MAPBIOMAS

Projeto de Mapeamento Anual da Cobertura e Uso do Solo

Guianas: Guyana, French Guiana and Suriname - Appendix

Collection 6

Version 1.0

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1 Country general characterization

The Guianas (Guyana, Suriname and French Guiana) border Brazil in the south, Venezuela in the west and the Atlantic Ocean in the north, occupying an area of 441,906 km², which 211,157 km² are in Guyana, 146,523 km² in Suriname and 84,226 km² are from French Guiana. Together, the three countries are divided into 22 states (10 of the states are located in Guyana, 10 in Suriname and 2 in French Guiana), with French Guiana being the only one having a division by municipalities (42 in total) (Figure 1). With 97% of their territory occupied by Amazonian area and 90% covered with intact rainforest, it plays a critical role in mitigating climate change and in water regulation of the Amazon and Orinoco basins. About 35% of these regions are located in protected areas and indigenous territories; most of them in French Guiana (52% of the country), followed by Suriname (49%) and Guyana (19%).

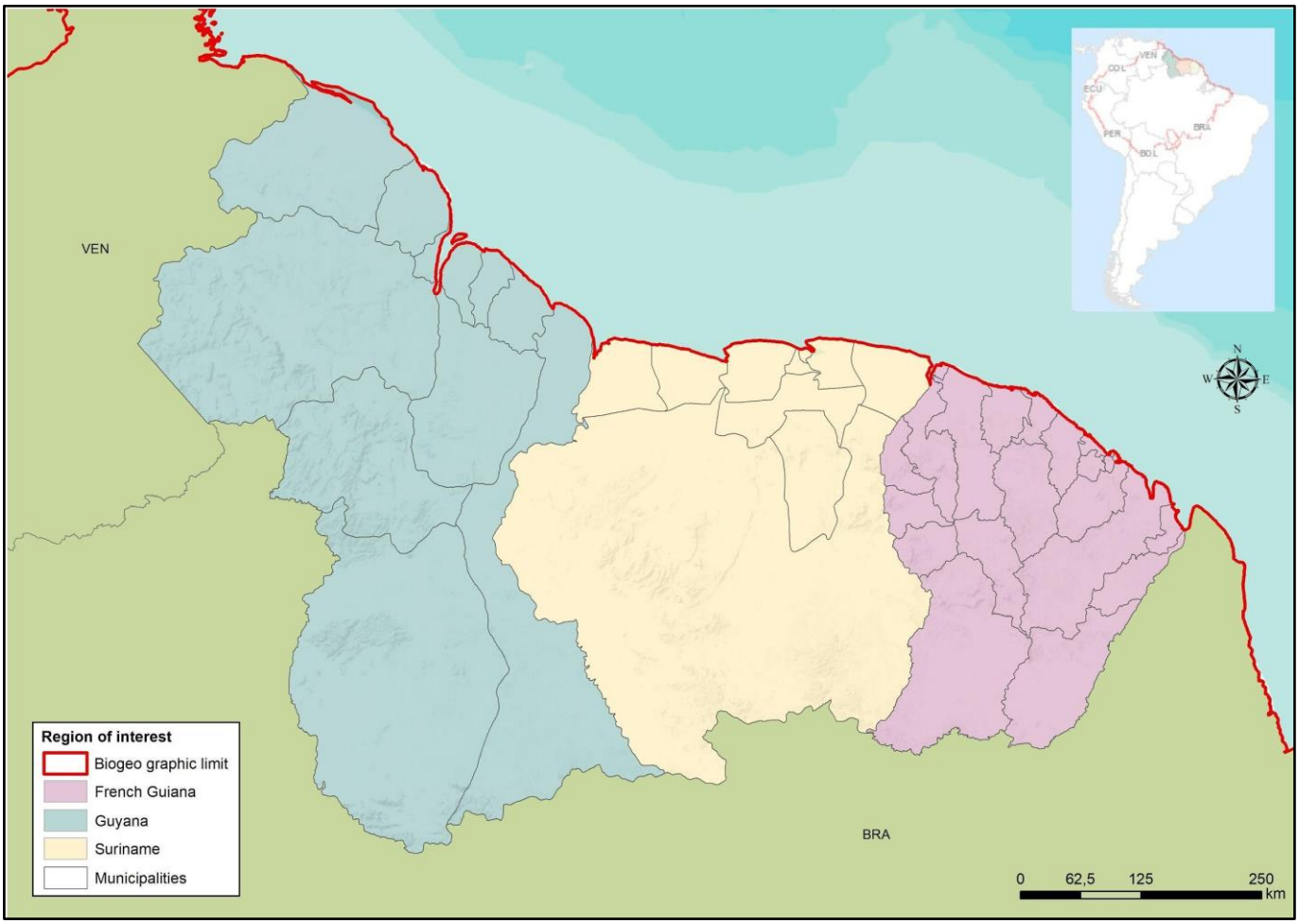


Figure 1. The location of Guianas with the division of countries (Guyana, Suriname and French Guiana), states and municipalities.

1.1 Brief context of Guyana

Guyana is a small and lightly populated country (approximately 785,034 people), most of the population is confined in coastal areas (World Population Review, 2020). Guyana is one of South America's poorest countries, where mining is one of its most important economic activities. Deforestation rates are likely low, Guyana lost about 0.3% of its forest cover annually in the first half of the 1990s. Roughly 60% of the country area is classified as primary forest, which is highly biodiverse (Mongabay,

2006). According to the International Tropical Timber Organization, forests in Guyana can be broken down as rainforest (36%), montane forest (35%), swamp (15%), dry evergreen (7%), seasonal forest (6%), and mangrove forest (1%).

1.2 Brief context of French Guiana

The French Guiana population (around 295,784 people) is concentrated mainly around the capital Cayenne, the largest city, and the coastal regions (World Population Review, 2020). The country has a developing market economy, sustained by aid and technical assistance from France. The gross national income per capita is among the highest in South America and most of the labor force is employed in services and industry, in agriculture subsistence farming and pasture supporting mainly cattle, pigs, and poultry (Britannica, 2019). According to the French Guiana Environmental Profile published by Mongabay (2006), even though the rainforests of French Guiana are largely unexploited, more than 90% is forested and about 95% consists of primary forest. The annual deforestation rate in the country is less than 0.2% and it has actually declined by 17.4% since the end of the 1990s.

