the national level over the past decade, in particular through the involvement of countries in the REDD+ mechanism. The objective of REDD+ is to assess the greenhouse gas emissions caused by deforestation and forest degradation, based on the measurement of activity data (deforested or degraded areas) and emission factors (carbon content of forests). However, these data are disparate and heterogeneous between the territories, which complicates the analysis and comparison of the dynamics of change at the regional level. Although some global products provide homogeneous and comparable information in the region, such as the Global land cover map produced by the European Space Agency (ESA) Climate Change Initiative (CCI) at 300m resolution, their resolution is too coarse to reflect the existing pressures on the dense forests of the Guiana Shield. Mining activity for example, known as being one of the main drivers of deforestation and impactful on ecosystems, is poorly detected by such products.

As detailed LULC change information is the basis to produce the Ecosystem natural capital accounts (ENCA), which is one of the goal of ECOSEO, the project aimed to fill this current gap by producing the region's first LULC change map. Taking into account the constraints linked to the time and resources available in the project, the production was carried out in a pragmatic way, capitalizing as much as possible on existing data in the countries. Based on the availability of national data, but also on global data for other ENCA-related tasks, the selected pivot years were 2000 and 2015. For reasons of timing related to the production of ecosystem accounts, two distinct products were ultimately generated:

- A "primary" product at 30m resolution
- A "secondary" product at 100m resolution

The secondary product is an intermediate product developed earlier in the project to serve as an input for ecosystem accounting. It was built from global data supplemented by national data and covers the entire ECOSEO's study area, namely Guyana, Suriname, French Guiana and the state of Amapá in Brazil.

The primary product, produced only from national data at higher resolution, provides more details for the territories of Guyana, Suriname and French Guiana (the state of Amapá could not be included due to lack of local resources available to generate the product at the time).

The purpose of this report is to describe the data, methodology and results of the primary product as well as to present the secondary product. The primary product can be used as an input to the future production of ecosystem accounts at a more precise and localized scale. It provides also a more detailed vision of the dynamics of LULC change within the Guianas, which can also serve as an input for any other type of study in the region.

II | Study area

The study area is located within the Guiana Shield ecoregion (Figure 1). The primary product at 30m resolution based on local data covers the Guianas, i.e. French Guiana, Suriname and Guyana. In order to cover all the four territories involved in the ECOSEO project, including the state of Amapá in Brazil, a secondary product at 100m resolution has been produced from global and national data.

For project timing reasons, the secondary product, available earlier in the project, served as input for the production of ecosystem accounts of natural capital. The higher resolution of the primary product is intended to provide more details and precisions for future use, such as updated ecosystem accounts from finer data and / or any other cross-border or national study in the region.

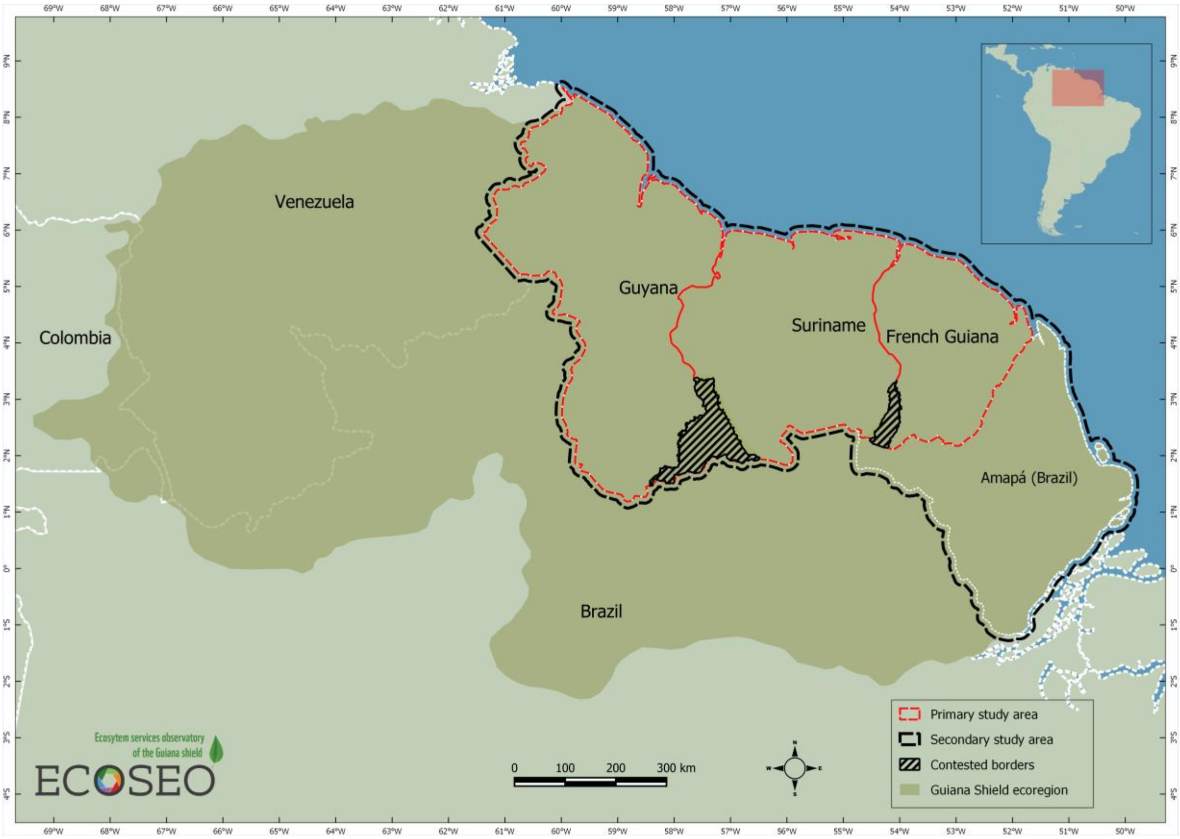


Figure 1 : Study area of primary and secondary LULC products

III | Data & methodology

As mentioned in the introduction, given the limited time and resources of the project, it was not realistic to commonly produce LULC maps from scratch based on wall-to-wall processing of satellite images. The objective consisted in making the most of the various available data within the territories in order to produce wall-to-wall consistent and homogenized information at high resolution on a regional scale for the reference years 2000 and 2015. The data and methodology described in this section refers thus to the production of the primary product at 30m resolution. A brief description of the input data and method used to build the secondary product at 100m resolution is given in the result section.

III.1 Nomenclature & technical specifications

III.1.1 Forest definition & Minimum mapping unit

ECOSEO classifies land as forest according to the definition outlined in the Marrakech Accords (UNFCCC, 2001), which meet the following criteria:

- Tree cover of minimum 30%
- Attains a minimum height of 5m at maturity
- A minimum area of 1ha

The minimum mapping unit (MMU), which is the smallest object represented on the map, is defined in accordance with the definition of forests adopted, i.e. 1ha. In the context of this study, shifting cultivation is excluded from the definition of forest and considered as agriculture, such as for the majority of the territories involved in this study. In Suriname, however, the national definition of forests includes shifting cultivation activities, which differs from the definition adopted here.

III.1.2 Detailed LULC types

The first step of the methodology was to define a common subdivision of LULC types in order to prepare the basics for the ecosystem natural capital accounting (ENCA), which is the building block of the ECOSEO project. In the ENCA quick start package (ENCA-QSP – Weber, 2014) methodological guide, such a subdivision is proposed based on the Land-cover ecosystem functional units (LCEFU) classification.

The principle of the LCEFU classification is to recommend a top level of 14 classes (plus the sea) as a common level for SEEA-EEA (System of Environmental Economic Accounting - Experimental Ecosystem Accounts) tests (Table 1). The LCEFU classification is derived from the classification of land-cover types presented in the SEEA-CF[3], which has been further developed by the FAO[4], IGNFI and the European Environment Agency (EAA) (Di Gregorio et al., 2011). This aggregated level can then be subdivided, depending on specific needs, while maintaining overall consistency by following the FAO land cover classification system (LCCS) rules.

[3] SEEA CF, Chapter V Asset accounts, Land cover classes, paragraphs 5.257 to 5.262. In: Jean-Louis Weber (2014). Ecosystem Natural Capital Accounts: A Quick Start Package, Montreal, Technical Series No. 77, Secretariat of the Convention on Biological Diversity, 252 pages.

[4] The LCEU classification has benefited from recent progress of the FAO land cover classification system (LCCS) version 3 which has been established as an application of the geomatics rules adopted at the international level by ISO TC211 on the basis of the land cover meta language (LCML) developed by FAO.

Class	Label
01	Urban and associated developed areas
02	Homogeneous herbaceous cropland
03	Agriculture plantations, permanent crops
04	Agriculture associations and mosaics
05	Pastures and natural grassland
06	Forest tree cover
07	Shrubland, bushland, heathland
08	Sparsely vegetated areas
09	Natural vegetation associations and mosaics
10	Barren land
11	Permanent snow and glaciers
12	Open wetlands
13	Inland water bodies
14	Coastal water bodies and inter-tidal areas
	Sea (interface with land)

Table 1 : Land Cover Ecosystem functional Units (LCEFU) classification (Annex VII.1 provides the details of LCEFU and types at three hierarchical levels)

Based on the LCEFU classification and the information contained in the various national existing products, the classification shown in Table 2 has been adopted by the ECOSEO consortium for mapping LULC at 30m resolution. The classification is subdivided in two levels of details and level 2 is the one selected to map the territories.

Class level 1	*Class level 2*	*Label*
1	**Artificial surfaces (including urban and associated area)**	
	11	*Infrastructure*
	12	*Settlements*
	13	*Mineral extraction sites*
2	**Cropland**	
	21	*Herbaceous crops*
	22	*Woody crops*
	23	*Shifting cultivation*
3	**Grassland**	
	30	*Grassland*
4	**Forest Tree cover**	
	41	*Forest tree cover*
	42	*Mangroves*
5	**Shrubland, bushland, heathland**	
	50	*Shrubland, bushland, heathland*
6	**Barren land**	
	60	*Barren land*
7	**Wetland**	
	71	*Open wetlands*
	72	*Water bodies*

Table 2 : ECOSEO LULC classification

III.1.3 Land cover change flows

The ENCA-QSP broadly follows the Land and Ecosystem Accounting (LEAC) methodology for land-cover accounting. One of the principles is to group the one-to-one land-cover changes between two dates into processes called land-cover flows. This method simplifies the analysis of changes by grouping them into a major category of change, corresponding to processes that can be considered similar in terms of impact on ecosystems. In our case for example, the land-cover matrix of transition from one date to another shows that there are ((13 x 13)-13) = 156 possible elementary changes, which is very difficult to interpret, especially on a map. When using a more detailed land-cover classification, the theoretical number of possible changes can be very large and, therefore, the resulting classification of little use.

In accounting, the stocks of land cover correspond to the surfaces of the land-cover map, whereas the flows of land cover are consumption and formation. The classification of land-cover flows takes into account the practical possibility of interpreting the information provided by land-cover observations at two dates. Flows can generally be related to anthropogenic activities, but in some cases uncertainties result from the fact that change results from a combination of many causes, natural and human; a special category is necessary for these. The computation matrix below (Table 3) shows the LULC flows classification developed in ECOSEO, based on the LULC classification and ENCA-QSP recommendations. Processes involving forests are recorded in all land-cover aggregated flows (Figure 2). More details about these flows are reported in Annex VII.2.

Year T0 \ Year T1		Infrastructure	Settlements	Mineral extraction sites	Herbaceous crops	Woody crops	Shifting cultivation	Grassland	Forest tree cover	Mangroves	Shrubland, bushland, heathland	Barren land	Open wetlands	Inland water bodies
		11	12	13	21	22	23	30	41	42	50	60	71	72
Infrastructure	11	lf0	lf3	lf3	lf7	lf7	lf7	lf7	lf7	lf7	lf7	lf7	lf7	lf6
Settlements	12	lf3	lf0	lf3	lf7	lf7	lf7	lf7	lf7	lf7	lf7	lf7	lf7	lf6
Mineral extraction sites	13	lf3	lf3	lf0	lf7	lf7	lf7	lf5	lf5	lf7	lf5	lf6	lf6	lf6
Herbaceous crops	21	lf1	lf1	lf8	lf0	lf3	lf3	lf5	lf5	lf5	lf5	lf6	lf6	lf6
Woody crops	22	lf1	lf1	lf8	lf3	lf0	lf3	lf5	lf5	lf5	lf5	lf6	lf6	lf6
Shifting cultivation	23	lf1	lf1	lf8	lf3	lf3	lf0	lf5	lf5	lf5	lf5	lf6	lf6	lf6
Grassland	30	lf1	lf1	lf8	lf2	lf2	lf2	lf0	lf5	lf5	lf6	lf6	lf6	lf6
Forest tree cover	41	lf1	lf1	lf8	lf2	lf2	lf2	lf6	lf0	lf3	lf4	lf4	lf7	lf6
Mangroves	42	lf1	lf1	lf8	lf2	lf2	lf2	lf6	lf3	lf0	lf7	lf6	lf6	lf6
Shrubland, bushland, heathland	50	lf1	lf1	lf8	lf2	lf2	lf2	lf6	lf5	lf5	lf0	lf6	lf6	lf6
Barren land	60	lf1	lf1	lf8	lf2	lf2	lf2	lf6	lf5	lf5	lf6	lf0	lf6	lf6
Open wetlands	71	lf1	lf1	lf8	lf2	lf2	lf2	lf6	lf7	lf7	lf6	lf6	lf0	lf3
Inland water bodies	72	lf1	lf1	lf8	lf2	lf2	lf2	lf6	lf7	lf5	lf6	lf6	lf3	lf0

lf1	Artificial development
lf2	Agriculture development
lf3	Internal conversions, rotations
lf4	Management and alteration of forested land
lf5	Restoration and development of habitats
lf6	Changes of land-cover due to natural and multiple causes
Lf7	Other land cover changes n.e.c. and reclassification
Lf8	Mining development
lf0	No observed land-cover change

Table 3 : ECOSEO LULC flow classification (adapted from Weber (2014))

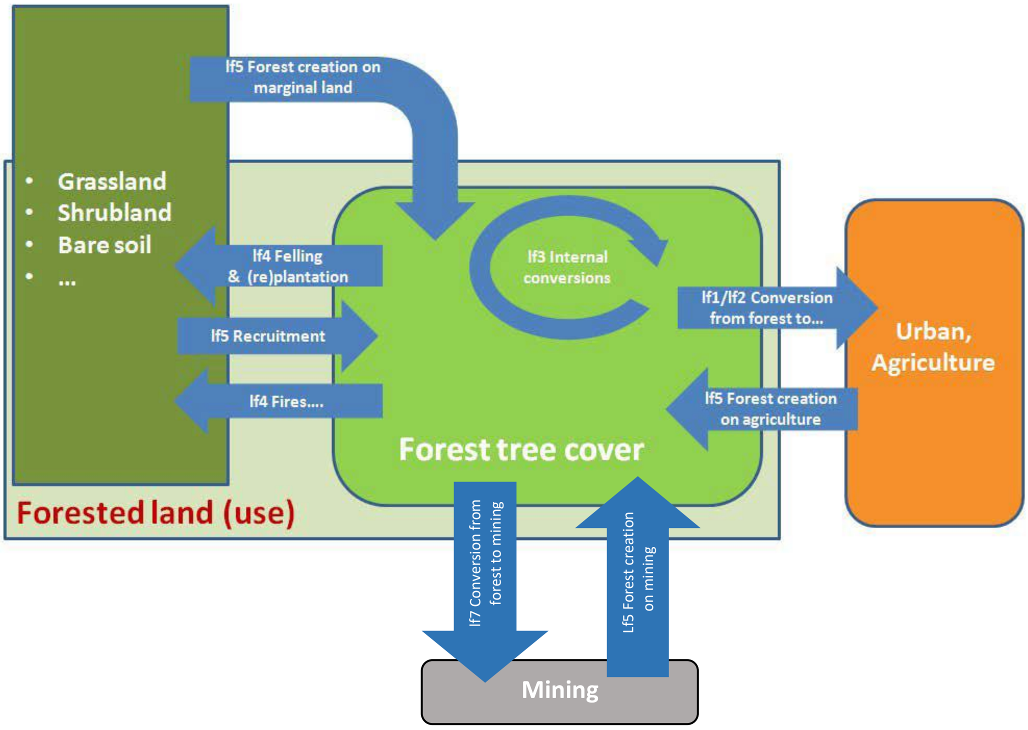


Figure 2 : Land cover flows on forest tree cover (adapted from Weber (2014))

III.2 LULC mapping in French Guiana

French Guiana do not possess wall-to-wall LULC maps for years 2000 and 2015 but LULC data is available across the territory for years 2001 and 2015. The main objective of the production to reach wall-to-wall information was to reclassify these input data according to ECOSEO's nomenclature and to classify the rest of the territory.

III.2.1 Input data

Table 4 provides the source and the description of the main LULC input data that were used to produce the 2000 and 2015 maps in French Guiana. Additionally eight Landsat 4/5 images between from 1999 to 2001 and a cloud-free mosaic of very high resolution from 2015 were used to complete the analysis in the central area of the territory, mostly unmapped (Figure 3).

	Data name	Data source	Description
1	LULC data on the coastline for 2001 & 2015 ('Occupation du sol 2001 et 2015 sur la bande littorale')	ONF	Vector layers composed of 5 classes of level 1, 15 of level 2 and 41 of level 3, resulting from the photo-interpretation of high (e.g. SPOT 4/5) or very high-resolution satellite images (e.g. Pleiades). These data are available for free download via the GIS Géoguyane platform.
2	Annual LULC maps from 2005 to 2019 over the territory of the Amazonian Park of French Guiana (PAG) ('Occupation du sol annuelle sur le territoire du Parc Amazonien de Guyane (PAG) de 2005 à 2018')	PAG	Vector layers composed of ten classes, resulting from the photo-interpretation of high or very high-resolution satellite images (ex: SPOT 4/5/6, Pleiade, Landsat or Sentinel 2). These data are available for free download via the GIS Géoguyane platform.
3	Annual gold mining data from 2001 to 2019	ONF/ Observatory of mining activity (OAM)	Vector data produced by photo-interpretation of medium, high or very high-resolution images (e.g. Landsat, Sentinel 2, SPOT 4/5/6)

4	Surface hydrology ('Hydrographie surfacique') & roads	National Geographic Institute (BD-CARTHAGE & BD-TOPO)	Vector data providing the spatial location of surface water bodies and roads
5	Cadastre 2004	IGN	Vector data providing spatial information of cadastre
6	Map of the natural landscapes of the mainland forest of French Guiana and Amapá (landscape units) - Inselbergs ('Cartographie des paysages naturels de la forêt de terre ferme de Guyane et d'Amapá'). 2001	ENGREF, IEPA, IRD	The mapping of natural landscapes is based on a typology of 17 homogeneous landscape units. It provides the location of inselbergs, which are rock outcrops on the youngest parts of the granite base. They can be made up of simple granitic plates exposed on the hillside or real domes. The production was carried out by remote sensing from Landsat 5 TM satellite images from 1989 to 1999.

Table 4 : French Guiana input data for LULC mapping

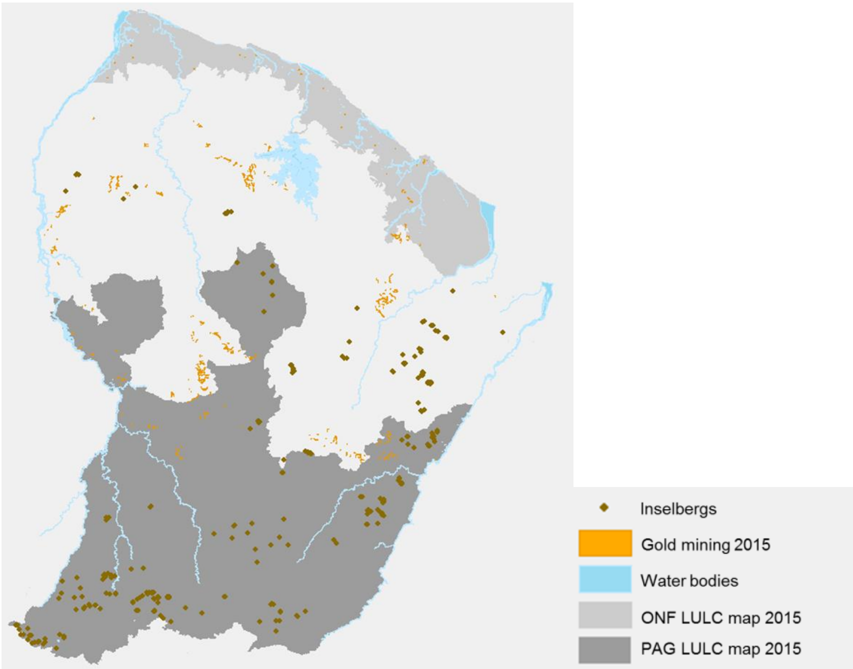


Figure 3 : Coverage of main 2001 LULC data used as input to produce the wall-to-wall LULC map in French Guiana

III.2.2 Methodology

III.2.2.1 Extract and merge LULC information from input data

The objective was first to reclassify both LULC maps available on the territory using correspondence tables (see Annex VII.3), namely:

- Input data #1: ONF LULC map in the north
- Input data #2: PAG LULC map in the south

The resulting map was then used to overlap the additional one-class input data, i.e. mining (input data #3), water bodies and roads (input data #4) and inselbergs (input data #6).

