MapBiomas 10-meters

Algorithm Theoretical Basis Document (ATBD)

Collection 4

Version 1

August, 2026

Table of Contents

Executive Summary 2
1. Introduction 4
    1.1. Scope and content of the document 4
    1.2. Overview 4
    1.3. Region of Interest 5
    1.4. Key Science Applications 7
2. Overview and Background Information 8
    2.1. Context and Key Information 8
        2.1.1. MapBiomas Network 8
        2.1.2. Remote Sensing Data 8
        2.1.3. Google Earth Engine and MapBiomas Computer Applications 9
    2.2. Historical Perspective: Existing Maps and Mapping Initiatives 9
        2.2.1. Global Land Use and Land Cover Data 9
        2.2.2. National Land Use and Land Cover Data 11
        2.2.3. Regional and Biomes Land Use and Land Cover Data 12
3. General Methodological Description 12
    3.1. Sentinel-2 Mosaics 14
    3.2. MapBiomas feature space 14
    3.3. Legend 15
    3.4. Classification 17
4. Integration and Post-classification 17
    4.1 Integration 17
    4.2. Filters on Integrated Maps 17
    4.3. Statistics 18
5. Accuracy Assessment 18
    5.1 Accuracy assessment overview 18
    5.2 Sampling design 18
    5.3. Response design 19
    5.4. Analysis 19
    5.5. Preliminary results 20
    5.6. Concluding remarks of accuracy assessment 22
6. Map Collections and Analysis 22
7. Practical Considerations 24
8. Concluding Remarks and Perspectives 24
9. References 25
APPENDICES 28
ANNEXES 28
    Annex I: MapBiomas Network 28
    Annex II: Prevalence rules 31

Executive Summary

The MapBiomas 10-meters Algorithm Theoretical Basis Document (ATBD) for Collection 4, published in August 2026, provides a comprehensive technical overview of the methodology, processing pipeline, and technical protocols adopted to ensure the transparency and reproducibility of Brazil's annual land use and land cover (LULC) mapping. In 2023, building on the experience gained from mapping using 30m Landsat imagery, MapBiomas launched the MapBiomas 10-meters Collection 1 (beta), covering the period from 2016 to 2022 and 18 LULC classes. While Collection 2 expanded the time series to 2023 with 21 classification classes, Collection 3 advanced the series through 2024 and introduced a 22nd class dedicated to Photovoltaic Solar Power Plants, mapped using deep learning techniques. Due to changes in auxiliary data availability, the year 2016 was discontinued in the third collection. For Collection 4, covering the period from 2017 to 2025, four new classes were mapped: Wind Farms (beta), Flooded Savanna (beta), and Herbaceous and Shrub Formation, and Salt Marsh (beta), totaling 26 classes. For the other classes, the same methods used for Collection 3 were generally applied, with specific changes regarding biomes that are described in the respective appendices.

Processing petabyte-scale geospatial data is achieved via the Google Earth Engine cloud platform using JavaScript and Python. Key technological features in Collection 4 include the integration of Satellite Embeddings data from AlphaEarth Foundations and Google starting in 2017 to boost classification accuracy. The workflow combines robust machine learning and deep learning architectures, employing Random Forest, Gradient Tree Boosting—specifically for the Caatinga biome—and U-Net Convolutional Neural Networks for specialized classes such as aquaculture, apicum, mining, and perennial crops. Following initial classification, the data undergoes eight spatial and temporal post-classification filters to eliminate noise, ensure temporal stability, and smooth out variations in agricultural and planted forest areas, establishing a minimum mapping unit of 0.25 hectares.

Geographically, the mapping covers all six official Brazilian biomes—Amazon, Cerrado, Caatinga, Atlantic Forest, Pampa, and Pantanal—based on IBGE's 2025 boundaries. To maximize precision, the processing is segmented by biome and further divided into key cross-cutting themes, including Pasture, Agriculture, Coastal Zone, Mining, and Urban Areas. These sector-specific maps are subsequently integrated pixel by pixel according to hierarchical prevalence rules defined by thematic experts.