1.3 Brief context of Suriname

Suriname has extensive forest cover with an important savanna component in different landscapes at locations. The country population (584,700 people) is concentrated in the capital (Paramaribo) and coastal cities (World Population Review, 2020). Less than 1% of Suriname’s land is cultivated, half of the farmland is planted with rice and some it is exported (Mongabay, 2006; FAO, 2005). Moreover, according to the Forest Legality Initiative (2016), Suriname's estimated annual deforestation rate is approximately 0.02%. However, the country is one of the top bauxite producers in the world (Britannica, 2019). In recent years the Surinamese government has recently taken steps to raise and keep the ecotourism industry strong.

2 Other national mapping initiatives

There are several national mapping initiatives of land cover and land use in Guyana, French Guiana, and Suriname, but cover only a few years or shorter time series (Table 1).

Table 1. General information about other national mapping initiatives in Guyana, French Guiana and Suriname.

País	Reference	Map type	Year	Link to download
Guyana	Guyana Lands and Surveys Commission (GLSC), Land Information and Mapping Division (LIM)	Resource map	2014	https://glsc.gov.gy/services/maps/#GLSC_Map_Catalog
Guyana	The National Land Use Plan of Guyana	National vegetation	2001	https://glsc.gov.gy/wp-content/uploads/2017/05/National-Land-Use-Plan-Final-Oct-2013.pdf
Guyana	The National Land Use Plan of Guyana	Areas of deforestation	1990-2011	https://glsc.gov.gy/wp-content/uploads/2017/05/National-Land-Use-Plan-Final-Oct-2013.pdf
Guyana	The National Land Use Plan of Guyana Summary	Land use / Land cover	2012	https://glsc.gov.gy/wp-content/uploads/2017/05/Summary-Booklet-of-the-National-Land-Use-Plan.pdf
Guyana	WWF, ONF Guyane and Parc Amazonien de Guyane (PAG)	Land use summary	2015	https://www.geoguyane.fr/geonetwork/srv/fre/catalog.search#/metadata/3d681d4f-b8bd-48b2-80d2-04a215a8a099
French Guiana	(2008) Notices bibliographiques. EchoGéo. DOI: 10.4000/echogeo.7353	Land use	1998	https://journals.openedition.org/com/1102?file=1
French Guiana	(2011) V. Gond et al. DOI: 10.1016/j.jag.2011.01.004	Landscape types	2000	https://www.sciencedirect.com/science/article/pii/S0303243411000055#!
Suriname	GONINI National Land Monitoring System of Suriname	Land use and land cover after deforestation 2000-2017	2009, 2013, 2015 and 2017	https://www.gonini.org/
Suriname	GONINI National Land Monitoring System of Suriname	National land use and land cover	2015	https://www.gonini.org/
Suriname	GONINI National Land Monitoring System of Suriname	Vegetation	2010	https://www.gonini.org/