This step is performed for building the 2000 LULC map from the 2001 input data and the 2015 LULC map from the 2015 input data.

III.2.2.2 Classify unmapped areas

To complete the analysis in order to obtain a wall-to-wall map, the areas not covered by the input data (see Figure 3) were classified based on semi-automatic classification of the input satellite data. The 2000 gaps were completed via the photointerpretation of Landsat 4/5 acquired between 1999 and 2001. It was then updated in 2015 by the photointerpretation of the changes from the IGN VHR mosaic of 2015. In some areas, to speed up the process, and particularly the detection of roads or tracks, an iso-cluster unsupervised classification was carried out to support manual photointerpretation (Figure 4).

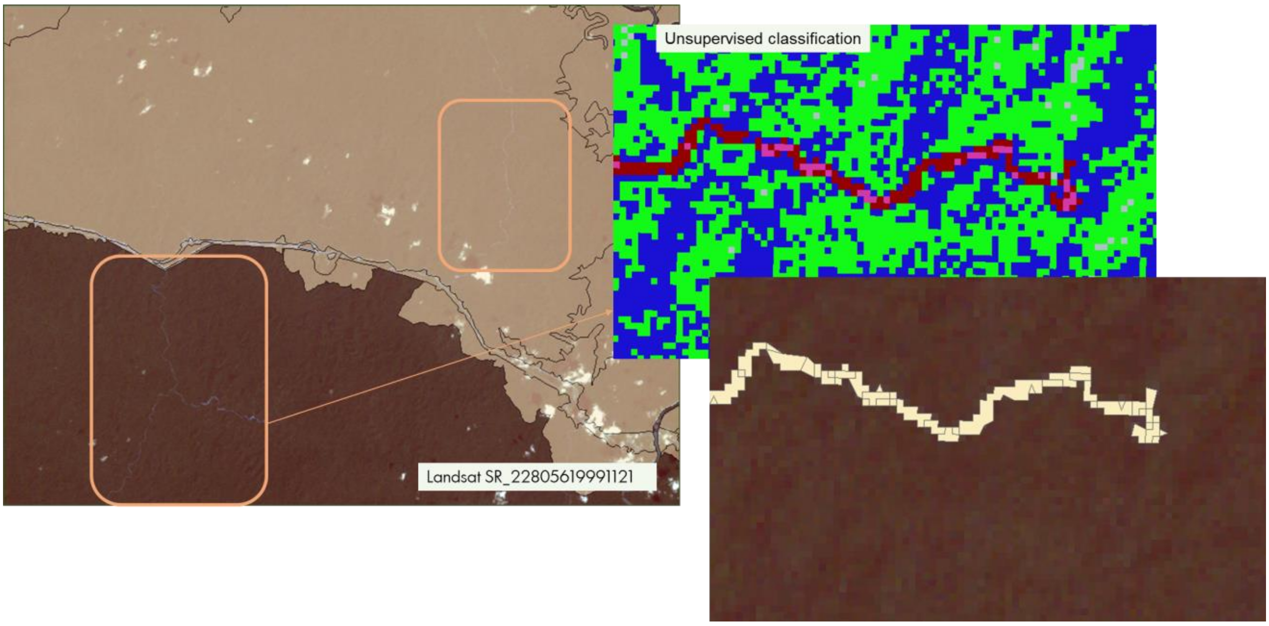


Figure 4 : Unsupervised classification of Landsat 4 image to support manual delineation of roads and tracks from photointerpretation

III.2.2.3 Rasterize and sieve

The last step was to rasterize the vector layers at 30m resolution and reclassify all isolated objects smaller than 1ha to the neighbouring majority class in order to respect the minimum mapping unit (MMU). The projection used to generate the final map is UTM 22N (EPSG: 32622).

III.3 LULC mapping in Suriname

Since its creation in 2012, the Forest Cover Monitoring Unit (FCMU), based at the Foundation for Forest Management and Production Control (SBB) in Suriname, aims to contribute to the strengthening of the National Forest Monitoring System (NFMS) by generating information about forest cover change.

Among the products generated, the monitoring of deforestation and the post-deforestation labelling of changes were carried out for the period 2000-2015 in the framework of the ACTO project “Monitoring the Forest Cover of the Amazon Region”. The continuation of monitoring deforestation, its drivers and the LULC change was made possible within the REDD+ program. All the available data within the NFMS, was used as input to produce the 2000 and 2015 LULC maps for Suriname in the framework of the ECOSEO project. As the methodology for producing this data has been the subject of a detailed report (SBB, 2017), only the main stages are listed below, emphasizing the adaptation of the results to the technical specifications of ECOSEO.

III.3.1 Input data

The main input data consist of the 2000-2015 deforestation map (Figure 5) and the 2015 national LULC map (Figure 6). The deforestation map includes the classes Forest, Non-forest, Hydrography, Shifting cultivation and Deforestation, whereas, the national LULC map labels land use and land cover classes, streamlined with IPCC classes, such as Mining, Infrastructure, Built area, Agriculture, Secondary vegetation, etc..

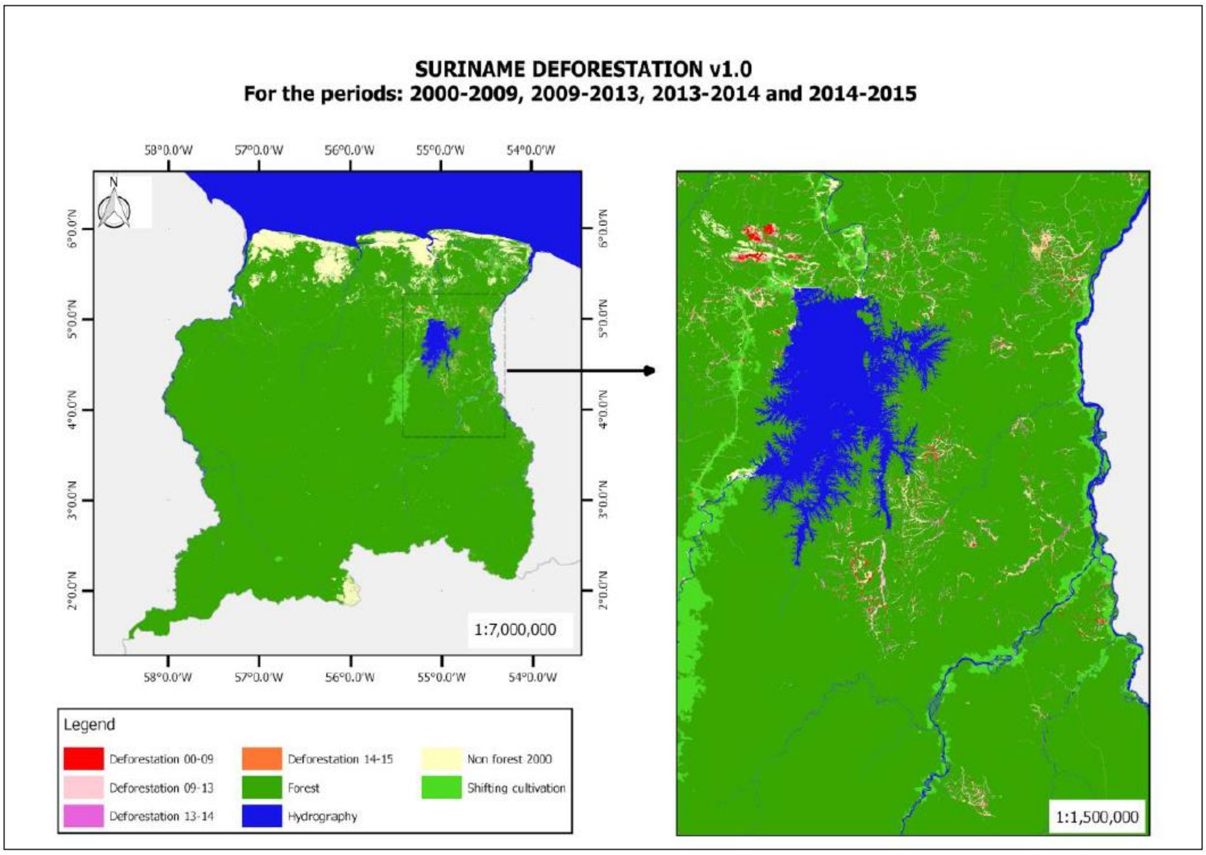


Figure 5 : Deforestation map of Suriname for the time periods: 2000-2009, 2009-2013, 2013-2014 and 2014-2015 (source: SBB, 2017)

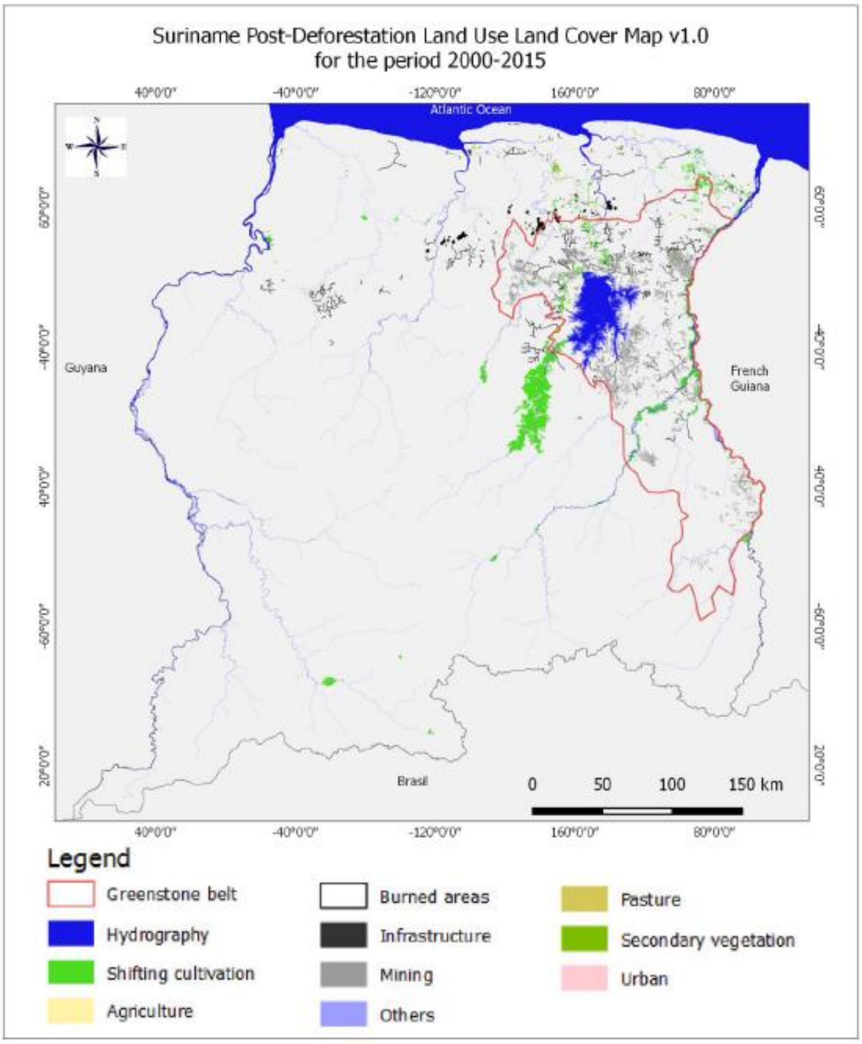


Figure 6 : Overview of the Suriname Post-deforestation LULC map 2000-2015 (source: SBB, 2017)

The methodology to produce the deforestation map is inspired by the method used by the Brazilian National Institute for Space Research (INPE) to monitor deforestation in Brazil. The method, which is based on freely available Landsat images, has been adjusted to Suriname's national conditions. Table 5 shows input data used to generate the results. The class assignment for the areas on Landsat covered with clouds was done using the Greenest pixel composite from Google Earth Engine in combination with the Global Forest Change data from Maryland University (Hansen et al., 2013). Lots of ancillary data, produced by SBB and other relevant institutes, were also collected and used (e.g. Fire Information for Resource Management System (FIRMS), forest & mining concessions…), providing a better understanding about the activities or changes that have taken place. The 2015 national LULC map was produced within the Cross Cutting Capacity Development (CCCD) project. The National Institute for Environmental and Development in Suriname (NIMOS) coordinated this project, where SBB was an important technical partner. The 2015 national LULC map was produced in a participative process where relevant national stakeholders were involved and validated the map.

Map produced	Data used		
	Satellite	Sensor	Year (s)
Basemap 2000	Landsat 5	Thematic mapper (TM)	1999, 2000 and 2001
Deforestation map 2000-2009	Landsat 5	Thematic mapper (TM)	2000-2009
Deforestation map 2009-2013	Landsat 7 Landsat 8	Enhanced Thematic Mapper plus (ETM+) Operational Land Imager (OLI)	2013
Deforestation map 2013-2014	Landsat 8 SPOT 5 and Spot 6	Operational Land Imager (OLI)	2014
Deforestation map 2014-2015	Landsat 8	Operational Land Imager (OLI)	2015
	Greenest pixel composite		2015
	Sentinel 2A[10]		2015
	Global forest change data from the University of Maryland (Hansen et al., 2013)		

Table 5 : Overview of data used to produce the 2000 – 2015 forest cover maps in Suriname (source: SBB, 2017)

The satellite-based monitoring of mangroves in 2018 later completed the 2015 LULC map (Figure 7).

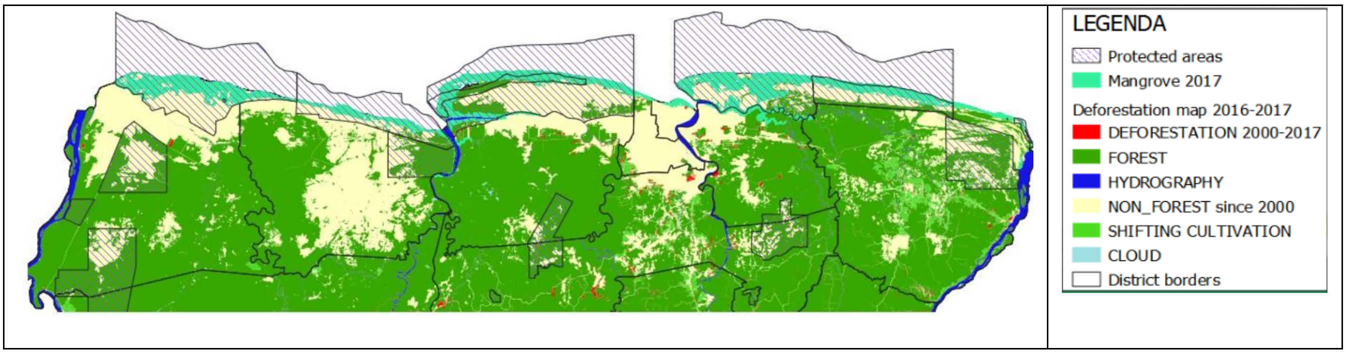


Figure 7 : Monitoring of Mangrove forest of 2017 in Suriname

III.3.2 Methodology

The production of the forest cover data is based on the Brazilian PRODES ("Projeto de Monitoramento do Desmatamento na Amazônia Legal por Satélite") method. It can be divided into three main stages: pre-processing, core-processing, and post-processing. Each stage is further subdivided in processing steps, which are illustrated on Figure 8 showing the production flowchart. The core-processing is a semi-automatic supervised classification of Landsat data using the Support vector machine (SVM) algorithm.

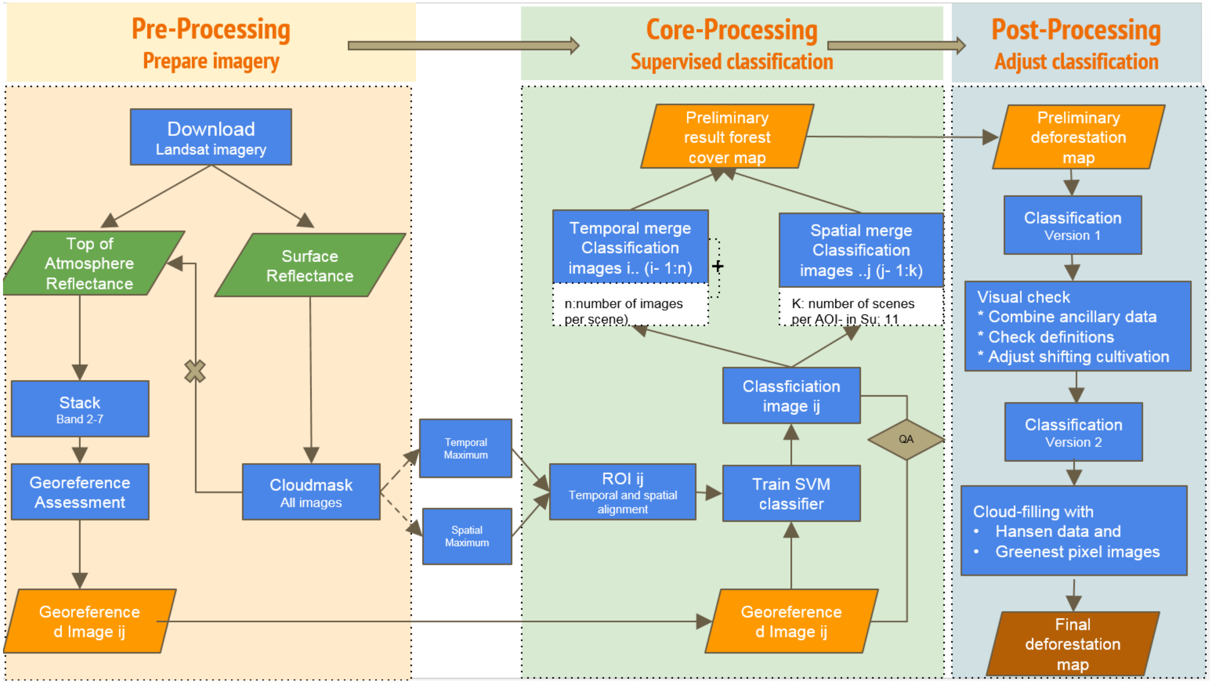


Figure 8 : Processes flowchart for producing the 2000-2015 deforestation maps in Suriname

The production of the 2015 national LULC map is based on digital data (available satellite imageries and ancillary data) and non-digital data (field experience of experts and stakeholders). The map was built through several steps:

a) Carrying out an internal classification, using ancillary data;
b) Validating the internal classification by gathering input data from stakeholders through work sessions;
c) Final classification with the gathered input data from stakeholders;
d) Assessing the total classified area that is validated.

Based on this data and the mangrove data, the 2000 and 2015 LULC maps could be produced in several stages:

a) Extract and merge LULC information from input data
b) Classify unmapped areas
c) Rasterize and sieve

III.3.2.1 Extract and merge LULC information from input data

Unlike the 2000 data, the Suriname LULC map of 2015 provides the details of the non-forest class. Therefore, the construction of the ECOSEO LULC map of 2015 was fully based on the extraction of LULC information from the latter, supplemented by the mangrove layer of 2017. Annex VII.4 provides the correspondence table of the Suriname LULC map of 2015 with the ECOSEO's classification.

III.3.2.2 Classify unmapped areas

Since the Suriname Basemap of 2000 did not provide details of the non-forest class, it was necessary to produce an LULC map from the information given by the Suriname LULC map of 2015 and the use of available satellite data of 2000 to update the information.

III.3.2.3 Rasterize and sieve

The last step was to rasterize the vector layers at 30m resolution and reclassify all isolated objects smaller than 1ha to the neighbouring majority class in order to respect the MMU. The projection used to generate the final map is UTM 21N (EPSG: 32621).

III.4 LULC mapping in Guyana

The wall-to-wall mapping and monitoring program has been a major undertaking by the GFC in the framework of the REDD+ Measurement, Reporting and Verification system (MRVS). In 2009, Guyana developed a framework for a national MRVS. 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. Mapping follows a well-documented Standard Operating Procedures (SOP). The SOPs establish the processes needed to streamline operations and standardize outputs that enable reporting of change.

LULC data is continuously updated for drivers of forest cover change, while LULC classes in non-forest areas are less detailed. The main objective of the production consisted therefore in extracting LULC information from forest cover change and in detailing the information in the non-forest areas.