Accuracy assessment was carried out based on reference samples in a stratified random design. The strata are defined by crossing the six Brazilian biomes (Amazônia, Caatinga, Cerrado, Mata Atlântica, Pampa and Pantanal) with the five Level-1 classes of the MapBiomas legend: Forest, Herbaceous & Shrubby Vegetation, Farming, Non-vegetated Area, and Water, with a total of 1,500 reference points. All six biomes have been assessed, yielding a national area-weighted overall accuracy of 91.8% (95% confidence interval 89.5–94.1%) over the approximately 851.5 million hectares mapped. Overall accuracy by biome ranges from 95.8% in the Pampa and 95.4% in the Amazônia to 85.0% in the Cerrado and 82.3% in the Pantanal, meeting the expectations for an operational land-cover product.

Ultimately, transitioning to a 10-meter resolution unlocks unprecedented opportunities for detailed environmental and spatial analysis. This enhancement allows researchers and policymakers to identify narrow riparian forests within Permanent Preservation Areas (APPs) along rivers and springs, monitor urban infrastructure expansion, improve climate risk modeling, and strengthen public policies aimed at controlling deforestation and reducing greenhouse gas emissions.

MapBiomas operates under an open-science model, providing free and public access to annual LULC maps, cloud-free annual Sentinel-2 image mosaics, transition and dynamic analysis data, and comprehensive geospatial statistics aggregated by administrative boundaries, conservation units, indigenous lands, and rural properties. All MapBiomas 10 m' maps and datasets are freely available on the project platform (https://plataforma.brasil.mapbiomas.org/cobertura_10m) and to download (https://brasil.mapbiomas.org/en/mapbiomas-cobertura-10m/), as well as all computational algorithms used in the MapBiomas classifications, which are available on Github (https://github.com/mapbiomas).

1. Introduction

1.1. Scope and content of the document

The purpose of this Algorithm Theoretical Basis Document (ATBD) is to describe the methods, processing workflow, and technical procedures applied in the MapBiomas 10 m collections, ensuring transparency, reproducibility, and proper interpretation of the products. The document covers the classification methods, the image processing workflow, the approach to integrating the biome and cross-cutting theme maps, post-classification procedures and the methodological updates of the annual maps of land use and land cover (LULC) in Brazil from 2017 to 2025 of the MapBiomas 10 m Collection 4. In addition, the document presents a historical context and background information, a general description of the satellite imagery datasets, and feature inputs.

Additional information about the classification of each biome and cross-cutting theme is available in the appendices at https://brasil.mapbiomas.org/en/mapbiomas-cobertura-10m/. All maps and statistics of MapBiomas 10 m Collection 3 are openly available through the MapBiomas platform: https://plataforma.brasil.mapbiomas.org. The scripts and workflows related to the collection are available in the project GitHub repositories: https://github.com/mapbiomas/brazil-all-initiatives.

1.2. Overview

The MapBiomas project was launched in 2015 with a goal of improving the understanding of land use and land cover dynamics in Brazil, through annual, nationwide mapping products. The first MapBiomas LULC maps were produced using a 30-m resolution Landsat archive available in the Google Earth Engine platform, encompassing the years from 1985 to the present. Since then, MapBiomas published ten LULC mapping collections in Brazil, updating a new collection each year.

MapBiomas aims to develop a collaborative, transparent, fast, reliable, and low-cost method for processing large-scale datasets and producing historical LULC time series. All data, maps, statistics, and further analyses are openly available through the MapBiomas platform (https://plataforma.brasil.mapbiomas.org/). All these are possible thanks to: i) Google Earth Engine platform, which provides access to data, image processing, standard algorithms, and the cloud computing facility; ii) freely available Landsat and Sentinel satellite imagery archives; iii) MapBiomas collaborative network of organizations and experts that share knowledge and mapping tools; and iv) visionary funding agencies that support the project (Souza Jr et al., 2020).

The MapBiomas 10 m Collection 4, launched in August 2026, covers the period of 2017 to 2025 and maps 26 LULC classes. As in Collection 3, Satellite Embeddings from AlphaEarth Foundations/Google were used in Collection 4 as auxiliary features in the classification process, updated training samples based on expert review, transition and temporal analyses.