3 Landsat image mosaics

3.1 Tiles division

The Guianas were divided into 40 tiles (Figure 2). Later, these tiles were partitioned by country and region to facilitate the parameterization of satellite image mosaics according to the specificities of each environment, totaling 55 tiles processed for each year of the time series (Table 2).

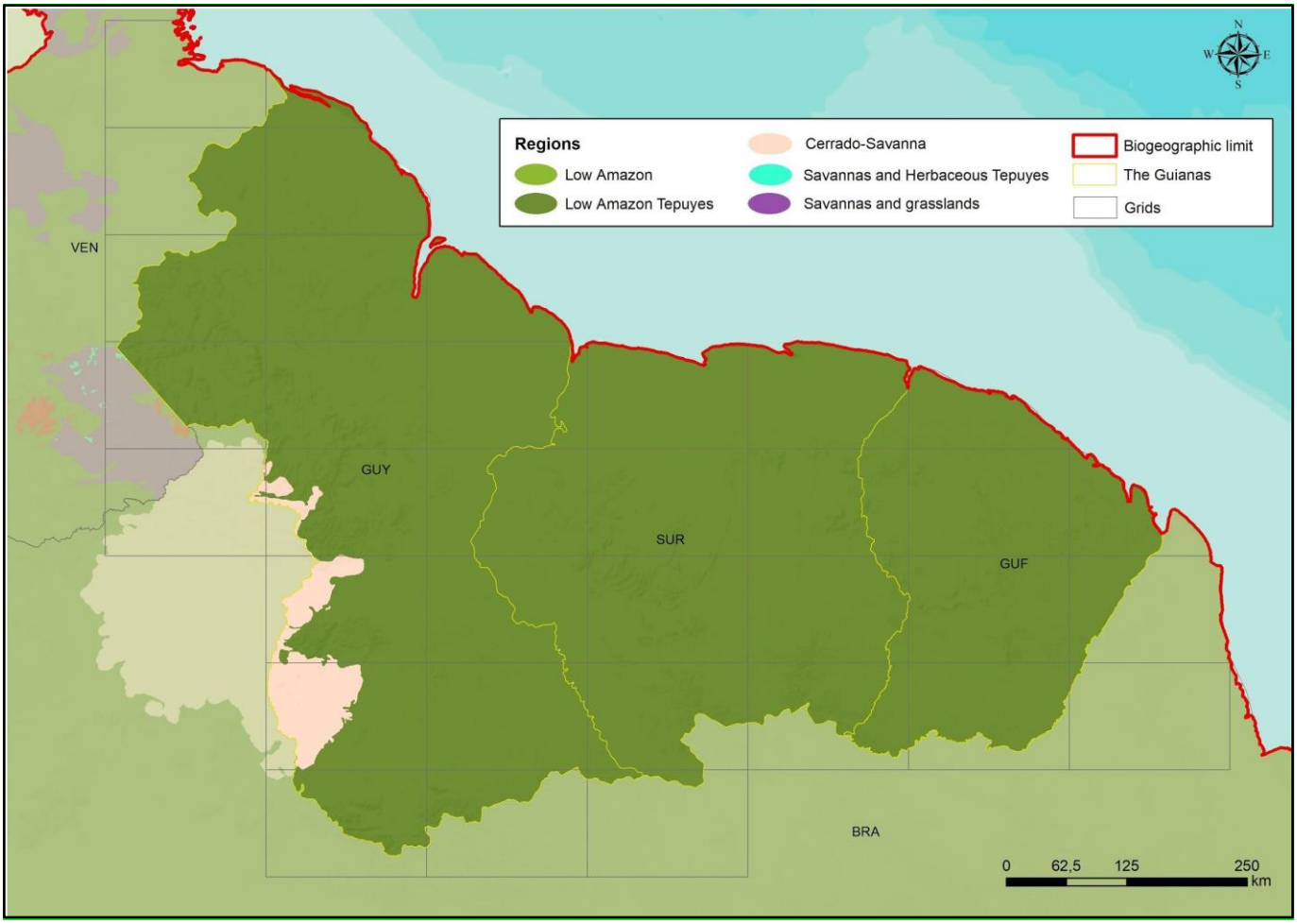


Figure 2. Scheme of regions and tiles used in the Guianas to partition the classification area, in the 1:250,000 scale.