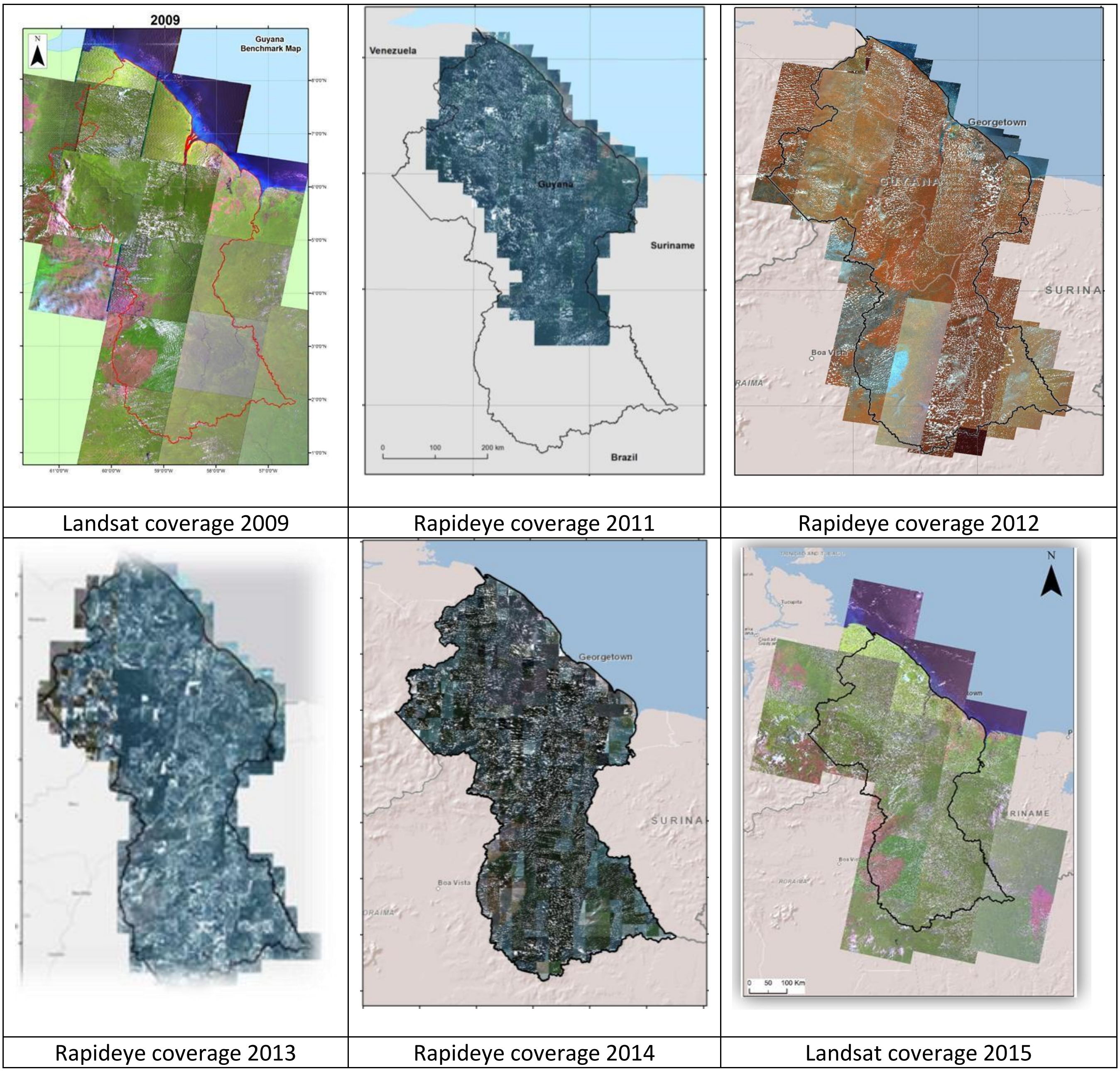
III.4.1 Input data

The input data comprised of data that was mapped under the MRVS. Data considered to be non-forest (areas that do not meet the criteria to be considered forest) and change data (Deforestation data).

The main monitoring data source for 2000 was Landsat 4, 5 and 7 images. Co-registration was then performed in the ENVI software by registering the imagery to the 2005 Guyana Landsat geo-cover base map. Quality control and assurance is done after each image processing step, which is done by randomly checking the number of pixel displacements between image and the base image. RapidEye images were also used. Co-registration was done on the 2011 and 2012 RapidEye images while 2013 and 2014 images came co-registered.

The main monitoring data used for 2015 was a compilation of Landsat 7&8. The images downloaded were already geo-corrected; hence, no co-registration was required. The Landsat images were downloaded and the bands stacked.

Figure 9 below shows examples of imagery coverage for the years, 2009, 2011, 2012, 2013, 2014 and 2015.



Landsat coverage 2009 | Rapideye coverage 2011 | Rapideye coverage 2012

Rapideye coverage 2013 | Rapideye coverage 2014 | Landsat coverage 2015

Figure 9 : Satellite imagery coverage in Guyana for the years 2009, 2011, 2012, 2013, 2014 and 2015

The input data used are as follows:

1. **Non-forest data**- this data was mapped and tracked from 1990 to present. It includes areas that are classified according to the IPCC classification scheme. However, for the purpose of the ECOSEO project the classes were re- attributed to suit the classification classes provided by ECOSEO. The layer is a vector layer and it covers all non-forest areas found in Guyana. The map below shows the separation of forest and non- forest areas.

Figure 10 : Forest – Non-forest map of Guyana (2010 – 2015)

2. **Change data**- this consist of deforestation and forest degradation areas that was mapped under the MRVS. This layer covers change area mapped for the entire country from 1990 to present. The areas are attributed based on the criteria set out under the MRVS project. However, for the purpose of the ECOSEO project the classes were re- attributed to suit the classification classes provided by ECOSEO. The layer is a vector layer and it covers all change due to deforestation and degradation areas found in Guyana. For the purpose of the ECOSEO project only change attributed as deforestation were used. Figure 11 & Figure 12 below show examples of historical data used in the project.

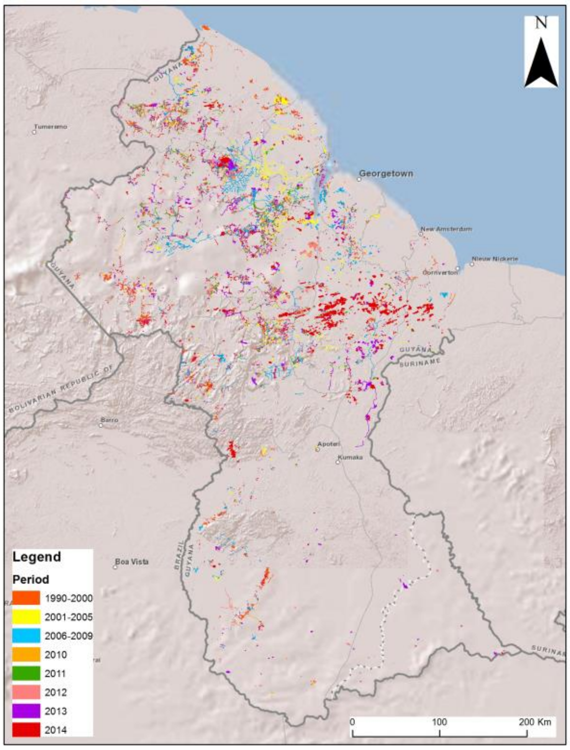


Figure 11 : Example of deforestation and forest degradation areas mapped under the MRVS that was used as input data in ECOSEO.

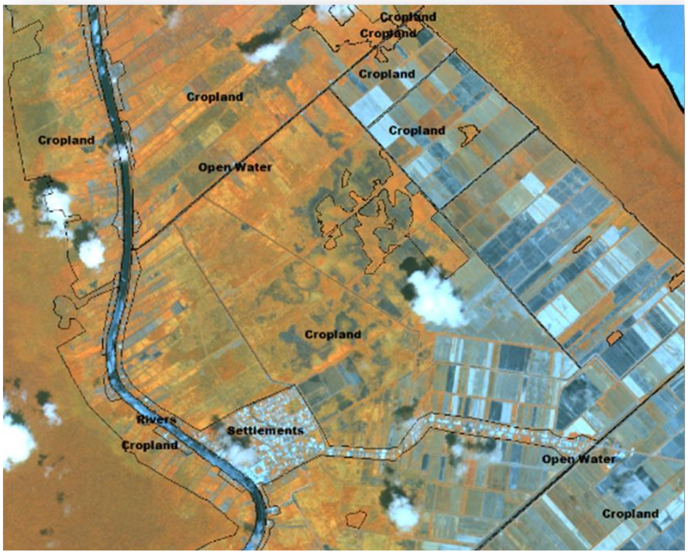


Figure 12 : Example of classification of Non Forest areas using Satellite imagery in Guyana.

Table 6 below shows layers and imagery that was used to create forest cover maps (2000-2015).

Layers Produced	Data used		
	Satellite	Sensor	Year(s)
Non-forest layer 2000	Landsat 4 and 5	Thematic Mapper (TM)	1987,1990,1992, 2000
Updated non forest layers 2009-2014	Landsat 5,7 and 8	Thematic Mapper (TM)	2009,2011,2012,2013,2014
Change Layers (Deforestation and Forest Degradation) 1990-2000	Landsat 4 and 5	Thematic Mapper (TM)	1987,1990,1992, 2000
Change Layers (Deforestation and Forest Degradation) 2001-2005	Landsat 4,5 and 7	Thematic Mapper (TM) Enhanced Thematic Mapper plus (ETM+)	2003,2004,2005
Change Layers (Deforestation and Forest Degradation) 2006-2009	Landsat 4,5 and 7	Thematic Mapper (TM) Enhanced Thematic Mapper plus (ETM+)	2006,2009
Change Layers (Deforestation and Forest Degradation) 2010	Landsat 7	Enhanced Thematic Mapper plus (ETM+)	2010
Change Layers (Deforestation and Forest Degradation) 2011	Landsat 5 and 7	Enhanced Thematic Mapper plus (ETM+)	2011
	RapidEye	REIS (RapidEye Earth Imaging System): Multi-spectral push broom imager	2011
Change Layers (Deforestation and Forest Degradation) 2012	Landsat 7	Enhanced Thematic Mapper plus (ETM+)	2012
	RapidEye	REIS (RapidEye Earth Imaging System): Multi-spectral push broom imager	2012
Change Layers (Deforestation and Forest Degradation) 2013	Landsat 8	Operational Land Imager (OLI)	2013
	RapidEye	REIS (RapidEye Earth Imaging System): Multi-spectral push broom imager	2013
Change Layers (Deforestation and Forest Degradation) 2014	Landsat 8	Operational Land Imager (OLI)	2014
	RapidEye	REIS (RapidEye Earth Imaging System): Multi-spectral push broom imager	2014
Change Layers (Deforestation and Forest Degradation) 2015	Landsat 7 and 8	Enhanced Thematic Mapper plus (ETM+)	2015

Table 6 : Input data used to create the 2000-2015 LULC map of Guyana

III.4.2 Methodology

To start the mapping process, Guyana has been divided into manageable tiles, each measuring 24 x 24 km. This enables a systematic review of the country using any kind of satellite imagery, since the grid is not tailored to a specific imagery footprint. Multiple coincident images over the same tile minimize the issue of cloud cover. The tiles are randomly assigned to operators in the mapping team (Figure 13).

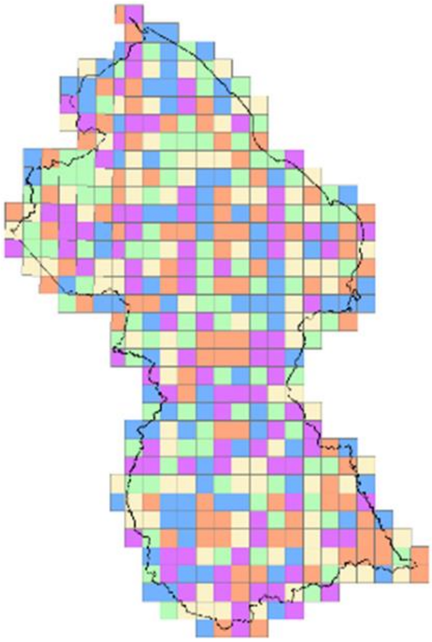


Figure 13 : Map showing 24 km tiles that were randomly assigned to mapping analyst

This process is based on a systematic tile-based manual change detection using ESRI ArcGIS. In summary, these are the main steps involved:

1. Operator selects a tile
2. Imports existing reference layers to assist with mapping
3. Undertake systematic change mapping, ensuring all changes mapped are clipped to the relevant tile
4. Update completion spreadsheet (pre-QA/QC) and return the updated mapping for QA/QC
5. Update completion spreadsheet (post-QA/QC) after passing checks

New features are mapped to record new change events, which are attributed with pre and post change event image evidence, driver of change event and resultant LULC class.

The input process is standardized using a customized GIS tool, which requires the operator to select attributes (e.g., driver and land use class) from a predefined list, as opposed to manually updating these fields. This reduces the chance of input errors.

There are two analyst roles involved in this process, QC and mapping analysts. QC analysts assist the mapping analysts by checking that workspaces are correctly setup, reviewing tiles (QA/QC) as they are completed, and provide updates and progress tracking of all spatial data. QC analysts are typically more experienced.

For ECOSEO 2000-2015 LULC production, since the input data and the mangrove data was already present, the maps could have been created. The data however needed to be tailored to suit the ECOSEO classifications. This was performed through the following steps:

1. **Data Extraction**-Data was extracted from both the non- forest and change layers according to the years required for the LULC maps. This was done by selecting all the data needed using the select by attributes tool. The data selected was then exported as a shapefile to create a new layer, which had only the data required for ECOSEO.

2. **Attribution**- the exported data was then reattributed according to the ECOSEO Classification schemes. New fields were created in this new layer according to the ECOSEO classification to enable attribution. The definition of each class that was provided by ECOSEO was used.

3. **Dissolve**-once attributed, the data was then dissolved using the ECOSEO level 1 classification scheme. The layer was further dissolved to match the level 2 classification scheme.

4. **Merge**- all data that fall within the same category was merged to ensure they were all in the same layer, under the same classification scheme.

III.5 Accuracy assessment

Actual land cover values vary from values that can be extracted from satellite-based classification processes. However, these actual values can be estimated after an assessment of accuracy and the creation of a classification error matrix (Olofsson et al., 2013). The underlying principle of accuracy assessment is that it compares the mapped classification to high-quality reference data, collected using a sample-based approach. Better quality reference data can be obtained from ground data, but since it is expensive and time consuming, it is more often obtained by satellite imagery or aerial photography with finer spatial resolution than the data used to create the classification.

The design and implementation of the accuracy assessment of the LULC map produced in ECOSEO is based on the recommendations of "good practices" of FAO (2016), themselves based on the work of Olofsson et al. (2014). When the LULC map is finalized, the accuracy assessment method is divided into three stages: the sampling design, the response design and analysis.

III.5.1 Finalization & quality check of the map

The first step is a general control of the quality of the cartographic data. Before carrying out the accuracy assessment of the LULC classes, the map must be considered as definitive.

III.5.2 Sampling plan

The sampling plan is the selection protocol for the subset of spatial units (pixels or polygons, for example) that will form the basis of the accuracy assessment. Choosing a sampling plan must take into account the specific objectives of the accuracy assessment and draw up a prioritized list of desirable design criteria. In the case of our study, to ensure that no rare / smaller class is missed or underrepresented, a stratified random sampling approach is implemented.

Stratified random sampling is a probability sampling plan, easy to implement and commonly used by the remote sensing community in the assessment of accuracy (see Cakir, Khorram & Nelson, 2006; Huang et al., 2010; Mayaux et al., 2006; Olofsson et al., 2011). Stratification has two main objectives. First, the strata may be of interest for reporting, that is, accuracy by land cover class or sub-region. The second objective of the stratification is to ensure a sufficient representation of the rare classes (for example, which represent only a small proportion of the area of interest). This is often the case for change classes but this can also be the case for an analysis on one date. Stratification allows in this case defining a sufficient number of samples in these rare classes in order to reduce the standard error for the estimation of the user's accuracy. For this reason, the stratification in this study is based on the LULC change classes and an independent sample is produced for each class and for each territory.

To build the sample, the first step is to define its size. This must be representative of the number of spatial units (pixels or area), making it large enough to obtain reliable estimates, but as small as possible in order to reduce the analysis time, and therefore the costs. Determining the size of this sample is an inexact science, as it depends on precise and geographic information unknown before the assessment. Although there are formulas for calculating the overall sample size and its distribution, it is up to the user to decide the best way to determine the sample size. For our study, the adequate overall sample size for stratified random sampling has been estimated from the following Cochran (1977) equation:

$$n = \frac{(\sum W_i\, S_i)^2}{[S(\widehat{O})]^2 + (1/N)\sum W_i\, {S_i}^2} \approx \left(\frac{\sum W_i\, S_i}{S(\widehat{O})}\right)^2$$

Equation 1: Calculation of the size of the representative global sample for the realization of the stratified sampling plan (Cochran, 1977). Where, N is the number of units in the area of interest (number of global pixels if the spatial unit is a pixel), S (Ô) is the standard error of the estimated global accuracy that we want to obtain, Wi is the proportion of area mapped for class i, and Si is the standard deviation of class i.

The overall sample size resulting from this calculation can then be distributed between the classes in several ways, either by equal distribution or by proportional distribution. In the equal distribution, the overall sample size is distributed equally between the classes. In proportional distribution, the overall sample size is distributed proportionally according to the class area, so that the rare classes receive a small proportion of the total sample size. Since stratification is used for rare classes, it is necessary to ensure that there is a sufficient number of samples in each class, i.e. a minimum of 20 to 100 samples (Congalton and Green, 2008).

To calculate the overall sample size, we used the Excel spreadsheet proposed by FAO (2016)[5], which incorporates Cochran's equation (1977). The distribution of these points within each class is carried out proportionally in order to consider the rare classes.

When the size and distribution of the samples have been defined for each territory on the basis of the classification results, the second step consisted in randomly generating the sampling points within each class. This step has been performed class by class using the map and a script in the QGIS software.

III.5.3 Response design

The response design defines how to determine whether the map and the reference data agree. It consists first in defining reference data sources to compare with the cartographic data, assuming that the reference classification will be more precise than the classification that has been produced. There are two methods to ensure this: i) The reference data source must be of better quality (satellite or aerial image of higher spatial or radiometric resolution and / or field data) than the data source used for classification, or ii) the process of creating the reference classification should be more precise if the same data source are used.

[5] https://www.dropbox.com/s/wsihmlldebjc024/sample_size_stratified_simple_random.xlsx?dl=0

In this study, given the limited access to reference data sources of higher resolution, the second method has been selected. Experts of each territories have carried out manual photointerpretation of the samples for their own territory to generate reference data of high quality.

III.5.4 Analysis protocol

The analysis protocol is the ultimate step. It consists in translating the information contained in the comparison of map and reference data into accuracy and area estimates, and how to quantify the uncertainty associated with them. Most calculations are based on the confusion matrix (also called the error matrix), which contrasts the map and reference classification (Table 7).

The confusion matrix is a simple cross-tabulation of the mapped LULC classes and the reference data from the sampling points. It organizes the acquired sample data in a way that summarizes key results and facilitates the quantification of accuracy and area. The main diagonal of the matrix highlights the correct classifications, while the elements outside the diagonal indicate errors of omission and commission. Commission error is the complimentary measure to user's accuracy, calculated by subtracting 100% from the user's accuracy for each class. Commission error, calculated for each of the map classes, is the probability that the spatial unit classified into a given category on the map represents that category in the reference data. Omission error is the complimentary measure to producer's accuracy, calculated by subtracting 100% from the producer's accuracy for each class. Omission error, calculated for each of the map classes, is the probability that the spatial unit classified into a given category in the reference data represents that category in the map data.

		Reference				
		Class 1	Class 2	Class 3	Class 4	Total
Map	Class 1	p_{11}	p_{12}	p_{13}	p_{14}	$p_{1.}$
	Class 2	p_{21}	p_{22}	p_{23}	p_{24}	$p_{2.}$
	Class 3	p_{31}	p_{32}	p_{33}	p_{34}	$p_{3.}$
	Class 4	p_{41}	p_{42}	p_{43}	p_{44}	$p_{4.}$
	Total	$p_{1.}$	$p_{.2}$	$p_{.3}$	$p_{.4}$	1

Table 7 : Population confusion matrix of four classes. Cell entries (pij) represent proportion of area (Source: FAO, 2016)

The measures of accuracy are derived from the confusion matrix and reported with their respective confidence intervals. They generally include overall accuracy, user accuracy and producer accuracy. Overall accuracy is the proportion of the area classified correctly, and therefore refers to the probability that a randomly selected area on the map is classified correctly. User's accuracy is the proportion of the area classified as class i that is also class i in the reference data. It provides users with the probability that a particular area of the map of class i is also that class on the ground. Producer's accuracy is the proportion of area that is reference class j and is also class j in the map. It is the probability that class j on the ground is mapped as the same class.

The overall map accuracy is not always representative of the accuracy of individual classes (GFOI, 2013). High overall map accuracy does not guarantee high accuracy for individual classes. Therefore, both producer's and user's accuracy for all single classes need to be considered. A high user's accuracy and low producer's accuracy for class i, for example, indicate that most of the class i in the map was also class i in the reference data, but that the map missed catching a fair amount of class i. The performances for each class can also be calculated separately from the following indicators: precision, recall and F-score. Precision is the ratio of correctly predicted positive observations to the total of predicted positive observations. The recall is the ratio between the correctly predicted positive observations and all the observations of the current class. The F-score is the weighted average of the precision and the recall, according to the following formula: 2 * (Recall * Precision) / (Recall Precision). Therefore, this score takes into account both false positives and false negatives. The more these indicators tend towards 1 (or 100%), the more efficient the model is for the class considered. Additionally, total sample size, the number of strata and the allocation of the total sample size to the strata can favor one accuracy measure over the other.

The accuracy assessment serves also to derive the uncertainty of the map area estimates. Whereas the map provides a single area estimate for each LULC without confidence interval, the accuracy estimates adjusts this estimate (**adjusted area estimate**) and also provides confidence intervals as estimates of uncertainty. It is recommended to base that estimation on p.k, which is the total of the columns of the reference class k in the confusion matrix (Equation 2

Equation 2).

$$\hat{p}_{\cdot k} = \sum_{j=1}^{q} \hat{p}_{ik}.$$

Equation 2 : Calculation of p.k to adjust the area estimate of the class obtained from the map.

This analysis protocol has been carried out in the QGIS software using a script developed specifically from the algorithms provided by Olofsson et al. (2013) and Mas et al. (2014). This script uses the map and the reference data to generate the confusion matrix, the measurements of accuracy, the adjusted area estimates, as well as the associated uncertainties.

IV | Results

IV.1 Primary LULC map at 30m resolution

IV.1.1 LULC cover maps of the Guianas

The following figures illustrate mapping results for both years 2000 (Figure 14 & Figure 15) and 2015 (Figure 16 & Figure 17), as well as the LULC change flows between 2000 and 2015 (Figure 18 & Figure 19).

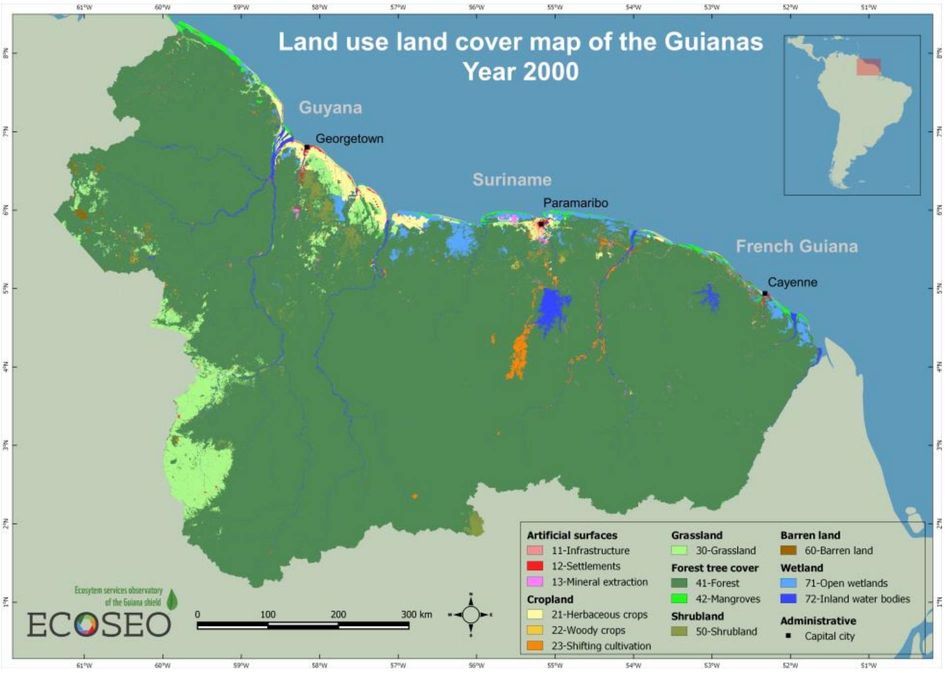


Figure 14 : LULC map of the Guianas in 2000 at 30m resolution

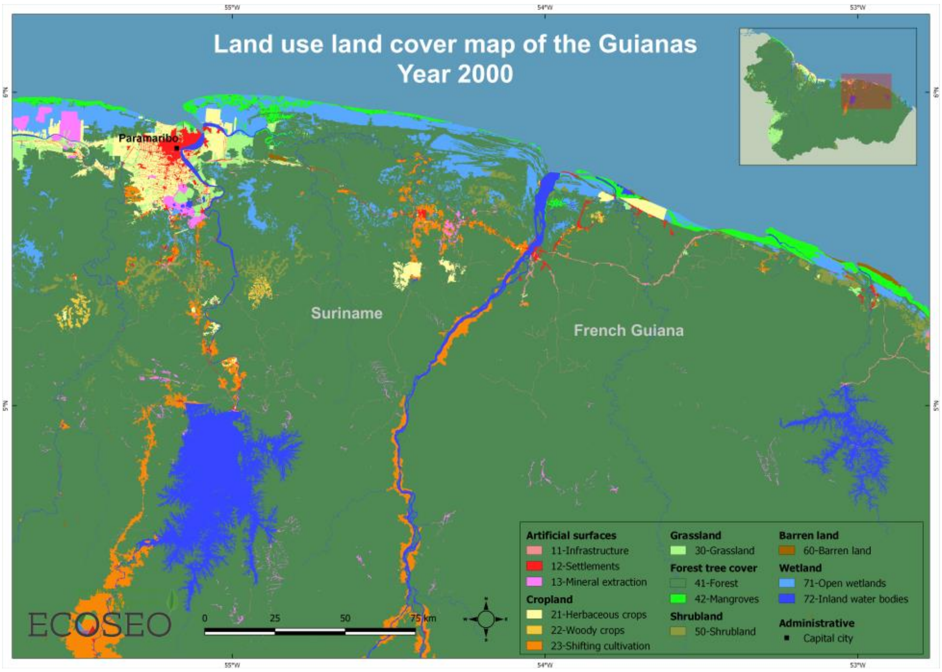


Figure 15 : LULC map of the Guianas in 2000: Zoom on the transboundary area between Suriname and French Guiana, separated by the Maroni River

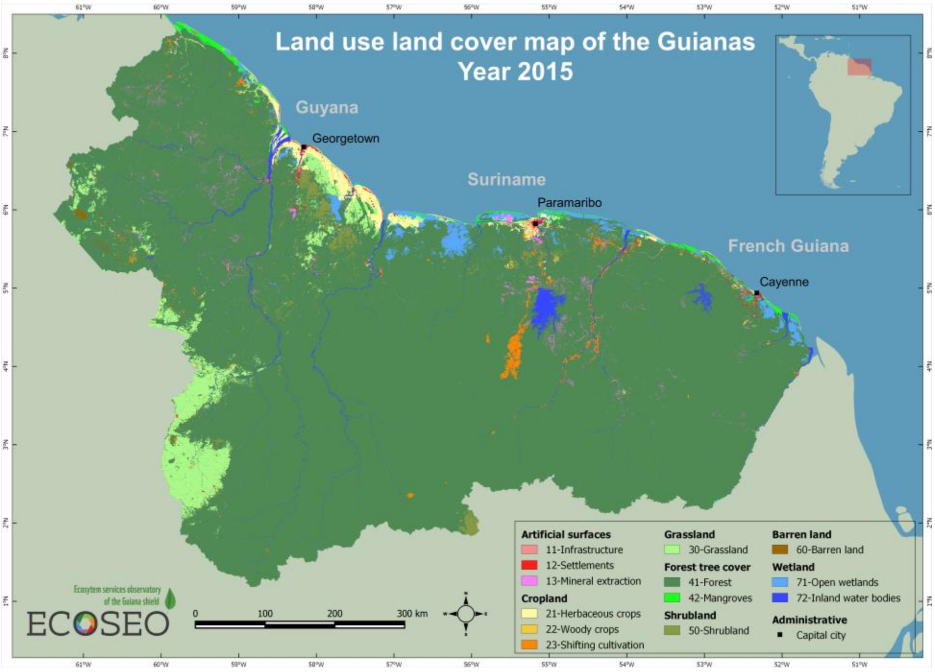


Figure 16 : LULC map of the Guianas in 2015 at 30m resolution

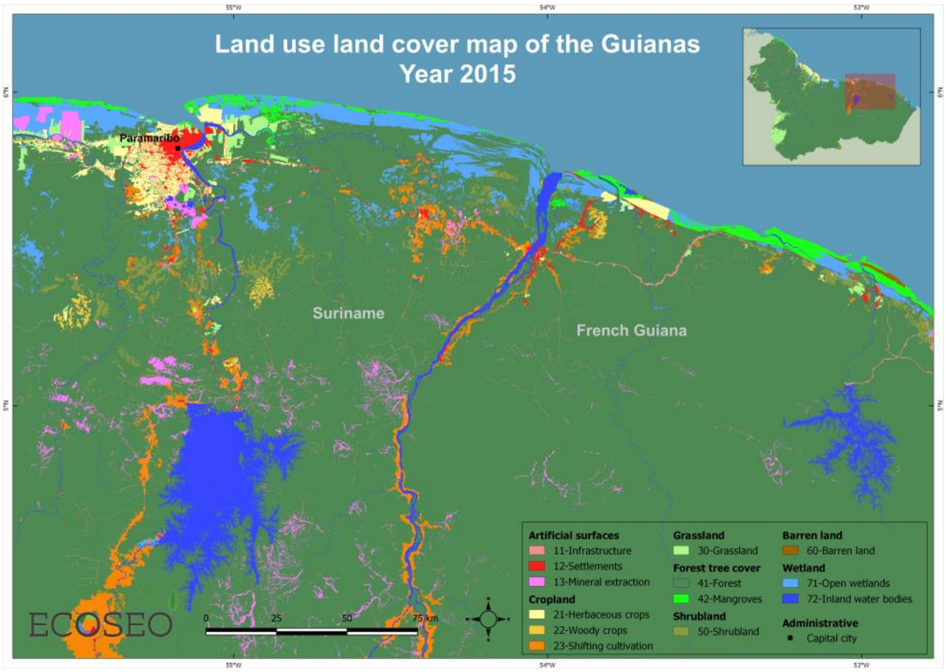


Figure 17 : LULC map of the Guianas in 2015: Zoom on the transboundary area between Suriname and French Guiana, separated by the Maroni River

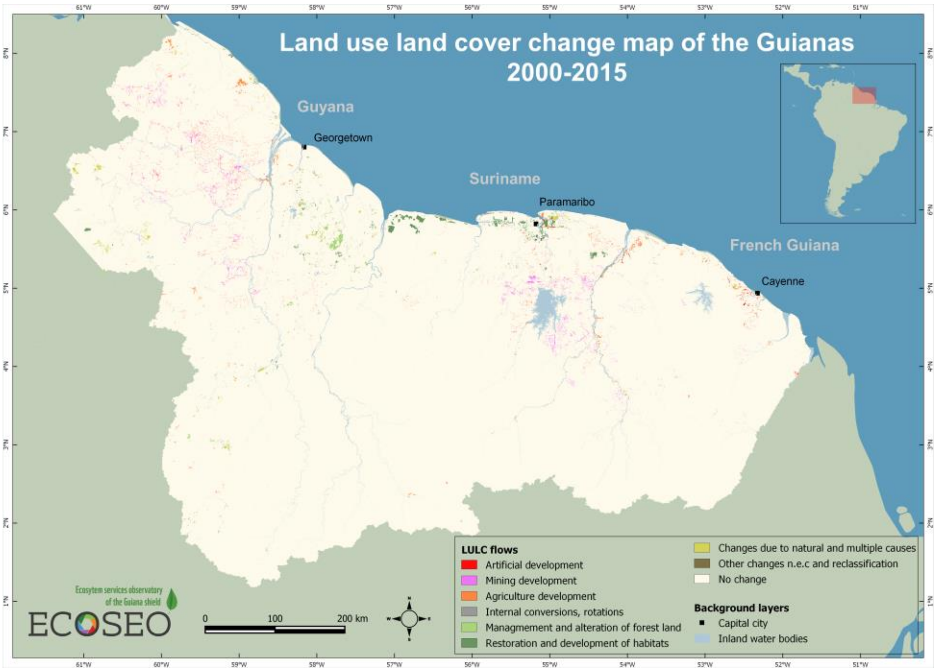


Figure 18 : Map of LULC change flows in the Guianas between 2000 and 2015 at 30m resolution

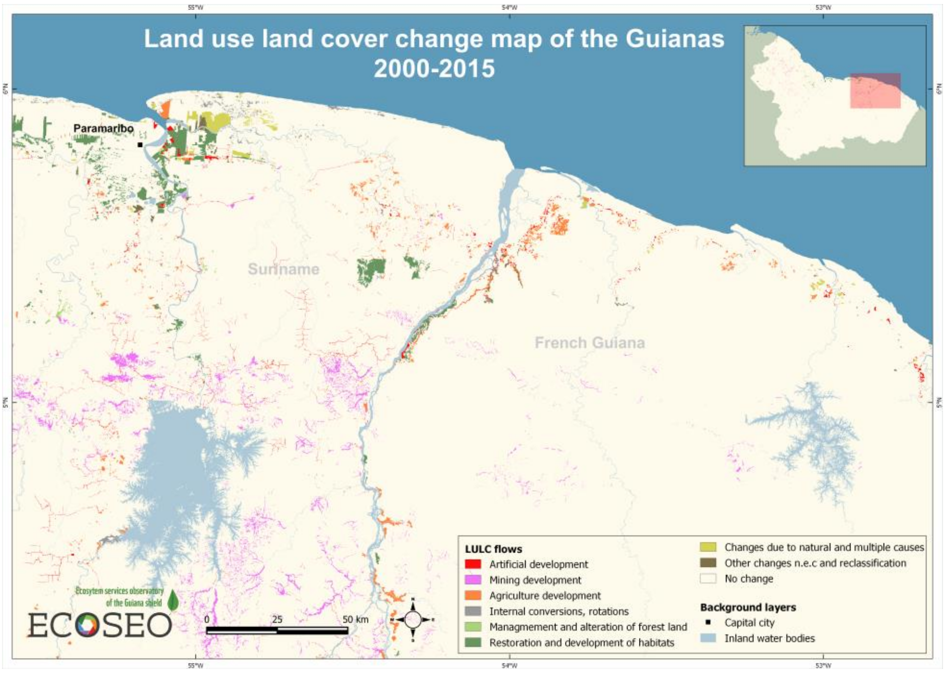


Figure 19 : Map of LULC change flows in the Guianas between 2000 and 2015: Zoom on the transboundary area between Suriname and French Guiana, separated by the Maroni River

IV.1.2 Statistics and accuracy

IV.1.2.1 Sampling plan

The sampling plan was developed from the 2000-2015 LULC change map, for which the accuracy assessment was carried out. The decision to focus the analysis on the change map comes mainly from a lack of time and resources to carry out the accuracy assessment of each product individually.

Nevertheless, the change map being the result of the crossing of the 2000 and 2015 layers, the quality of this map gives us an indirect indication of the quality of the other two sub-products.

Annex VII.5 provides the details of the calculation of the sampling plan that, according to the parameters integrated in the Cochran equation, indicated a minimum necessary of 2097 samples to carry out a representative analysis. After adjustment, a total of 2160 points were generated with a minimum distance of 500m (Figure 20). The distribution was made in proportion to the area covered by each territory, namely: 900 points in Guyana, 750 in Suriname and 510 in French Guiana. Within each territory, the sample points were then distributed in a stratified manner by LULC flow in order to obtain a minimum number of representative samples per stratum (Table 8). As shown in Figure 20, some samples are intersecting in the south at the border of Suriname with Guyana on the west and with French Guiana in the east. It corresponds to contested areas for which a double analysis is carried out.

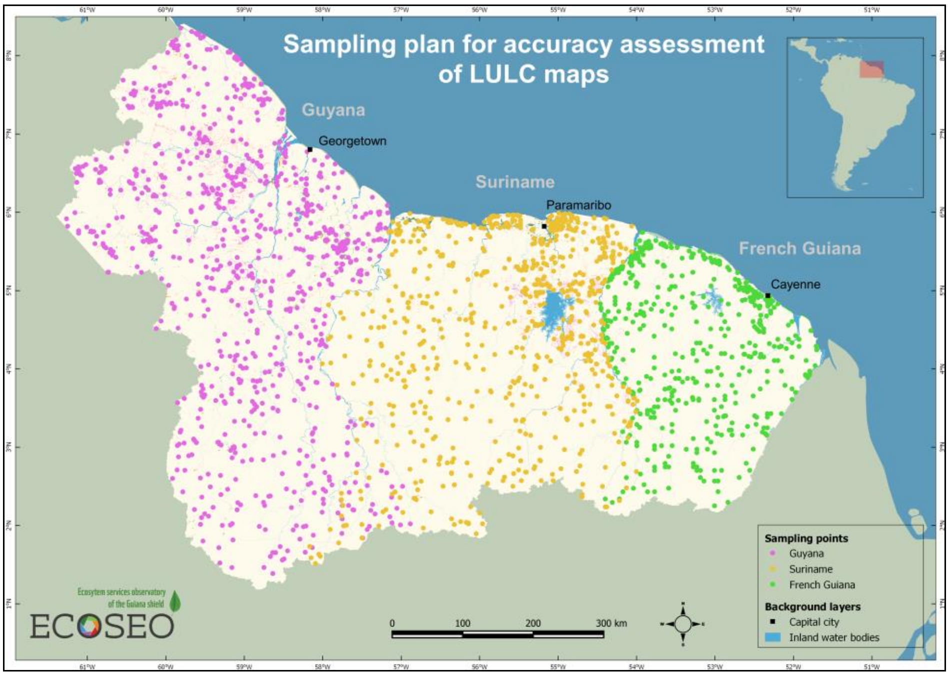


Figure 20 : Sampling plan to assess the accuracy of the LULC change map 2000-2015

LULC change flows		Guyana	Suriname	French Guiana	Total (Guianas)
lf1	Artificial development	70	45	40	**155**
lf2	Agriculture development	70	60	70	**200**
lf3	Internal conversions, rotations	0	45	20	**65**
lf4	Management and alteration of forest land	70	25	10	**105**
lf5	Restoration and development of habitats	60	70	20	**150**
lf6	Changes of land-cover due to natural and multiple causes	70	40	30	**140**
lf7	Other land cover changes n.e.c and reclassification	25	25	20	**70**
lf8	Mining development	90	70	70	**230**
lf0	No observed land-cover change	445	370	230	**1045**
	Total	**900**	**750**	**510**	**2160**

Table 8 : Distribution of the sampling points per territory and per LULC change flow

IV.1.2.2 Accuracy assessment results

After analysis of these samples, the confusion matrix was generated, from which the indicators of accuracy could be derived (see Annex VII.6 for detailed results at the Guianas scale as well as per territory). The first assessment is based on the normalized confusion matrix, which presents the error matrix in terms of estimated area proportions instead of absolute sample. The estimated area proportions normalize the absolute sample counts by the map area and are used to calculate the users and producer's accuracy.

Based on the analysis of the normalized confusion matrix, it emerges that the LULC change map of the Guianas has an **Overall accuracy of 94.5% (+/- 1.3%)**, which gives high confidence on the general results. Nevertheless, high overall accuracies do not reflect the accuracy of each class, especially when the analysis is based on area proportions. In our case, the high overall accuracy comes essentially from the high accuracy of the lf0_no-change class, which covers the majority of the territory (>94%). If we analyse the absolute sample instead of estimated area proportions, the Overall accuracy drops to 79.3%, which reflects more the accuracy of the change classes. From such analysis, quality indicators, such as precision, recall and F-score, show better performance for each class (Table 9) compared to the producer and user's accuracy estimated from the normalized error matrix. The statistical analysis based on area proportions shows that the producer's accuracy of the change classes are low (<30%), which means potential high level of omissions, i.e. an underestimation of the changes. The user's accuracy is however generally better for most classes of change, which means that commission errors are lower than omissions.

Although the results of the accuracy assessment can be considered satisfactory, the statistical analysis shows a generalized underestimation of the changes. The results therefore deserve to be improved and / or completed in the future. First, samples should be added in the change classes to further strengthen the accuracy assessment results to get a finer reading of the quality of the results. Secondly, the cartographic results could be improved by photo-interpretation.