Table 2. Total number of Landsat images mosaics processed by country, considering partition in tiles and regions

Country	Region	Number of mosaics processer per year	Mosaics processed 1985-2023
Guyana	Low Amazon	22	858
	Cerrado-Savanna	4	156
French Guyana	Low Amazon	12	468
Suriname	Low Amazon	17	663
Total		**55**	**2145**

3.2 Workspace processing

Several tests were done to define the images' optimum period to compose the annual mosaics. Due to the high impact of clouds presence covering the Guianas territory, it was decided to restrict the image selection parameters to a minimum. In other words, the decision was to maintain a large window for the selection of the initial and final dates of the mosaics and to avoid restricting the percentage of cloud cover. This increased the availability of images for composing the median mosaics.

The dates were selected individually for each of the 55 tiles and for each year. The criteria for selecting these dates were a maximum window of twelve months between the months of January and December. The median value of the pixels selected during this broader period demonstrated to better accommodate the forest mapping difficulties presented in the more restrictive window tests. Finally, 39 preliminary annual mosaics (1985-2023) were generated for each of the three countries (Table 3).

Table 3. Summary of the parameters used in the construction of the data mosaics.

Region	Satellite	Year	Period	%Clouds
Low Amazon	L5	1985-1999	01/01-30/12	100
	L5/L7	2000-2001		
	L8	2013-2021		
	L9	2022-2023		
Cerrado-Savanna	L5	1985-1999	01/01-30/12	100
	L5/L7	2000-2001		
	L8	2013-2021		
	L9	2022-2023		

3.3 Blacklist

In this stage, all the preliminary annual mosaics processed in the Workspace were visually assessed by a remote sensing specialist. The total number of mosaics considering the 55 tiles and 39-year time series was 2145 (1014 in Guyana; 468 in French Guiana; and 663 in Suriname), 18% were reprocessed after excluding images with huge cloud interferences from the median mosaic.

4 Classification

4.1. Legend

The Guianas legend was extracted from the general legend used by the MapBiomas Amazonia team (Figure 3), therefore the mapping classes are: Dense forest (3); Mangroves (5); Flooded Forest (6); Non-forest wetlands (11); Grasslands (12); Agriculture (18); Agriculture or pasture (21); Urban Infrastructure (24); Other non-vegetated areas (25); Mining (30) and River, lake and ocean (33).

ID	COLLECTION 5 (1985-2022)
1	**1. Forest**
3	1.1.1. Forest Formation
5	1.1.3. Mangroves
6	1.1.4. Floodable Forest
10	**2. Non-Forest Natural Formations**
11	2.1. Wetland
12	2.2. Grassland
14	**3. Farming**
18	3.2. Agriculture
21	3.3. Mosaic of Uses
22	**4. Non-vegetated Areas**
24	4.2. Urban Infrastructure
25	4.3. Other non-vegetated areas
30	4.4. Mining
26	**5. Water**
33	5.1. River, Lake and Ocean
27	**6. Not observed**

Figure 3. General legend of land use and land cover for Guianas in MapBiomas Amazonia Collection 5.

4.2 Definition of classification regions

The classification regions were defined mainly based on countries' relief shape and ecosystem characteristics. Human occupation (cities and farming) in the coastal zone was also considered. Regarding these aspects, four reference maps were combined to identify comparative areas with different environmental characteristics (Figure 5): (i) the Ecosystems of South America from the U.S. Geological Survey - Nature Conservancy (2008); (ii) the South American Landscape also from the Nature Conservancy (2005); (iii) the Shuttle Radar Topography Mission (SRTM) 90m digital elevation data from the National Aeronautics and Space Administration (NASA); and (iv) the world Ecoregions from Dinerstein *et al.* (2017).

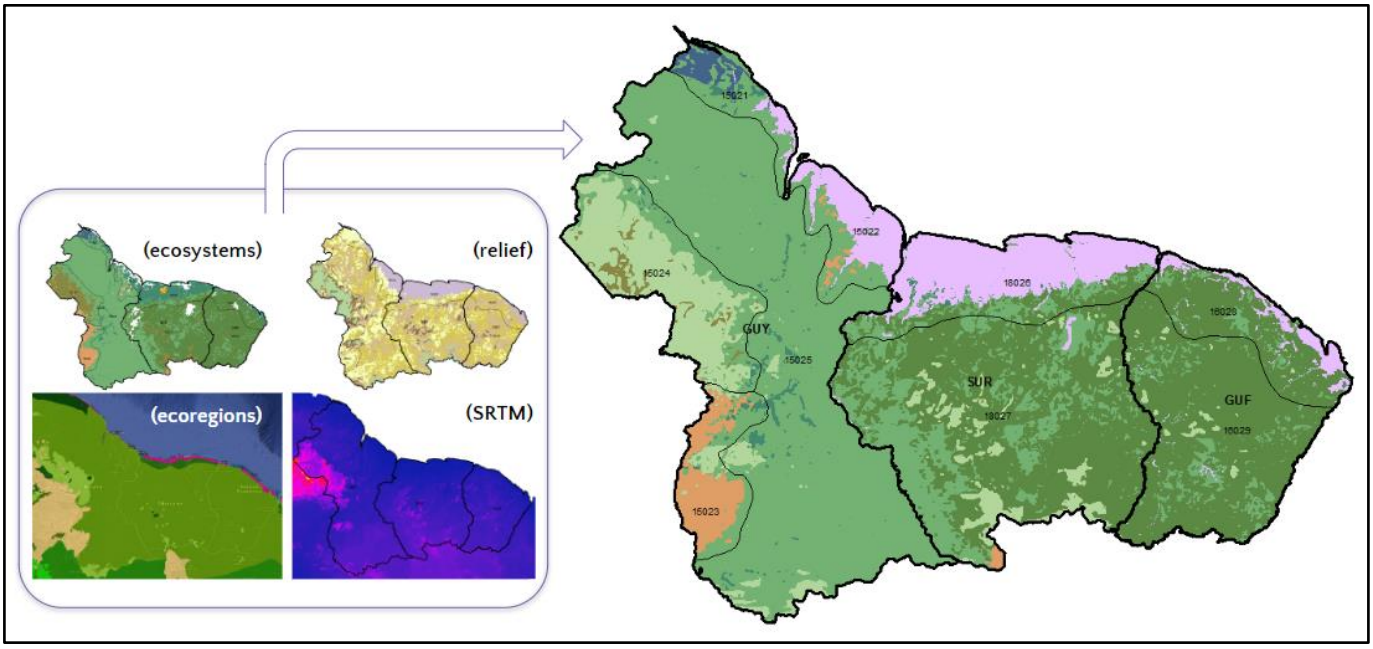
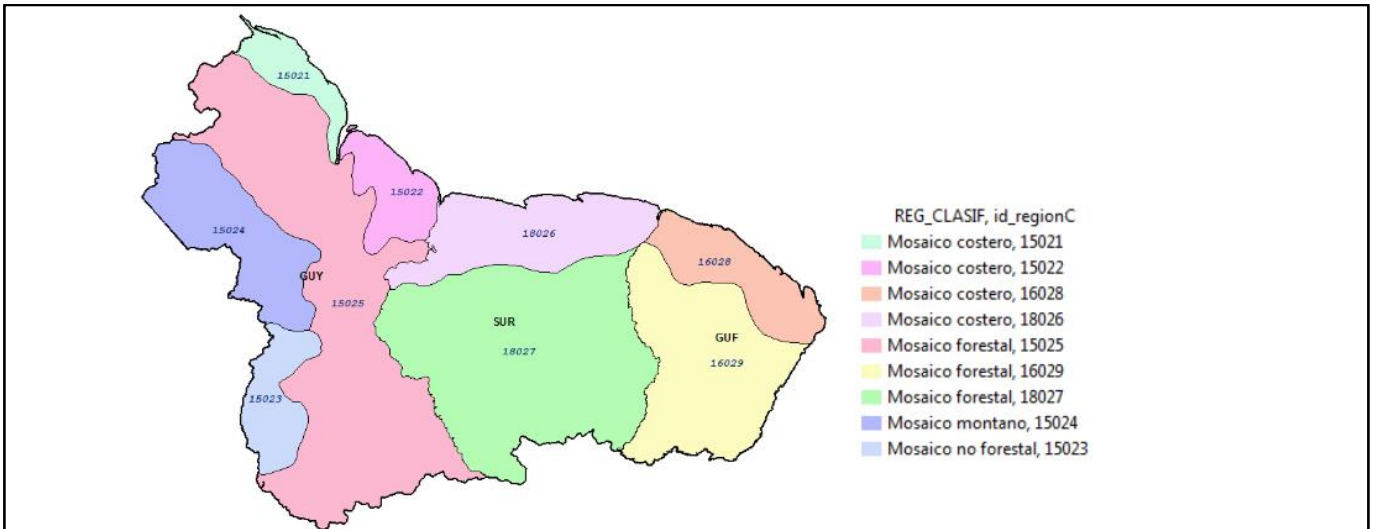