Class		Precision	Recall	F-score
lf1	Artificial development	75%	78%	77%
lf2	Agriculture development	85%	94%	89%
lf3	Internal conversions, rotations	76%	81%	78%
lf4	Management and alteration of forest land	29%	97%	45%
lf5	Restoration and development of habitats	57%	88%	69%
lf6	Changes of land-cover due to natural and multiple causes	30%	80%	44%
lf7	Other land cover changes n.e.c and reclassification	25%	74%	38%
lf8	Mining development	80%	91%	85%
lf0	No observed land-cover change	94%	75%	84%

Table 9 : Precision, recall and F-score of each land cover flow of the Guianas LULC change map based on the analysis of the absolute sample

IV.1.2.3 Measurement and estimation of LULC areas

LULC maps 2000 & 2015

The Guianas, including French Guiana, Suriname and Guyana, covers a total area of 443 450 km^2.

The mapping results show that in 2000, the area was dominated at 89.5% by tropical rainforest, followed by grassland (3.9%), wetland (inland water bodies and open wetland - 3%) and herbaceous crop (1.1%). The forest cover rate is the highest in French Guiana (94.9%), followed by Suriname

(91.7%) and Guyana (86.2%) (Figure 21). In 2015, the forest is still largely dominant in the Guianas with 88.8% of land cover, but it is decreasing in comparison with 2000 to the benefit of other LULC classes, especially artificial areas (infrastructure & mining) and cropland. Although slightly reduced, the forest remains at a high rate in each territory, with French Guiana still at the top of the list with 94.4%, followed by Suriname (91.4%) and Guyana (85.4%) (Figure 22).

Figure 23 compares the surface covered by each LULC class at the Guianas scale for years 2000 and 2015. The tables in Annex VII.7 provide the precise figures for both years (areas and proportions).

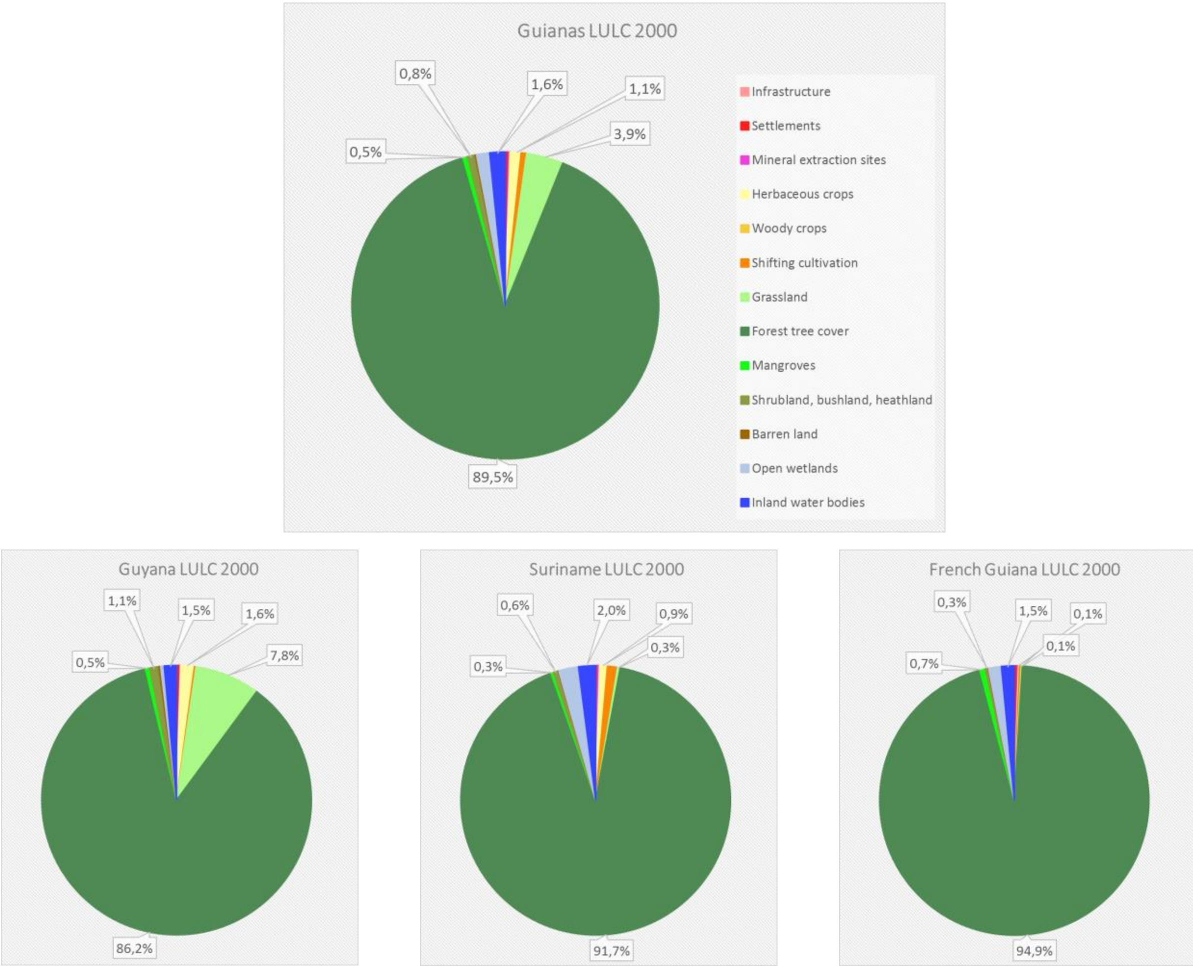


Figure 21 : LULC distribution at the Guianas scale and for each territory in 2000

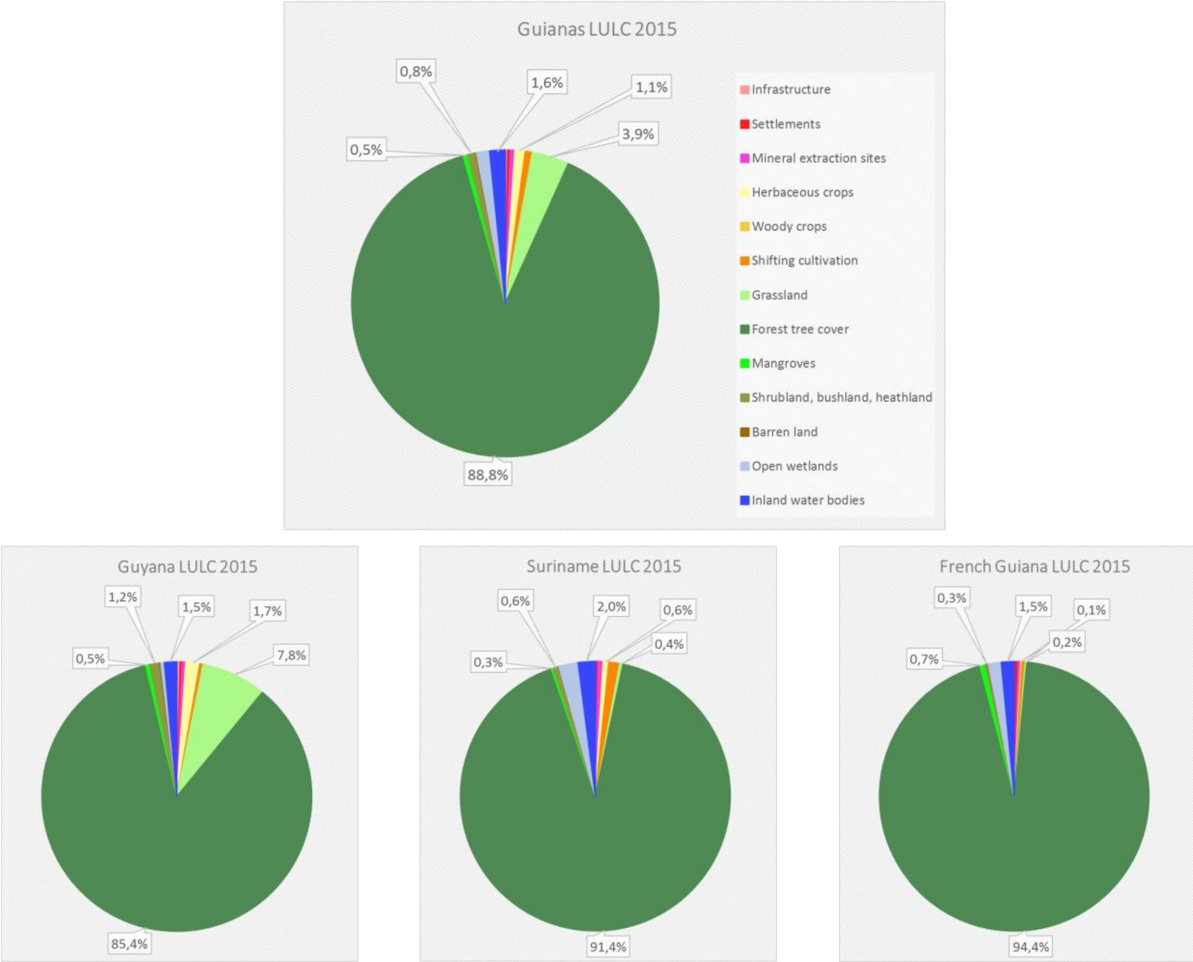


Figure 22 : LULC distribution at the Guianas scale and for each territory in 2015

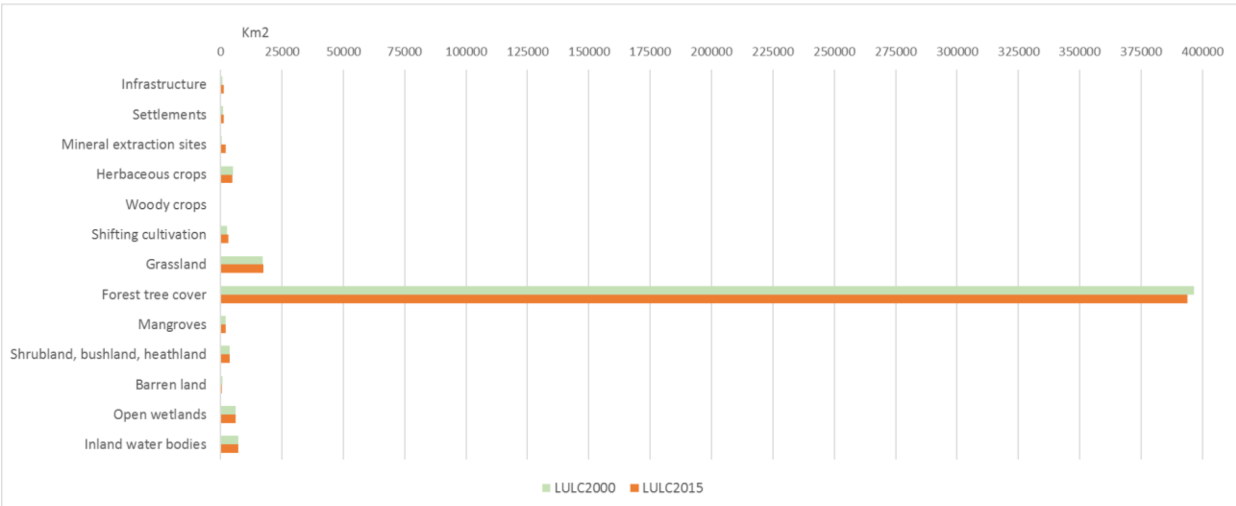


Figure 23 : Surface covered by each LULC class at the Guianas scale for years 2000 and 2015

LULC change map 2000-2015

LULC changes between 2000 and 2015 represented 1.3% of the territory of the Guianas (98.7% remained stable). Figure 24 shows the distribution of areas measured on the map by type of change, for the entire Guianas region and for each territory separately. Although the map generally underestimates the changes, the results show that the first driver of change at the regional level is mining development, which is also the largest contributor of change in Guyana and the second in Suriname and French Guiana. In Guyana, the sector contributed 10.4% to Guyana's GDP in 2015. The growth in mining was fostered by an upsurge in gold declarations by local and foreign mining companies (Guyana Office for investment mining[6]). According to the map, mining activity, which is booming in the region since the 2000s, led to the conversion of 1,522 km^2 (152,211 ha) of land between 2000 and 2015. The second driver of change is the restoration of habitats (1205 km^2), to which Suriname contributes the most, as it is the primary cause of land conversion in the country. In the coastal area of Suriname, some old plantations, abandoned large-scale agriculture and grassland areas have been naturally regenerated to forest during time. The third cause of change is agricultural development (923 km^2), which represents the primary driver in French Guiana.

Annex VII.8 gives the precise figures of areas and proportions covered by the different LULC change flows between 2000 and 2015. Annex VII.9 shows the adjusted map area estimates (and their uncertainty), calculated from the accuracy assessment analysis. Given the low producer's accuracy of most classes of change, the changes are estimated to be much larger for most classes but with high uncertainties.

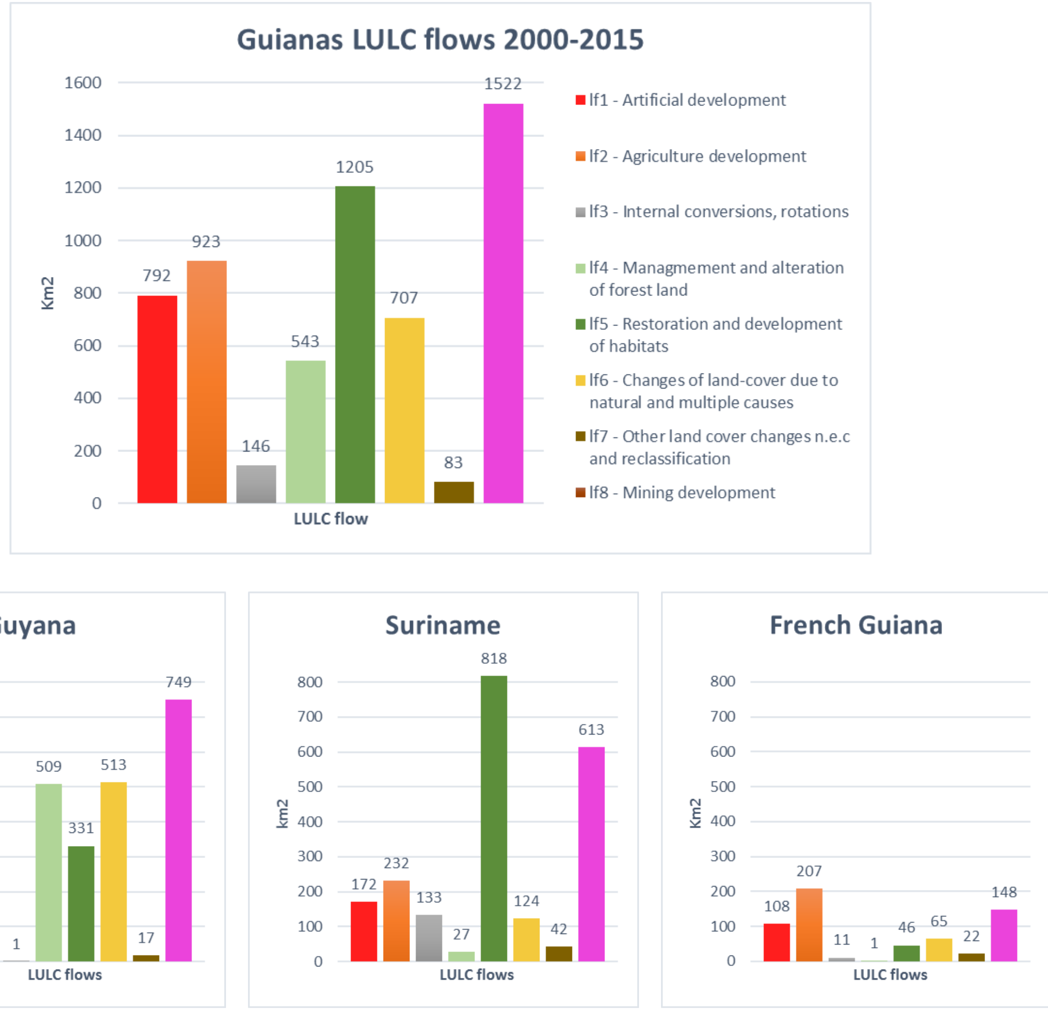


Figure 24 : LULC change flows between 2000 and 2015 for the Guianas region and per territory.

[6] http://goinvest.gov.gy/sectors/mining/#:~:text=While%20the%20mining%20sector%20is,iron%2C%20and%20nickel%20among%20others

IV.2 Secondary product at 100m resolution

This section illustrates the mapping results of the secondary product, constructed from global and national data at the level of the four territories (including the state of Amapá).

The main source of global data for the Guianas is the LULC map from ESA-CCI at 300m resolution, completed by national data. The source of national data is the same as for the primary product (except for some layers that were not yet available at the time of map production).

Regarding the state of Amapá, for which the primary map at 30m resolution has not been produced, the main input data is the SEEA version of the Land use /land cover map produced by the Brazilian Institute of Geography and Statistics (IBGE). This map has been produced for Brazil in 2000, 2010, 2012 and 2014 from object classification of MODIS (250 m) images and integrates information from an agriculture census. A particular attention has been paid to land cover change monitoring which makes the map fit for accounting. Only aggregated levels have been taken for consistency with the other territories (e.g. only one class of mixed agriculture instead of 3 in IBGE's classification level 1). Oppositely, adjustments have been done for 3 classes for which exogenous data were available for all the region:

- Mangroves from GMW v2 baseline map. GMW is the Global Mangrove Watch operated by UNEP/ WCMC. (https://www.globalmangrovewatch.org/ Data download at http://data.unep-wcmc.org/datasets/45)
- Burnt areas from MODIS MOD64/MCD64 (http://modis-fire.umd.edu/)
- Deforestation by gold mining (mapped at high resolution by the ECOSEO partners, here by the Amapá SEMA)

The main processing steps were:

- The IBGE maps (.shp) has been re-projected to World Mercator (EPSG: 3395), and firstly rasterised at 50m and then resampled at 100m to generate pixels of 1ha. This procedure safeguards the mapping of land cover changes. Lastly, it has been reclassified to the ENCA-ECOSEO legend.
- The 3 additional layers have been processed to match the land cover grid system:
    - Mangroves: rasterisation at 100m and "Expand" of 1 pixel to fix small problems of geometry (due to reprojection and/or resampling of the various layers) and sieve isolated pixels;
    - Burnt areas: resampling to 100m of the MOD64 250m pixels;
    - Deforestation by gold mining: rasterisation at 100m.
- Finally, the 3 additional layers have been overlaid to the IBGE/ENCA maps 2000 and 2014.

The following figures illustrate the LULC maps generated for the years 2000 and 2015, and the 2000-2015 change flows.