Figure 5. A scheme representing the combination of four reference maps used to define the classification regions.

Therefore, nine different classification regions were defined, which could be agglomerated in four main groups (coastal mosaic, forest mosaic, montane mosaic and non-forest mosaic). The location of each region, its limits and its main ecosystem characteristics are observed in Figure 6.



Pais	Regiones	id_regionC	REG_CLASIF	DESCRIPCIO
Guyana	Amazonía Baja	15021	Mosaico costero	Zonas de planicies aluviales y costeras, pantanos, manglares y mosaico forestal
Guyana	Amazonía Baja	15022	Mosaico costero	Zonas de planicies aluviales y costeras con bosque inundables y manglares, mosaico forestal y vegetacion esclerofila sobre dunas
Guyana	Amazonía Baja	15023	Mosaico no forestal	Zonas planas con mosaico forestal y vegetación no forestal
Guyana	Cerrado-Sabana	15023	Mosaico no forestal	Zonas planas con mosaico forestal y vegetación no forestal
Guyana	Amazonía Baja	15024	Mosaico montano	Zonas de altiplanos y valles con bosque húmedo montano y montano bajo
Guyana	Cerrado-Sabana	15024	Mosaico montano	Zonas de altiplanos y valles con bosque húmedo montano y montano bajo
Guyana	Amazonía Baja	15025	Mosaico forestal	Zona planas, onduladas y colinas con bosque sedimentario simple, bosque estacional, bosque lluvioso, bosque montano y bosque semi-caducifolio
Suriname	Amazonía Baja	18026	Mosaico costero	Zonas de planicies aluviales y costeras con bosque inundables y manglares, mosaico forestal y vegetacion esclerofila sobre dunas
Suriname	Amazonía Baja	18027	Mosaico forestal	Zona planas, onduladas y colinas con bosque sedimentario simple, bosque estacional, bosque lluvioso, bosque montano y bosque semi-caducifolio
Guiana Fran	Amazonía Baja	16028	Mosaico costero	Zonas de plancies aluviales y costeras con bosque inundables, manglares y mosaico forestal
Guiana Fran	Amazonía Baja	16029	Mosaico forestal	Zona planas,onduladas y colinas con bosque estacional siempreverde de colinas

Figure 6. The regions used in the Guianas to partition the classification area.

4.3 Cross-cutting themes

With different classification tests, a limitation was detected in the differentiation of certain classes, so they were classified separately. These classes are called cross-cutting themes and are mapped with binary classification algorithms (Class of interest and “Not Observed” class). This strategy was applied, within the scope of the Guianas, for the classes:

- Mangrove (ID=5);
- Floodable Forest (ID = 6);
- Agriculture (ID=18);
- Urban Infrastructure (ID=24) and
- Mining (ID=30)
- River, lake and ocean (ID=33)

Details of each methodology are found in the appendices of each cross-cutting theme.

4.4 Classification algorithm, training samples and parameters

After generating the image mosaics and feature space, the first step in the classification is to correct the stable areas mapped in Collection 5 (1985-2022) of the Guianas. This correction was made by region through visual interpretation of the Landsat images mosaics.

Then, is selected a reference year to calculate the proportion of each stable class in the classification region and use the result to draw training samples on the Collection 4 stable area map. The year that best represents reality were identified for each region and the training samples number was standardized (Table 4).

Table 4. Collection 5 annual map selected as reference for calculating the proportion of stable areas per classification region.

Country	Regions		Step P03
	ID v1	ID v2	P03
Guyana	15021	50201	Reference year: 2000 Number of samples: 100-1000
Guyana	15022	50202	Reference year: 2000 Number of samples: 100-1000
Guyana	15023	50203	Reference year: 2000 Number of samples: 100-1000
Guyana	15023	50903	Reference year: 2000 Number of samples: 100-1000
Guyana	15024	50204	Reference year: 2000 Number of samples: 100-1000
Guyana	15024	50904	Reference year: 2000 Number of samples: 100-1000

Guyana	15025	50205	Reference year: 2000 Number of samples: 100-1000
Suriname	18026	80201	Reference year: 2000 Number of samples: 100-1000
Suriname	18027	80202	Reference year: 2000 Number of samples: 100-1000
French Guiana	16028	60201	Reference year: 2000 Number of samples: 100-1000
French Guiana	16029	60202	Reference year: 2000 Number of samples: 100-1000

In the next step, the machine learning algorithm called random forest ran to generate a preliminary classification of the complete Collection 6 time series (1985-2023). All regions were classified using 60 decision trees. With this first version ready, the gap-fill filter was applied, as described in the General ATBD.

After this filter, the classification cycle is repeated with the preliminary classification as the basis (no longer Collection 5). Therefore, the map of stable areas of the filtered preliminary classification is created. Consequently, the reference years are selected and stable training samples are drawn (Table 5).

Table 5. Preliminary classification annual map selected as reference for calculating the proportion of stable areas per classification region.

Country	**Regions**		**Step P03**
	ID v1	**ID v2**	**P03**
Guyana	15021	50201	Reference year: 2000 Number of samples: 100-1000
Guyana	15022	50202	Reference year: 2000 Number of samples: 100-1000
Guyana	15023	50203	Reference year: 2000 Number of samples: 100-1000
Guyana	15023	50903	Reference year: 2000 Number of samples: 100-1000
Guyana	15024	50204	Reference year: 2000 Number of samples: 100-1000
Guyana	15024	50904	Reference year: 2000 Number of samples: 100-1000
Guyana	15025	50205	Reference year: 2000 Number of samples: 100-1000

Suriname	18026	80201	Reference year: 2000 Number of samples: 100-1000
Suriname	18027	80202	Reference year: 2000 Number of samples: 100-1000
French Guiana	16028	60201	Reference year: 2000 Number of samples: 100-1000
French Guiana	16029	60202	Reference year: 2000 Number of samples: 100-1000

The set of stable samples is evaluated by classification region to identify whether there is a need for sample complementation. Complementary training samples were selected for all regions, according to Table 6. Thus, the final set of training samples (stable + complementary) was used in the processing of the random fores. In this stage, 60 decision trees were also applied for the classification. After this, the following steps are post-classification filters.

Table 6. Number of complementary training samples selected per mapping class for each classification region.

Country	Regions		Number of complementary training samples
	ID v1	ID v2	
Guyana	15021	50201	Dense Forest: 500 Non-forest wetlands: 500 Agriculture or pasture: 500 River, lake and ocean: 500
Guyana	15022	50202	Dense Forest: 500 Non-forest wetlands: 500 Grasslands: 500 Agriculture or pasture: 500 Other non-vegetated areas: 500 River, lake and ocean: 500
Guyana	15023	50203	Dense Forest: 500 Non-forest wetlands: 500 Grasslands: 500 River, lake and ocean: 500
Guyana	15023	50903	Dense Forest: 500 Non-forest wetlands: 500 Grasslands: 500
Guyana	15024	50204	Dense Forest: 500 Grasslands: 500
Guyana	15024	50904	Dense Forest: 500 Grasslands: 500
Guyana	15025	50205	Dense Forest: 500 Grasslands: 500

Suriname	18026	80201	Dense Forest: 500 Non-forest wetlands: 500 Grasslands: 500 Agriculture or pasture: 500 River, lake and ocean: 500
Suriname	18027	80202	Dense Forest: 500 Grasslands: 500 Other non-vegetated areas: 500 River, lake and ocean: 500
French Guiana	16028	60201	Dense Forest: 500 Non-forest wetlands: 500 Grasslands: 500 Agriculture or pasture: 500 Other non-vegetated areas: 500 River, lake and ocean: 500
French Guiana	16029	60202	Dense Forest: 500 River, lake and ocean: 500

5 Post-classification

5.1 Gap-fill filter

The gap-fill filter was used to fill possible no-data values as explained in the General ATBD. No-data values (“gaps”) are theoretically not allowed and are replaced by the temporally nearest valid classification. In this procedure, if no “future” valid position is available, then the no-data value is replaced by its previous valid class. Up to three prior years can be used to fill in persistent no-data positions. Therefore, gaps should only exist if a given pixel has been permanently classified as no-data throughout the entire temporal domain (1985-2023).