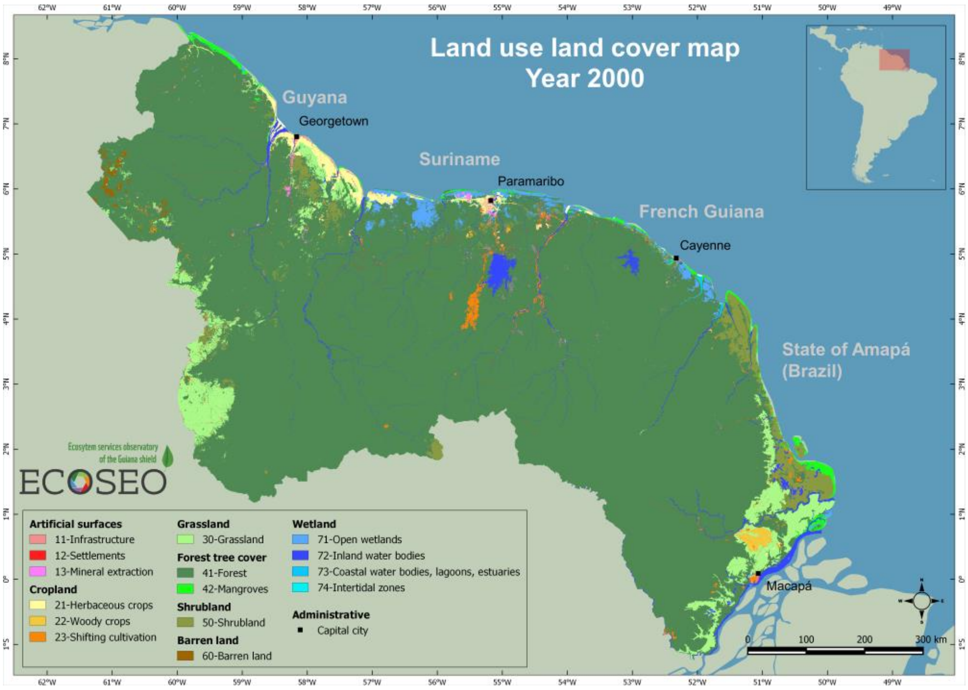


Figure 25 : LULC map of ECOSEO's study area in 2000 at 100m resolution

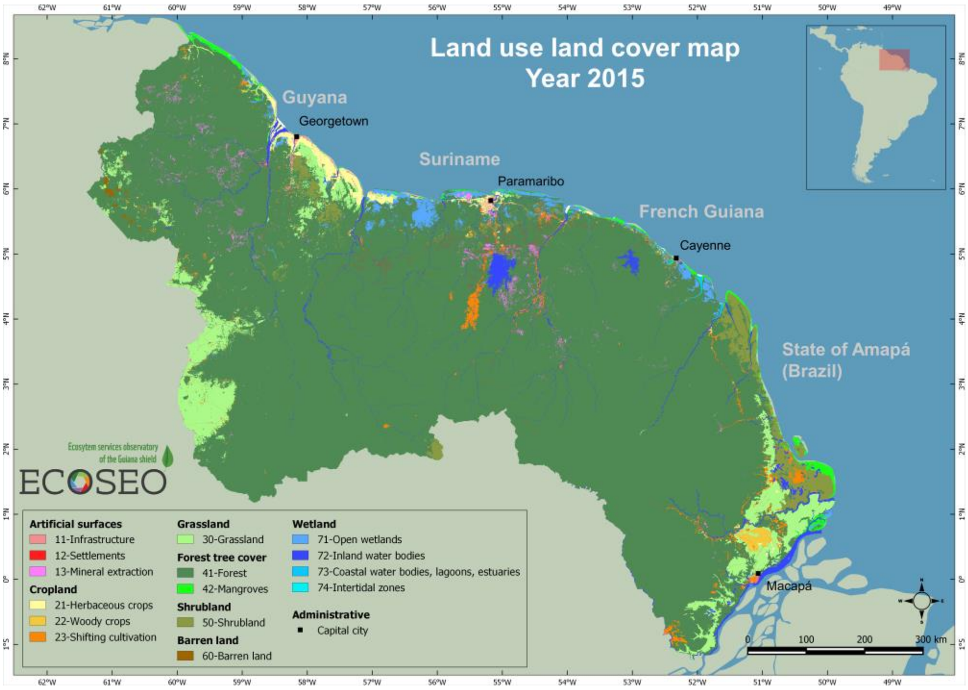


Figure 26 : LULC map of ECOSEO's study area in 2015 at 100m resolution

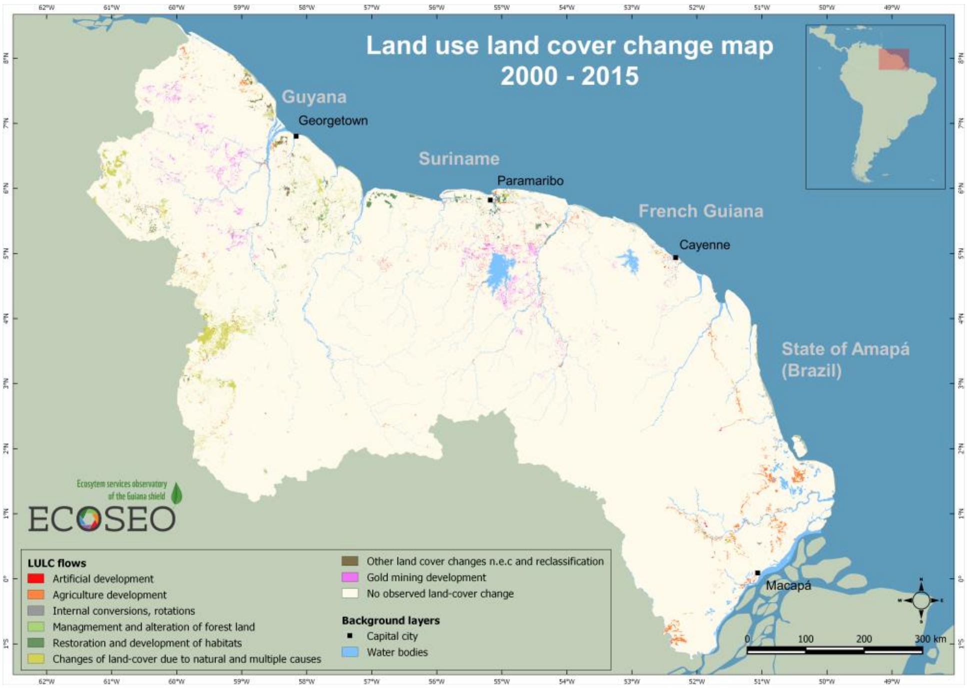


Figure 27 : Map of LULC change flows in ECOSEO's study area between 2000 and 2015 at 100m resolution

The figures below show the LULC distribution for the state of Amapá in 2000 and 2015 (Figure 28), and the LULC change flows between 2000 and 2015 (Figure 29). The precise figures of areas and proportions are given in Annex VII.10. These statistics, extracted from this secondary product at 100m resolution for the state of Amapá, complete the results presented before for the Guianas region based on the primary product at finer resolution.

The state of Amapá is, like other territories, largely dominated by tropical forest. However, the rate of forest cover is lower (~78%). About 18% of the territory consists of areas of grassland, shrubland and mangroves. With more than 200,000 ha, the mangrove cover is the most important in the region, representing about 50% of the mangroves in the entire study area. The primary cause of change in LULC is by far agriculture development (about 214,000 ha), which is more than twice as high as for the other three territories combined.

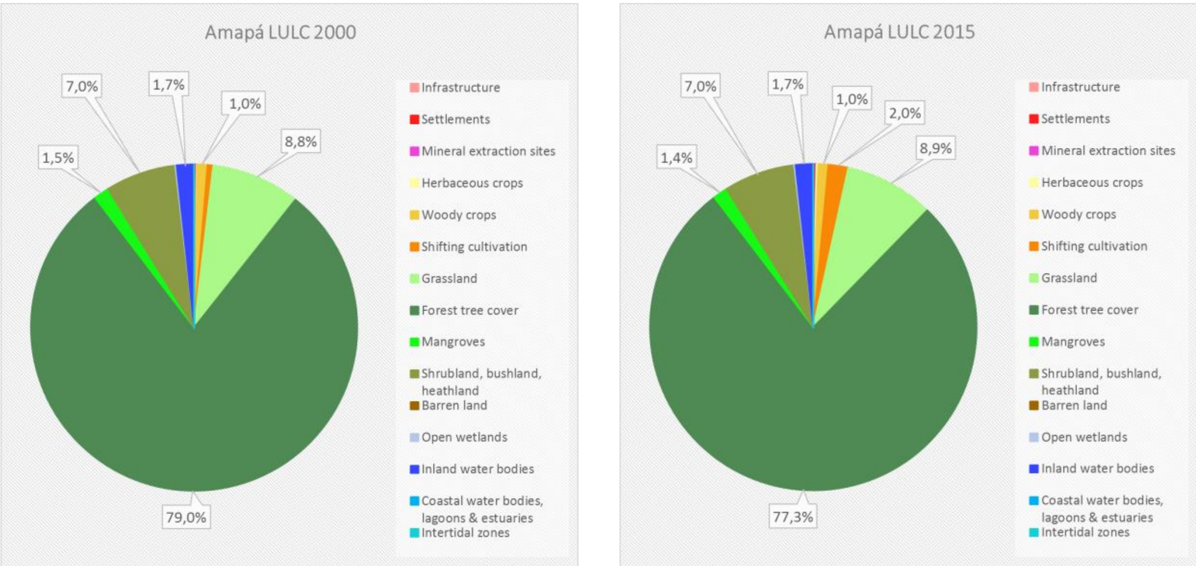


Figure 28 : LULC distribution for the state of Amapá in 2000 and 2015

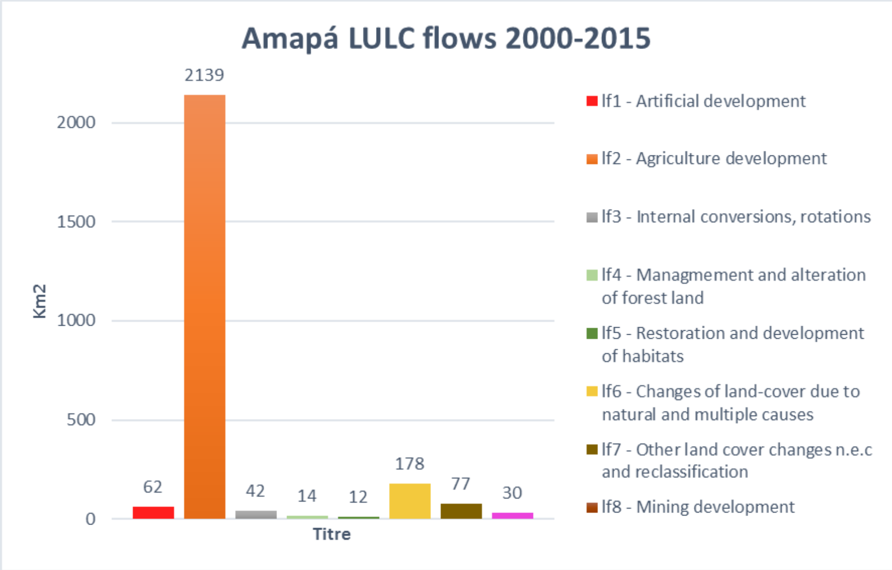


Figure 29 : LULC change flows between 2000 and 2015 for the state of Amapá

V | Conclusion & discussion

The analysis of satellite images around the years 2000 and 2015 has enriched our knowledge of land use and land cover within the Guiana shield, at the scale of the block formed by the four territories of this study. Although the data and production methods vary according to the territories, the results comply with the technical specifications and nomenclatures commonly defined. This common framework made it possible to produce the first regional LULC maps at medium resolution and to provide exhaustive information on LULC around 2000 and 2015, as well as to highlight changes. The LULC change map at 30m resolution of the Guianas yielded a high level of overall accuracy (94.5%) based on the normalized confusion matrix, taking into account area proportions. Analysing the absolute sample instead of estimated area proportions, the Overall accuracy drops to 79.3%, which reflects more the accuracy of the change classes. The accuracy of the secondary LULC maps at 100m resolution, which aim to complete the information for the state of Amapá, has not been assessed in the framework of this study. However, most of the input data used to construct the map is nationally validated data.

The results show that tropical moist forest is largely dominant in the entire study area that extends from the state of Amapá to Guyana, passing through French Guiana and Suriname. In 2000, it covered about 522,572 km^2, i.e. around 87% of the territory. Fifteen years later, in 2015, the forest still covers a large part of the territory (~86%) but nearly 1% of its area has been converted to other LULC classes, which corresponds to an estimated deforestation of 4,923 km^2.

LULC changes between 2000 and 2015 represented 1.3% of the study area (98.7% remained stable). The main causes of LULC change related to deforestation are agriculture, mining and to a lesser extent artificial development (see Annex VII.11).

Agricultural development appears by far as the first driver of change with 3,055 km^2, concerning mostly shifting cultivation in terms of agricultural practices. More than two-thirds of these changes are located in the state of Amapá, where agricultural development accounts for 84% of LULC changes between 2000 and 2015. The remaining third is distributed within the Guianas, where agricultural development is the second driver of change behind mining. In French Guiana, nevertheless, it remains the first driver of change in front of mining activity and settlements development. Considered as a key issue for the French department’s economy, agriculture has been a booming sector during the 2000-2015 period (and still is), supported by local policies (distribution of forested land for agricultural settlements and subsidies), in order to answer the increasing needs of the rapidly growing population. It takes place around inhabited areas along the coast and major border rivers. Between 2009 and 2014, utilised agricultural land increased by 33% in French Guiana (IEDOM, 2016). Agriculture contributes almost 20% to Guyana’s economy, accounts for more than 33% of employment, and almost 40% to the country’s export earnings. Agricultural developments causing deforestation in Guyana peaked in the year 2014, which saw an increase to 817 ha against less than 500 ha in the years 2012-2013 (GFC, 2019). It is likely, too, that agriculture will retain its significance in Guyana’s development trajectory (Ministry of Agriculture, 2012).

The second driver of change in the region is mining development with 1,539 km^2 of land conversion. These are mainly activities related to gold mining, legal as well as illegal. Although contributing to economic development in terms of revenues and job creation, gold mining has very negative impacts on the ecosystem. Forest recovery after mining is slow and qualitatively inferior compared to regeneration following other land uses. Unlike areas in nearby old-growth forest, large parts of mined areas remain bare ground, grass and standing water (Peterson et al., 2001). Moreover, the gold mining process often includes digging the bed of rivers causing turbidity and the use of mercury, which is highly remnant and toxic to humans and all biodiversity alike. In a process called bioaccumulation, mercury works its way up the food chain reaching high concentrations in predatory species such as some consumable fish species. Since 2000, legal and illegal gold mining has experienced a significant boom in the ecoregion (Rahm et al., 2017); especially in the Guianas where it is the first driver of LULC change. The development of mining activity between 2000 and 2015 intensifies as we move westwards of the region. Not very active in the state of Amapá (30 km^2), mining development is significant in Guyana (749 km^2) and Suriname (613 km^2), and to a lesser extent in French Guyana (148 km^2). Mainly influenced by the increase in the price of gold, the activity has become a major driver of deforestation in the region. The location of activities is strongly correlated by the geology of the area, particularly by the presence of the Greenstone belt. As the Greenstone belt is generally distributed across the territories, the activity follows the same pattern in the northern part of the territories, which is the most accessible. However, in Suriname, the Greenstone belt being mostly located in the far east of the territory, almost 100% of mining activity is concentrated in this border region, separated from French Guiana by the Maroni River (SBB, 2017). This area is particularly impacted by these activities on both sides of the border, where many cross-border movements and exchanges take place.

The third cause of change related to deforestation is artificial development, including the development of settlements and infrastructure. This phenomenon is consistent with the increase in the population in the region, which leads to an extension of housing and infrastructure. We will nevertheless note a significant development of infrastructure in Guyana compared to other territories. This is linked in particular to the development of mining activity in a dispersed manner over the territory, involving the development of an important network of tracks and roads.

Regarding other changes (not directly related to deforestation), it is important to stress the high level of habitat restoration and development, partly offsetting the loss of forest cover. In terms of area, it represents the third cause of LULC change between 2000 and 2015, accounting for 1,207 km2. Most of these restorations (~70%) take place in Suriname, where it appears to be the main cause of land conversion before mining activity. This situation is mainly due to the conversion along the coast of grassland areas and abandoned large-scale agriculture areas. Some agricultural areas in district Saramacca were abandoned due to limited and lack of infrastructure. The farmers could therefore not carry out their agriculture practices properly.

The study provided needed supplemental geospatial information at medium resolution on 2000–2015 LULC change to enable the production of the first Ecosystem Natural Capital Accounts (ENCA), supported by the Convention on Biological Diversity (CBD). The study also helped to identify LULC change hotspot locations in the region. The project's LULC change map dataset and corresponding analysis discussed in this paper enabled a baseline record of the LULC change for 2000–2015 that is available for aiding follow-on transboundary or transnational studies in support of water, disaster, forest, and agricultural management efforts in the region. The 2000–2015 LULC change map from the project could possibly be refined with additional data processing techniques in order to improve the accuracy of results and/or the resolution of information for the state of Amapá. Further processing would also be useful to complete and update the results by including an additional year of monitoring for the current period, mapping LULC change since 2015.

VI | References

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VII | Annexes

VII.1 Details of Land cover Ecosystem functional classes

LCEFU: Land Cover Ecosystem functional classes	LCEFU contents: main and other land cover type	
01 Urban and associated developed areas	**LCT.1**	
011 Urban fabric and associated developed areas	LCT.01.b	
012 Dispersed human settlements	LCT.01.a	
02 Homogeneous herbaceous cropland	**LCT.02.c and LCT.02.d**	**continuums of LCT.02.a and LCT.02.b**
021 Rainfed homogeneous herbaceous cropland	LCT.02.c	continuums of LCT.02.a
0211 Medium to large size fields of herbaceous crops rainfed	*LCT.02.c*	
0212 Small size fields of herbaceous crops rainfed	*continuums of LCT.02.a*	
022 Irrigated or aquatic homogeneous herbaceous cropland	LCT.02.d	continuums of LCT.02.b
0221 Medium to large size fields of herbaceous crops irrigated or aquatic	*LCT.02.d*	
0222 Small size fields of herbaceous crops irrigated or aquatic	*continuums of LCT.02.b*	
03 Agriculture plantations, permanent crops	**LCT.03.b**	**continuums of LCT.03.a**
031 Agriculture plantations, permanent crops, rainfed	*part of LCT.03.b*	*part of continuums of LCT.03.a*
0311 Medium to large size fields of woody crops rainfed	*part of LCT.03.b*	
0312 Small size fields of woody crops rainfed	*part of continuums of LCT.03.a*	
032 Agriculture plantations, permanent crops, irrigated	*part of LCT.03.b*	*part of continuums of LCT.03.a*
0311 Medium to large size fields of woody crops rainfed	*part of LCT.03.b*	
0312 Small size fields of woody crops rainfed	*part of continuums of LCT.03.a*	
04 Agriculture associations and mosaics	**discontinuous LCT.02.a, LCT.02.b, LCT.03.a, LCT.05.b**	**LCT.4**
041 Multiples crops and small size pastures	*part of LCT.4*	
042 Layered crops	*part of LCT.4*	
043 Mosaics of small agriculture and natural plots	discontinuous LCT.02.a, LCT.02.b, LCT.03.a, LCT.05.a, and natural classes	
05 Pastures and natural grassland	**part of LCT.5**	
051 Pastures	continuums of LCT.05.b	
052 Natural grassland	LCT.05.a	
06 Forest tree cover	**part of LCT.06.b & LCT.06.c**	**LCT.7**
061 Forest broadleaves tree cover	part of LCT.06.b & LCT.06.c	
062 Forest deciduous tree cover	part of LCT.06.b & LCT.06.c	
063 Forest mixed tree cover	part of LCT.06.b & LCT.06.c	
064 Mangroves	LCT.7	
07 Shrubland, bushland, heathland	**LCT.8**	
08 Sparsely vegetated areas	**LCT.10**	
09 Natural vegetation associations and mosaics	**discontinuous LCT.05.a, LCT.6, LCT.8**	
10 Barren land	LCT.11	
11 Permanent snow and glaciers	LCT.12	
12 Open wetlands	LCT.9	
13 Inland water bodies	LCT.13	
131 Rivers and canals	LCT.13 part	
132 Lakes and reservoirs	LCT.13 part	
14 Coastal water bodies and inter-tidal areas	**LCT.14**	
141 Estuaries	LCT.14.a part	
142 Lagoons	LCT.14.a part	
143 Coastal flats (beaches and mudflats)	LCT.14.b part	
144 Coral reefs	LCT.14.b part	
Sea (interface with land)	-	-

Source: Jean-Louis Weber (2014). Ecosystem natural capital accounts: A quick start package, CBD Technical Series No. 77, Secretariat of the Convention on Biological Diversity, Montréal, 288 pp.

Land Cover Types detailed classification	
LCT.1	**Artificial surfaces (including urban and associated areas)**
LCT.01.a	Artificial surfaces from 10 to 50 %
LCT.01.b	Artificial surfaces from 51 to 100 %
LCT.2	**Herbaceous crops**
LCT.02.a	Small size fields of herbaceous crops rainfed
LCT.02.b	Small size fields of herbaceous crops irrigated or aquatic (rice)
LCT.02.c	Medium to large fields of herbaceous crops rainfed
LCT.02.d	Medium to large fields of herbaceous crops irrigated or aquatic (rice)
LCT.3	**Woody crops**
LCT.03.a	Small size fields of woody crops
LCT.03.b	Medium to large fields of woody crops
LCT.4	**Multiple or layered crops**
LCT.5	**Grassland**
LCT.05.a	Natural grassland
LCT.05.b	Improved grassland
LCT.6	**Tree covered area**
LCT.06.a	Tree covered area from 10 to 30-40 %
LCT.06.b	Tree covered area from 30-40 to 70 %
LCT.06.c	Tree covered area from 70 to 100 %
LCT.7	**Mangroves**
LCT.8	**Shrub covered area**
LCT.08.a	Shrub covered area from 10 to 60 % (open)
LCT.08.b	Shrub covered area from 60 to 100 % (closed)
LCT.9	**Shrubs and/or herbaceous vegetation aquatic or regularly flooded**
LCT.09.a	From 2 to 4 months
LCT.09.b	More than 4 months
LCT.10	**Sparsely natural vegetated areas**
LCT.11	**Terrestrial barren land**
LCT.11.a	Loose and shifting sand and/or dunes
LCT.11.b	Bare soil, gravels and rocks
LCT.12	**Permanent snow and glaciers**
LCT.13	**Inland water bodies**
LCT.14	**Coastal water bodies and inter-tidal areas**
LCT.14.a	Coastal water bodies (lagoons and/or estuaries)
LCT.14.b	Inter-tidal areas (coastal flats and coral reefs)

Source: Jean-Louis Weber (2014). Ecosystem natural capital accounts: A quick start package, CBD Technical Series No. 77, Secretariat of the Convention on Biological Diversity, Montréal, 288 pp.

VII.2 ECOSEO LULC flow classification

Adapted from Weber (2014):

lf1	Artificial development	
	lf11	Artificial development over agriculture
	lf12	Artificial development over forests
	lf13	Artificial development of other natural land cover
	lf14	Water bodies creation
	lf19	Other …
lf2	Agriculture development	
	lf21	Conversion from small scale/mosaic to large scale agriculture
	lf22	Conversion from grassland to agriculture
	lf23	Conversion from forest to agriculture
	lf24	Conversion from marginal land to agriculture
	lf29	Other …
lf3	Internal conversions, rotations	
	lf31	Internal conversion of artificial surfaces
	lf32	Internal conversion between agriculture crop types
	lf33	Internal conversion between forest types
	lf34	Internal conversions of natural land
	lf39	Other …
lf4	Management and alteration of forested land	
	lf41	Management, felling and replantation
	lf42	Fires, epidemics and other
	lf49	Other …
lf5	Restoration and development of habitats	
	lf51	Conversion from crops to set aside, fallow land and pasture
	lf52	Withdrawal of farming/ Landscape restoration
	lf53	Forest creation, afforestation of agriculture
	lf54	Forest creation, afforestation of marginal land
	lf55	Forest recruitment
	lf56	Restoration of degraded land
	Lf57	Forest creation, afforestation of mining
	lf59	Other …
lf6	Changes of land-cover due to natural and multiple causes	
	lf61	Climatic anomalies
	lf62	Climatic and other hazards
	lf69	Natural transitions n.e.s.
Lf7	Other land cover changes n.e.c. and reclassification	
Lf8	Mining development	
	lf71	Conversion from agriculture to mining
	lf72	Conversion from grassland to mining
	lf73	Conversion from forest to mining
	lf74	Conversion from marginal land to mining
	lf75	Other …
lf0	No observed land-cover change	

VII.2.1 Lf1 – Artificial development

Artificial development includes sprawl or extension of urban and associated areas, transport infrastructures, economic activity areas, and associated areas such as green urban areas and sports facilities, and quarries and waste landfills.

Creation of water bodies that change land cover dramatically is also lf1.

The main categories of lf1 are:

- artificial development over agricultural land;
- artificial development over forests;
- artificial development of other natural land cover.

Conversions within urban areas are not included here but recorded in lf3.

VII.2.2 Lf2 - Agriculture development

Agriculture development includes conversion of forests, and natural and semi-natural land to agriculture. Conversion from small-scale agriculture, with associations of crops, mosaics and small linear features, to homogeneous cropland (farmland restructuring) is lf2.

lf2 can be described according to the land-cover types consumed, for example as:

- conversion from small-scale/mosaic farmland to large-scale agriculture;
- conversion from grassland to agriculture;
- conversion from forest to agriculture;
- conversion from marginal land to agriculture.

Conversions between crops are internal to agriculture and are not included here but recorded in lf3.

VII.2.3 Lf3 – Internal conversions and rotations

Internal conversions and rotations (lf3) are changes which can be observed within land-cover classes: artificial, urban, forest and other types. They require observation of detailed land-cover classes.

Internal conversions can be detailed according to specific changes in the areas:

- internal conversion of artificial surfaces: reclamation of brown-field sites, development of green urban areas, or conversion of dwellings to offices or industrial buildings into apartments;
- internal conversion between agriculture crop types: extension of irrigation systems, conversion between herbaceous and shrub/tree permanent crops. Crop rotations can be recorded as lf3; Conversions between homogeneous cropland and agricultural mosaics or pasture/grassland are not recorded in lf3 but in lf2 (intensification of use) or lf5 (extensification);
- internal conversion between forest types: conversions between evergreen and deciduous, shifts between mono-specific and homogeneous stands;
- internal conversions of natural and semi-natural land types which can be observed at a detailed level.

lf3 will appear in land-cover accounts when detailed data are aggregated into broader classes, in which case they are recorded in the diagonal of the change matrix. In accounts directly generated from the LCEU 15 classes, lf3 will only be used in a first step to record changes between herbaceous and woody agricultural cropland. However, lf3 can also be introduced into the accounting tables on the basis of additional statistical information, in which case accounts are balanced with a reduction of no observed change (lf0) equal to the introduced lf3. For these reasons, ENCA presents two different change matrices: the computational matrix which results from the processing of two land-cover maps, and the accounting matrix where actual no changes are recorded not in the diagonal (reserved for lf3 aggregations) but in rows and columns.

VII.2.4 Lf4 - Management and alteration of forested land

Forest management refers to long time-spans with a succession of steps. Depending on the frequency of accounting, all steps are described (annual accounts) or intermediate steps are consolidated. Also, forests are socio-ecological systems that include areas with forest-tree cover (LCF06) and other areas that are managed by foresters and are considered as part of forests in a land-use sense. This distinction is reflected in land-cover accounts. Processes involving forests are recorded in all land-cover aggregated flows.

It includes the effects of regular forest management, in particular tree felling whether or not followed by replanting. It is observed as a shift from tree cover to various classes of used (artificial and agriculture) or non-used land cover (bare soil, grass, shrub, etc.), in the latter case temporarily considered as still part of forests in a land-use sense. Forest creation on (non-forest) marginal land and recruitment from the growth of young trees which are part of the forested land are both recorded in the same class (lf5).

Forest management includes protection from hazards and restoration after damage. Forest tree-cover degradation by fire, wind and pests is therefore recorded in the same aggregated class as tree felling[7].

VII.2.5 Lf5 – Restoration and development of habitats

Restoration and development of habitat groups represents flows resulting from anthropogenic processes. The main items are:

- conversion from crops to set-aside, fallow land and pasture;
- conversion from cropland to sparse and other natural vegetation in the context of shifting cultivation;
- landscape restoration (hedgerows replanting, etc.);
- withdrawal of farming;
- forest creation, afforestation of agricultural land;
- forest creation, afforestation of marginal land;
- forest recruitment.

VII.2.6 Lf6 - Changes of land cover due to natural and multiple causes

In many cases, land-cover flows cannot be clearly allocated to a particular human activity. This is the case with change driven by climate change regarding temperature, rainfall regime and hazards such as storms. For managed forests, damage is classified as lf4 (management and alteration of forested

[7] There is a difference here from the approach of IPCC/LULUCF where fires that are independent of any anthropogenic cause are excluded. The point will be taken in the biomass/carbon account where the two types of fire will be distinguished.

land) and development as lf5 (restoration and development of habitats). Unmanaged natural transitions are recorded in lf6. Main lf6 flows are:

- effects of climatic anomalies: droughts, seasonal regimes, etc.;
- effects of climatic and other hazards (except effects on forests): storms, floods, landslides;
- coastal erosion;
- melting of permanent snow and glacier;
- volcanic eruptions, earthquakes, tsunamis;
- indirect effects of overexploitation of natural resource (e.g. progressive degradation by overgrazing or slash-and-burn agriculture);
- natural transitions in unmanaged land.

VII.2.7 Lf7 - Other land-cover changes not elsewhere classified (n.e.c.) and revaluation

This class records unlikely changes such as conversion of urban areas to agriculture or forest. Revaluation is also recorded in lf7. It corresponds to changes in classification due to potential errors in the initial database. As long as the initial database is not revised and upgraded, such false change is recorded as revaluation. Once revision is done, revaluation will be reclassified, generally as no observed change.

A second level of detail can be introduced in the land-cover flows classification. It has to be decided according to needs and will require a more detailed land-cover classification to implement it. Annex II gives an example as an illustration.

VII.2.8 Lf8 - Mining development

Mining development includes conversion of forests, and natural and semi-natural land to agriculture.

If2 can be described according to the land-cover types consumed, for example as:

- conversion from agriculture to mining;
- conversion from grassland to mining;
- conversion from forest to mining;
- conversion from marginal land to mining.

VII.3 Correspondence table of existing LULC data in French Guiana and ECOSEO's classification

Correspondence table of the ONF LULC data on the coastline (CLC) with ECOSEO's classification (ECO)

CLC_N1	CLC_N3	CLC_N3_tx	ECO_N1	ECO_N1_tx	ECO_N2
1	111	Tissu urbain continu	1	Urban and associated developed areas	1.2
	112	Tissu urbain discontinu			1.2
	113	Bâti isolé			1.2
	114	Habitat pluridisciplinaire			1.2
	121	Zones industrielles ou commerciales			1.1
	122	Réseaux routiers et réseaux de communication et espaces associés			1.1
	123	Zones portuaires			1.1
	124	Aéroports			1.1
	131	Extraction de matériaux			1.3
	132	Décharges			1.1
	133	Chantiers			1.1
	140	Espace vert urbain			1.2
2	211	Terres arables hors périmètres d'irrigation	2	Cropland	2.1
	213	Rizières			2.1
	222	Vergers et petits fruits			2.2
	231	Prairies	3	Grassland	3
	242	Systèmes culturaux et parcellaires complexes (abattis)	2	Cropland	2.3
	243	Territoires principalement occupés par l'agriculture avec présence de végétation (abattis itinérant)			2.3
3	317	Forêts inondables ou inondées primaires	4	Forest Tree cover	4.1
	318	Mangroves			4.2
	319	Plantations forestières			4.1
	321	Savanes sèches	5	Shrubland, bushland, heathland	5
	322	Savanes inondables ou inondées			5
	331	Plages, dunes et sables	6	Barren land	6
	332	Roches nues, savanes roches			6
	341	Forêt dégradées de terres ferme	4	Forest Tree cover	4.1
	342	Forêts inondables ou marécageuses dégradées			4.1
	343	Forêt et végétations arbustives en mutation			4.1
4	411	Marais intérieurs et marécages boisés	7	Wetland	7.1
	412	Marécages ripicoles			7.1
	421	Marais maritimes			7.2
5	512	Plans d'eau			7.2
	513	Pisciculture et autres bassins			7.2
3	3151	Forêts sur cordons sableux	4	Forest Tree cover	4.1
	3152	Forêts de la plaine côtière ancienne			4.1
	3153	forêts basses sur sable blanc			4.1
	3154	forêts littorales sur rochers			4.1
	3161	Forêts hautes			4.1
	3162	Forêts basses			4.1

Correspondence table of the PAG LULC data in the south with ECOSEO's classification (ECO)

TYPE	Description	ECOSEO_L1	ECOSEO_L2	ECOSEO_DESCRIPTION
AF	Abattis frais	2	2.3	Shifting cultivation
A1	Abattis 1 ans			
A2	Abattis 2ans			
AD	Aérodrome	1	1.1	Infrastructure
AG	Agriculture fixe	2	2.1	Homogeneous herbaceous cropland
EV	Emprise voierie	1	1.1	Infrastructure
FA	Forêt ancienne	4	4.1	Forest tree cover
HA	Habitations	1	1.2	Settlements
OR	Orpaillage		1.3	Mineral extraction sites
PA	Pâturages	3	3	Pastures and natural grassland
RC	Recru			
SN	Sol nu	6	6	Barren land
SP	Spécial	5	5	Shrubland, bushland, heathland
VP	Végétation particulière	4	4.1	Forest tree cover

VII.4 Correspondence table of existing LULC data in Suriname and ECOSEO's classification

ECOSEO LULC classification				Suriname LULC data	
Level 1		Level 2		Suriname LULC map 2015	Suriname Mangroves 2017
Class	Label	Class	Label	Label	Label
1	Artificial surfaces (including urban and associated area)	11	Infrastructure	Road, Airport, Airstrips, Port, Canal, Dam, Dike, Log yard	
		12	Settlements	Urban, Sub-urban, Rural, Small town, Villages	
		13	Mineral extraction sites	Gold, Bauxite, Petroleum, Building materials	
2	Cropland	21	Herbaceous crops	Small scale agriculture, Large scale agriculture	
		22	Woody crops	Small scale agriculture, Large scale agriculture	
		23	Shifting cultivation	Shifting cultivation	
3	Grassland	30	Grassland	Pasture and Grassland	
4	Forest Tree cover	41	Forest tree cover	Abandoned Forest, Abandoned plantation, Planted Forest, Undisturbed forest	
		42	Mangroves		Mangrove
5	Shrubland, bushland, heathland	50	Shrubland, bushland, heathland	Open savanna	
6	Barren land	60	Barren land	Bare soil and Rock	
7	Wetland	71	Open wetlands	Abandoned openswamp, Open swamp	
		72	Inland water bodies	Lake and river/ creeks	

VII.5 Definition of the sampling plan for the accuracy assessment of the mapping results

Calculation and adjustment of the sampling size at the scale of the Guianas (based on FAO (2016)[8])

	LULC flows between 2000 and 2015									
	lf1	lf2	lf3	lf4	lf5	lf6	lf7	lf8	lf0	
	Artificial development	**Agriculture development**	**Internal conversions, rotations**	**Managmement and alteration of forest land**	**Restoration and development of habitats**	**Changes of land-cover due to natural and multiple causes**	**Other land cover changes n.e.c and reclassification**	**Gold mining development**	**No observed land-cover change**	**Total**
Area in pixels	872088,3841	1018028,808	160365,9895	597127,3245	1327381,009	780030,2564	90740,7368	1677330,71	503805551,8	510328645
Wi (Mapped proportion)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,99	1,00
Ui (Expected user's accuracy)	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,70	
Si (Standard deviation)	0,43	0,43	0,43	0,43	0,43	0,43	0,43	0,43	0,46	
*Wi*Si*	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,45	0,46
										0,01
										2097

Distribution of sampling points per territory

Territory	Weighted by country area	Adjusted
Guyana	965	900
Suriname	747	750
French Guiana	385	510
Total GUIANAS (3 territories)	**2097**	**2160**

[8] https://www.dropbox.com/s/wsihmlldebjc024/sample_size_stratified_simple_random.xlsx?dl=0

Sampling plan in Guyana

	ENCA Fluxes									
	lf1	lf2	lf3	lf4	lf5	lf6	lf7	lf8	lf0	**TOTAL**
	Artificial development	**Agriculture development**	**Internal conversions, rotations**	**Managmement and alteration of forest land**	**Restoration and development of habitats**	**Changes of land-cover due to natural and multiple causes**	**Other land cover changes n.e.c and reclassification**	**Gold mining development**	**No observed land-cover change**	
km2	505	477	1	509	331	513	17	749	208274	**211376**
%	**0,2%**	**0,2%**	**0,0%**	**0,2%**	**0,2%**	**0,2%**	**0,0%**	**0,4%**	**98,5%**	**100,0%**

Distribution of sampling points per territory

Territory	Calculated	Adjusted
Guyana	966,4549921	900

	Sample size per stratum (Guyana)									**TOTAL**
equal	113	113	0	113	113	113	113	113	113	**900**
proportional	2	2	0	2	1	2	0	3	887	**900**
Adjusted	70	70	0	70	60	70	25	90	445	**900**

Sampling plan in Suriname

	ENCA Fluxes									
	lf1	lf2	lf3	lf4	lf5	lf6	lf7	lf8	lf0	**TOTAL**
	Artificial development	**Agriculture development**	**Internal conversions, rotations**	**Managmement and alteration of forest land**	**Restoration and development of habitats**	**Changes of land-cover due to natural and multiple causes**	**Other land cover changes n.e.c and reclassification**	**Gold mining development**	**No observed land-cover change**	
km2	172	232	133	27	818	124	42	613	161508	**163668**
%	**0,1%**	**0,1%**	**0,1%**	**0,0%**	**0,5%**	**0,1%**	**0,0%**	**0,4%**	**98,7%**	**100,0%**

Distribution of sampling points per territory

Territory	Calculated	Adjusted
Suriname	748,3267756	750

	Sample size per stratum (Suriname)									**TOTAL**
equal	83,33	83,33	83,33	83,33	83,33	83,33	83,33	83,33	83,33	**750**
proportional	0,79	1,06	0,60	0,13	3,75	0,57	0,19	2,81	740,11	**750**
Adjusted	45	60	45	25	70	40	25	70	370	**750**

Sampling plan in French Guiana

	ENCA Fluxes									
	lf1	lf2	lf3	lf4	lf5	lf6	lf7	lf8	lf0	**TOTAL**
	Artificial development	**Agriculture development**	**Internal conversions, rotations**	**Managmement and alteration of forest land**	**Restoration and development of habitats**	**Changes of land-cover due to natural and multiple causes**	**Other land cover changes n.e.c and reclassification**	**Gold mining development**	**No observed land-cover change**	
km2	108	207	11	1	46	65	22	148	83643	**84252**
%	**0,1%**	**0,2%**	**0,0%**	**0,0%**	**0,1%**	**0,1%**	**0,0%**	**0,2%**	**99,3%**	**100,0%**

Distribution of sampling points per territory

Territory	Calculated	Adjusted
French Guiana	384,6761253	510

	Sample size per stratum (French Guiana)									**TOTAL**
equal	56,67	56,67	56,67	56,67	56,67	56,67	56,67	56,67	56,67	**510**
proportional	0,66	1,25	0,06	0,01	0,28	0,39	0,13	0,89	506,32	**510**
Adjusted	40	70	20	10	20	30	20	70	230	**510**

VII.6 Accuracy assessment figures of the LULC change map

Guianas (3 territories)

Overall accuracy: 94.5% (+/- 1.3%)

The confusion matrices presented here are the normalized confusion matrices, which present the error matrix in terms of estimated area proportions instead of absolute sample. It compares the mapping results (line) to the reference data, i.e. the results of the photo-interpretation of the samples (column). The estimated area proportions normalize the absolute sample counts by the map area and are used to calculate the users and producer's accuracy, as well as the uncertainties.

Mapping results	QC/Reference data (Photo-interpretation)									
Class	lf1	lf2	lf3	lf4	lf5	lf6	lf7	lf0	lf8	Total
lf1	0.0013	0.0	0.0	0.0	0.0	0.0	0.0	0.0003	0.0001	0.0018
lf2	0.0001	0.0018	0.0	0.0	0.0	0.0	0.0	0.0002	0.0	0.0021
lf3	0.0	0.0	0.0003	0.0	0.0	0.0	0.0	0.0001	0.0	0.0003
lf4	0.0	0.0	0.0	0.0004	0.0	0.0	0.0	0.0009	0.0	0.0012
lf5	0.0	0.0	0.0	0.0	0.0015	0.0	0.0	0.0011	0.0	0.0027
lf6	0.0	0.0	0.0	0.0	0.0	0.0005	0.0	0.0011	0.0	0.0016
lf7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0001	0.0	0.0002
lf0	0.0159	0.0079	0.0053	0.0009	0.0053	0.0026	0.0018	0.9363	0.0106	0.9866
lf8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0006	0.0028	0.0034
Total	0.0173	0.0097	0.0056	0.0012	0.0069	0.0032	0.0019	0.9407	0.0134	

Table 10 : Normalized confusion matrix of the 2000-2015 LULC change map of the Guianas

Land cover flow		Producer Accuracy (100% - omission)	Producer Accuracy Uncertainty (%)	User Accuracy (100% - commission)	User Accuracy Uncertainty (%)
lf1	Artificial development	8.18	3.73	70.68	7.74
lf2	Agriculture development	18.18	9.68	84.9	5.07
lf3	Internal conversions, rotations	4.44	3.44	75.0	11.34
lf4	Management and alteration of forest land	28.04	41.25	28.0	8.8
lf5	Restoration and development of habitats	22.55	14.21	56.76	7.98
lf6	Changes of land-cover due to natural and multiple causes	15.27	15.32	30.47	7.97
lf7	Other land cover changes n.e.c and reclassification	2.53	3.74	25.37	10.42
lf8	Mining development	20.66	9.24	80.93	5.25
lf0	No observed land-cover change	99.53	0.04	94.9	1.29

Table 11 : Producer and user's accuracy of each land cover flow of the Guianas LULC change map based on the normalized confusion matrix

French Guiana

Overall accuracy: 98.6% (+/- 1.4%)

	QC/Reference data (Photo-interpretation)										
	Class	lf1	lf2	lf3	lf4	lf5	lf6	lf7	lf0	lf8	Total
Mapping results	lf1	0.0013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0013
	lf2	0.0	0.0023	0.0	0.0	0.0	0.0	0.0	0.0001	0.0	0.0025
	lf3	0.0	0.0	0.0001	0.0	0.0	0.0	0.0	0.0	0.0	0.0001
	lf4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	lf5	0.0	0.0	0.0	0.0	0.0005	0.0	0.0	0.0001	0.0	0.0005
	lf6	0.0	0.0	0.0	0.0	0.0	0.0005	0.0	0.0002	0.0	0.0008
	lf7	0.0001	0.0	0.0	0.0	0.0	0.0	0.0001	0.0001	0.0	0.0003
	lf0	0.0	0.0042	0.0	0.0	0.0	0.0085	0.0	0.98	0.0	0.9928
	lf8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0002	0.0016	0.0018
	Total	0.0014	0.0065	0.0001	0.0	0.0005	0.009	0.0001	0.9807	0.0016	

Table 12 : Normalized confusion matrix of the 2000-2015 LULC change map of French Guiana