5.3 Temporal filter

The temporal filter uses sequential classifications in a three-to-five-years unidirectional moving window to identify temporally non-permitted transitions. Based on generic rules (GR), the temporal filter inspects the central position of three to five consecutive years, and if the extremities of the consecutive years are identical but the centre position is not, then the central pixels are reclassified to match its temporal neighbour class. Another generic temporal rule is applied to the extremity of consecutive years. In this case, if the classifications of the first and last years are different from its neighbours, this values are replaced by the classification of its matching neighbours.

In Guyana, French Guiana and Suriname the logic for prioritizing classes for the temporal filter were the same. The rule for the first year was executed for the native classes (3, 11 and 12), followed by the rule for the middle years executed for the classes 33, 12, 21, 3 and 25, and finally the temporal filter rule for the last year executed for the unnatural class (21). Some rules were applied more than once in different prioritizations to improve the temporal connection between the annual maps, as in the case of classes 3, 12 and 21. Below is the code with the temporal filter rules execution order used in the script.

order_exec_first = [3, 11, 12];
order_exec_last = [21];
order_exec_middle = [33, 12, 21, 3, 25];

5.4 Spatial filter

The generated after the classification were submitted filtering procedures. The spatial filter increases the spatial consistency between the classes eliminating the solitary group of pixels of a specific class in the middle of another class. This process was applied to all classes and the specific routine can be found in details on the ATBD general description.

5.5 Frequency filter

This filter takes into consideration the occurrence frequency throughout the entire time series. Thus, all class occurrence with less than a given percentage of temporal persistence are filtered out. This mechanism contributes to reducing the temporal oscillation associated to a given class, decreasing the number of false positives and preserving consolidated trajectories. Each classification region in the Guianas have customized applications of frequency filters, see more details in Table 7. It is worth mentioning that the frequency filter was applied to correct not only native areas but also unnatural areas in the group of regions defined as coastal mosaic due to the old human occupation in these areas.

Table 7. Customized parameters of the frequency filter applied in each classification region.

Regions			**Frequency filter parameters**		
Country	**ID v1**	**ID v2**	**Classes considered in the pixel mask eligible for filter application**	**Percentage to define the mask of eligible pixels to apply the filter**	**Percentage of temporal persistence applied**
Guyana	15021	50201	Native classes	90	70
			Unnatural classes	70	50
Guyana	15022	50202	Native classes	90	70
			Unnatural classes	70	50
Guyana	15023	50203	Native classes	90	80
Guyana	15023	50903	Native classes	90	80
Guyana	15024	50204	Native classes	90	80

Guyana	15024	50904	Native classes	90	80
Guyana	15025	50205	Native classes	90	80
Suriname	18026	80201	Native classes	90	80
			Unnatural classes	70	50
Suriname	18027	80202	Native classes	90	80
French Guiana	16028	60201	Native classes	90	80
			Unnatural classes	70	50
French Guiana	16029	60202	Native classes	90	80

5.6 Incidents filter

The incident filter was applied to remove pixels that changed too many times in the 39 years of time spam. This avoids changes in the border of the classes and helps to stabilize originally noise pixel trajectories. You can see the minimum changes and connections parameters details in the General ATBD.

5.7 Integration

The results obtained from the general classification map and cross-cutting themes were integrated as a single map for each year of analysis. Following the integration rules shown in Table 8.

Table 8. Prevalence rules for class integration in the Guianas.

Prevalence	Class	Class ID	Source
1	Mining	30	Cross-cutting
2	Mangrove	5	Cross-cutting
3	Urban Infrastructure	24	Cross-cutting
4	Agriculture	18	Cross-cutting
5	River, lake and ocean	33	Cross-cutting
6	River, lake and ocean	33	General
7	Other non vegetated areas	25	General
8	Mosaic of uses	31	General
9	Wetland	11	General
10	Grassland	12	General
11	Floodable Forest	6	Cross-cutting
12	Forest Formation	3	General

6 References

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