Class		Producer Accuracy	Producer Accuracy Uncertainty	User Accuracy	User Accuracy Uncertainty
lf1	Artificial development	93.65	5.61	100.0	0.0
lf2	Agriculture development	34.52	43.94	91.43	6.56
lf3	Internal conversions, rotations	65.58	34.88	70.0	20.08
lf4	Management and alteration of forest land	100.0	0.0	80.0	24.79
lf5	Restoration and development of habitats	99.69	0.58	85.0	15.65
lf6	Changes of land-cover due to natural and multiple causes	5.69	7.54	66.67	17.78
lf7	Other land cover changes n.e.c and reclassification	63.47	37.76	35.0	20.9
lf8	Mining development	100.0	0.0	90.0	7.03
lf0	No observed land-cover change	99.93	0.02	98.72	1.44

Table 13 : Producer and user's accuracy of each land cover flow of the French Guiana LULC change map

Suriname

Overall accuracy: 99.2% (+/- 0.7%)

	Class	lf1	lf2	lf3	lf4	lf5	lf6	lf7	lf0	lf8	Total
		QC/Reference data (Photo-interpretation)									
Mapping results	lf1	0.0009	0.0	0.0	0.0	0.0	0.0	0.0	0.0001	0.0	0.001
	lf2	0.0	0.0012	0.0	0.0	0.0	0.0	0.0	0.0002	0.0	0.0014
	lf3	0.0	0.0	0.0006	0.0	0.0	0.0	0.0	0.0001	0.0	0.0008
	lf4	0.0	0.0	0.0	0.0001	0.0	0.0	0.0	0.0	0.0	0.0002
	lf5	0.0001	0.0	0.0	0.0	0.0031	0.0001	0.0	0.0017	0.0	0.005
	lf6	0.0	0.0	0.0	0.0	0.0	0.0004	0.0	0.0003	0.0	0.0008
	lf7	0.0	0.0	0.0	0.0	0.0001	0.0	0.0001	0.0001	0.0	0.0003
	lf0	0.0027	0.0	0.0	0.0	0.0	0.0	0.0	0.9815	0.0027	0.9868
	lf8	0.0001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0036	0.0037
	Total	0.0038	0.0012	0.0006	0.0001	0.0032	0.0005	0.0001	0.984	0.0063	

Table 14 : Normalized confusion matrix of the 2000-2015 LULC change map of Suriname

Class		Producer Accuracy	Producer Accuracy Uncertainty	User Accuracy	User Accuracy Uncertainty
lf1	Artificial development	24.68	33.39	90.7	8.68
lf2	Agriculture development	98.42	3.01	83.05	9.57
lf3	Internal conversions, rotations	96.28	6.99	77.78	12.15
lf4	Management and alteration of forest land	100.0	0.0	88.0	12.74
lf5	Restoration and development of habitats	97.84	1.68	62.86	11.32
lf6	Changes of land-cover due to natural and multiple causes	76.49	21.96	55.0	15.42
lf7	Other land cover changes n.e.c and reclassification	100.0	0.0	48.0	19.58
lf8	Mining development	57.61	47.38	97.14	3.9
lf0	No observed land-cover change	99.75	0.06	99.46	0.74

Table 15 : Producer and user's accuracy of each land cover flow of the Suriname LULC change map

Guyana

Overall accuracy: 98.5% (+/- 0.8%)

	QC/Reference data (Photo-interpretation)									
	Class	lf1	lf2	lf4	lf5	lf6	lf7	lf0	lf8	Total
Mapping results	lf1	0.0014	0.0	0.0	0.0	0.0	0.0001	0.0009	0.0001	0.0024
	lf2	0.0	0.0019	0.0	0.0	0.0	0.0	0.0004	0.0	0.0023
	lf4	0.0	0.0	0.0	0.0	0.0	0.0	0.0024	0.0	0.0024
	lf5	0.0	0.0	0.0	0.0006	0.0	0.0	0.001	0.0	0.0016
	lf6	0.0	0.0	0.0	0.0001	0.0	0.0	0.0024	0.0	0.0024
	lf7	0.0	0.0	0.0	0.0	0.0	0.0	0.0001	0.0	0.0001
	lf0	0.0	0.0022	0.0	0.0044	0.0	0.0	0.9787	0.0	0.9853
	lf8	0.0	0.0	0.0	0.0	0.0	0.0	0.0014	0.0022	0.0035
	Total	0.0014	0.0041	0.0	0.0051	0.0	0.0001	0.9871	0.0023	

Table 16 : Normalized confusion matrix of the 2000-2015 LULC change map of Guyana

Class		Producer Accuracy	Producer Accuracy Uncertainty	User Accuracy	User Accuracy Uncertainty
lf1	Artificial development	100.0	0.0	57.14	11.59
lf2	Agriculture development	46.19	48.74	84.06	8.64
lf3	Internal conversions, rotations	/	/	/	/
lf4	Management and alteration of forest land	1.42	8e+16	0.0	0.0
lf5	Restoration and development of habitats	11.79	15.0	38.33	12.3
lf6	Changes of land-cover due to natural and multiple causes	1.48	8e+16	0.0	0.0
lf7	Other land cover changes n.e.c and reclassification	0.0	0.0	0.0	0.0
lf8	Mining development	95.48	4.86	61.11	10.07
lf0	No observed land-cover change	99.15	0.05	99.33	0.76

Table 17 : Producer and user's accuracy of each land cover flow of the Guyana LULC change map

VII.7 Areas covered by the different LULC classes in 2000 & 2015

	LULC 2000											
	Guianas (3 territories)			Guyana			Suriname			French Guiana		
	ha	km2	%	ha	km2	%	ha	km2	%	ha	km2	%
Infrastructure	63486	635	0,1%	36307	363	0,2%	14291	143	0,1%	12375	124	0,1%
Settlements	102885	1029	0,2%	52270	523	0,2%	29075	291	0,2%	20632	206	0,2%
Mineral extraction sites	54933	549	0,1%	11493	115	0,1%	32666	327	0,2%	10356	104	0,1%
Herbaceous crops	507164	5072	1,1%	346704	3467	1,6%	147400	1474	0,9%	6750	68	0,1%
Woody crops	11148	111	0,0%	-	-	-	7620	76	0,0%	3447	34	0,0%
Shifting cultivation	251162	2512	0,6%	40618	406	0,2%	193070	1931	1,2%	16283	163	0,2%
Grassland	1720127	17201	3,9%	1649777	16498	7,8%	52675	527	0,3%	10350	104	0,1%
Forest tree cover	39666672	396667	89,5%	18216088	182161	86,2%	15010412	150104	91,7%	7998650	79987	94,9%
Mangroves	216762	2168	0,5%	108194	1082	0,5%	49910	499	0,3%	55709	557	0,7%
Shrubland, bushland, heathland	357284	3573	0,8%	229146	2291	1,1%	97312	973	0,6%	27905	279	0,3%
Barren land	63253	633	0,1%	46388	464	0,2%	11239	112	0,1%	5763	58	0,1%
Open wetlands	611898	6119	1,4%	90434	904	0,4%	387338	3873	2,4%	128421	1284	1,5%
Inland water bodies	718218	7182	1,6%	310138	3101	1,5%	333815	3338	2,0%	128554	1286	1,5%
TOTAL	**44344992**	**443450**		**21137557**	**211376**		**16366825**	**163668**		**8425196**	**84252**	

	LULC 2015											
	Guianas (3 territories)			Guyana			Suriname			French Guiana		
	ha	km2	%	ha	km2	%	ha	km2	%	ha	km2	%
Infrastructure	127825	1278	0,3%	86719	867	0,4%	27550	275	0,2%	12384	124	0,1%
Settlements	116395	1164	0,3%	52392	524	0,2%	32650	327	0,2%	30399	304	0,4%
Mineral extraction sites	207318	2073	0,5%	87215	872	0,4%	93430	934	0,6%	25006	250	0,3%
Herbaceous crops	470654	4707	1,1%	353152	3532	1,7%	104036	1040	0,6%	7479	75	0,1%
Woody crops	14632	146	0,0%	-	-	-	7290	73	0,0%	7237	72	0,1%
Shifting cultivation	321586	3216	0,7%	82310	823	0,4%	209702	2097	1,3%	27912	279	0,3%
Grassland	1736168	17362	3,9%	1648282	16483	7,8%	63931	639	0,4%	16407	164	0,2%
Forest tree cover	39401044	394010	88,9%	18045111	180451	85,4%	14962843	149628	91,4%	7953923	79539	94,4%
Mangroves	208527	2085	0,5%	105224	1052	0,5%	44791	448	0,3%	55686	557	0,7%
Shrubland, bushland, heathland	376169	3762	0,8%	247063	2471	1,2%	100009	1000	0,6%	25879	259	0,3%
Barren land	44140	441	0,1%	29506	295	0,1%	9028	90	0,1%	5836	58	0,1%
Open wetlands	602720	6027	1,4%	90398	904	0,4%	378273	3783	2,3%	128422	1284	1,5%
Inland water bodies	717814	7178	1,6%	310183	3102	1,5%	333293	3333	2,0%	128625	1286	1,5%
TOTAL	44344992	443450		21137557	211376		16366825	163668		8425196	84252	

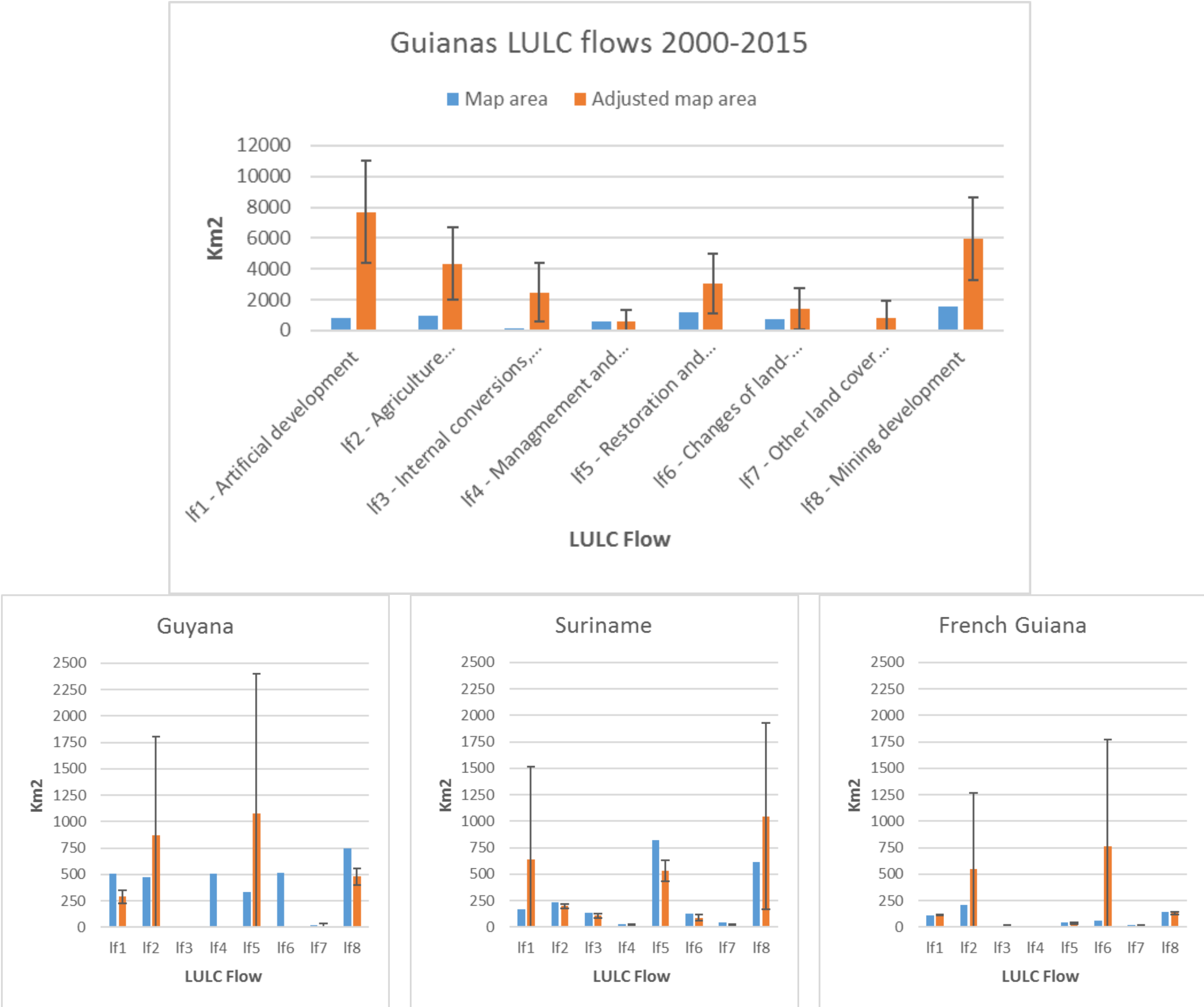
VII.8 Areas covered by the different LULC change flows between 2000 and 2015

	LULC change flows 2000-2015											
	Guianas (3 territories)			Guyana			Suriname			French Guiana		
	ha	km2	%	ha	km2	%	ha	km2	%	ha	km2	%
lf1 - Artificial development	79203	792	0,2%	50496	505	0,2%	17164	172	0,1%	10828	108	0,1%
lf2 - Agriculture development	92292	923	0,2%	47684	477	0,2%	23193	232	0,1%	20746	207	0,2%
lf3 - Internal conversions, rotations	14582	146	0,0%	-	-	-	13258	133	0,1%	1105	11	0,0%
lf4 - Managmement and alteration of forest land	54262	543	0,1%	50891	509	0,2%	2728	27	0,0%	122	1	0,0%
lf5 - Restoration and development of habitats	120541	1205	0,3%	33095	331	0,2%	81766	818	0,5%	4604	46	0,1%
lf6 - Changes of land-cover due to natural and multiple causes	70741	707	0,2%	51343	513	0,2%	12362	124	0,1%	6498	65	0,1%
lf7 - Other land cover changes n.e.c and reclassification	8252	83	0,0%	1745	17	0,0%	4231	42	0,0%	2191	22	0,0%
lf8 - Mining development	152211	1522	0,3%	74857	749	0,4%	61319	613	0,4%	14783	148	0,2%
0 - No observed land-cover change	43752908	437529	98,7%	20827377	208274	98,5%	16150804	161508	98,7%	8364318	83643	99,3%
TOTAL	44344992	443450		21137487	211375		16366825	163668		8425196	84252	

VII.9 Adjusted area estimates covered by the different LULC change flows between 2000 and 2015 based on the normalized confusion matrix

	Guianas (3 territories)			
	Map area (km2)	Adjusted Map Area (km2)	Adjusted Map Area Uncertainty (km2)	Adjusted proportions (%)
lf1 - Artificial development	792	7692	3299	1,7%
lf2 - Agriculture development	923	4321	2342	1,0%
lf3 - Internal conversions, rotations	146	2474	1915	0,6%
lf4 - Managmement and alteration of forest land	543	549	785	0,1%
lf5 - Restoration and development of habitats	1205	3045	1917	0,7%
lf6 - Changes of land-cover due to natural and multiple causes	707	1417	1357	0,3%
lf7 - Other land cover changes n.e.c and reclassification	83	829	1108	0,2%
lf8 - Mining development	1522	5962	2702	1,3%
0 - No observed land-cover change	437529	417163	5767	94,1%
TOTAL	443450			

	Guyana				Suriname				French Guiana			
	Map area (km2)	Adjusted Map Area (km2)	Adjusted Map Area Uncertainty (km2)	Adjusted proportions (%)	Map area (km2)	Adjusted Map Area (km2)	Adjusted Map Area Uncertainty (km2)	Adjusted proportions (%)	Map area (km2)	Adjusted Map Area (km2)	Adjusted Map Area Uncertainty (km2)	Adjusted proportions (%)
lf1	505	289	60	0,1%	172	637	879	0,4%	108	116	7	0,1%
lf2	477	868	935	0,4%	232	198	24	0,1%	207	550	715	0,6%
lf3	0	0	0	0,0%	133	107	18	0,1%	11	12	7	0,0%
lf4	509	0	0	0,0%	27	24	4	0,0%	1	1	0	0,0%
lf5	331	1076	1320	0,5%	818	532	97	0,3%	46	39	8	0,0%
lf6	513	0	0	0,0%	124	90	32	0,1%	65	761	1009	0,9%
lf7	17	14	20	0,0%	42	21	9	0,0%	22	12	8	0,0%
lf8	749	479	81	0,2%	613	1046	879	0,6%	148	133	11	0,2%
0 - No change	208274	208649	1618	98,7%	161508	162927	1245	98,5%	83643	82628	1233	96,9%
TOTAL	211376				163668				84252			


Guianas LULC flows 2000-2015
Map area
Adjusted map area
Km2
12000
10000
8000
6000
4000
2000
0
lf1 - Artificial development
lf2 - Agriculture...
lf3 - Internal conversions,...
lf4 - Managmement and...
lf5 - Restoration and...
lf6 - Changes of land-...
lf7 - Other land cover...
lf8 - Mining development
LULC Flow
Guyana
Suriname
French Guiana
Km2
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
lf1
lf2
lf3
lf4
lf5
lf6
lf7
lf8
LULC Flow

VII.10 Areas covered by the different LULC classes and the LULC change flows for the state of Amapá (Brazil)

	State of Amapá (Brazil)					
	2000			2015		
	ha	km2	%	ha	km2	%
Infrastructure	11474	115	0,1%	16633	166	0,1%
Settlements	21533	215	0,2%	21561	216	0,2%
Mineral extraction sites	1761	18	0,0%	4786	48	0,0%
Herbaceous crops	8018	80	0,1%	23906	239	0,2%
Woody crops	140881	1409	1,0%	139278	1393	1,0%
Shifting cultivation	77257	773	0,6%	274080	2741	2,0%
Grassland	1227791	12278	**8,8%**	1236914	12369	8,9%
Forest tree cover	11032025	110320	**79,0%**	10803035	108030	77,3%
Mangroves	211463	2115	**1,5%**	201461	2015	1,4%
Shrubland, bushland, heathland	976460	9765	**7,0%**	982911	9829	7,0%
Barren land	419	4	0,0%	419	4	0,0%
Open wetlands	20657	207	0,1%	21980	220	0,2%
Inland water bodies	239017	2390	**1,7%**	241793	2418	1,7%
Coastal water bodies, lagoons & estuaries	390	4	0,0%	390	4	0,0%
Intertidal zones	0	0	0,0%	0	0	0,0%
TOTAL	13969147	139691		13969147	139691	

	State of Amapá (Brazil)		
	LULC change flows 2000-2015		
	ha	km2	%
lf1 - Artificial development	6223	62	0,0%
lf2 - Agriculture development	213888	2139	1,5%
lf3 - Internal conversions, rotations	4173	42	0,0%
lf4 - Managmement and alteration of forest land	1380	14	0,0%
lf5 - Restoration and development of habitats	1225	12	0,0%
lf6 - Changes of land-cover due to natural and multiple causes	17773	178	0,1%
lf7 - Other land cover changes n.e.c and reclassification	7653	77	0,1%
lf8 - Mining development	2986	30	0,0%
0 - No observed land-cover change	13713847	137138	98,2%

VII.11 LULC change flows between 2000 and 2015 for the four territories

	LULC change flows 2000-2015														
	Guianas + Amapá (4 territories)			Guyana			Suriname			French Guiana			State of Amapá (Brazil)		
	ha	km2	%	ha	km2	%	ha	km2	%	ha	km2	%	ha	km2	%
lf1 - Artificial development	84711	847	0,1%	50496	505	0,2%	17164	172	0,1%	10828	108	0,1%	6223	62	0,0%
lf2 - Agriculture development	305510	3055	0,5%	47684	477	0,2%	23193	232	0,1%	20746	207	0,2%	213888	2139	1,5%
lf3 - Internal conversions, rotations	18536	185	0,0%	-	-	-	13258	133	0,1%	1105	11	0,0%	4173	42	0,0%
lf4 - Managmement and alteration of forest land	55122	551	0,1%	50891	509	0,2%	2728	27	0,0%	122	1	0,0%	1380	14	0,0%
lf5 - Restoration and development of habitats	120689	1207	0,2%	33095	331	0,2%	81766	818	0,5%	4604	46	0,1%	1225	12	0,0%
lf6 - Changes of land-cover due to natural and multiple causes	87976	880	0,1%	51343	513	0,2%	12362	124	0,1%	6498	65	0,1%	17773	178	0,1%
lf7 - Other land cover changes n.e.c and reclassification	15820	158	0,0%	1745	17	0,0%	4231	42	0,0%	2191	22	0,0%	7653	77	0,1%
lf8 - Mining development	153945	1539	0,3%	74857	749	0,4%	61319	613	0,4%	14783	148	0,2%	2986	30	0,0%
0 - No observed land-cover change	59056347	590563	98,6%	20827377	208274	98,5%	16150804	161508	98,7%	8364318	83643	99,3%	13713847	137138	98,2%
TOTAL	59898656	598987		21137487	211375			163668			84252		13969147	139691	