The products of the MapBiomas 10 m Collection 4 are the following:

• Land use and land cover annual maps of 10-meter resolution from 2017 to 2025;

• Sentinel-2 image cloud free annual mosaics;

• LULC transitions and temporal analysis, including number of classes, number of changes, and stable areas;

• LULC statistics and spatial analysis with political territories (e.g. biomes, states, municipalities), watersheds at different levels, protected areas (e.g. conservation units and indigenous territories), and other land tenure categories (e.g. rural settlements, quilombola lands).

In addition to the LULC collections, the MapBiomas network also makes other products available, such as the MapBiomas Water and Fire collections featuring annual and monthly maps of Brazil's water surface and fire scars from 1985 to the present, respectively. Annual maps of topsoil (0 - 30 cm) organic carbon stocks and soil texture mapping were launched as part of the MapBiomas Soil beta collection, along with the open soil research data repository SoilData. Since MapBiomas operates collaboratively with open data and methods, the network has expanded to other countries, engaging local institutions in mapping across all South American countries and Indonesia (https://brasil.mapbiomas.org/iniciativas-mapbiomas/).

1.3. Region of Interest

MapBiomas was created to produce LULC annual maps for the entire Brazilian territory, covering all the six official biomes of the country: Amazon, Atlantic Forest, Caatinga, Cerrado, Pampa, and Pantanal (Figure 1). A biome is a geographic region defined based on vegetation types associated with geomorphological and climatic conditions. Our maps are developed per biome and then integrated into a single map of Brazil's LULC classes in a post-processing step. The official Brazilian biomes map (1:250,000) developed by IBGE (2025) has been used. Classifying LULC classes at the biome level helps to better discriminate specific LULC classes and landscape patterns across the country (Table 1). In Brazil, the mapping approach was also divided into cross-cutting themes to improve the classification accuracy and quality: Agriculture, Pasture, Coastal Zone, Mining, and Urban Area.

Figure 1. Brazilian biomes used in the MapBiomas project to generate the Collection 4 of 10 m land use and land cover mapping products (source: IBGE, 2025).

Table 1. Land use and land cover characteristics of the Brazilian biomes.

Biome	Area (Mha) (Country %)	Land Cover	Predominant Land Use
Amazon	420.8 (49.5%)	Evergreen forest, with enclaves of savanna, natural grassland, and extensive wetlands and surface water.	Cattle ranching, agriculture, mining, logging and non-timber forestry production.
Atlantic Forest	110.7 (13.0%)	Evergreen forests, mangroves and sandbank vegetation along the coast. Deciduous and semi deciduous forests in the countryside and Araucaria moist forests in the South. Savanna formations and grasslands are also present. Vegetation is mostly in isolated patches.	Agriculture, cattle ranching, urban, forest plantation, artificial water reservoir.
Caatinga	86.3 (10.1%)	Dry woody and deciduous physiognomies	Agriculture, cattle ranching, smallholder livestock production, urbanization.
Cerrado	198.5 (23.3%)	Mosaic of savannas, grasslands and deciduous and semi deciduous forests	Agriculture, cattle ranching.
Pampa	19.46 (2.3%)	Mostly grasslands, but deciduous and semi deciduous forests, wetlands and herbaceous sandbank vegetation are also present	Agriculture (rice, soy, perennial crops), livestock production (in natural grasslands), forest plantation, and urbanization.
Pantanal	15.1 (1.8%)	Mostly savannas, grasslands and wetlands. Deciduous and semi deciduous forests are also present.	Agriculture and cattle ranching.

1.4. Key Science Applications

MapBiomas was initially designed to address knowledge gaps in Brazil's greenhouse gas emission estimates from the land-use change sector. However, its annual time-series of land use and land cover (LULC) maps also enable various scientific applications. In particular, the 10-meter resolution mapping enhances other detailed analyses, such as those focused on rural properties and urban areas. For example, higher-resolution imagery allows for more precise classification of certain land cover types, such as riparian forests in Permanent Preservation Areas (APP) along rivers and springs, among other applications:

- Mapping and quantifying LULC transitions
- Quantification gross and net forest cover loss and gain
- Monitoring water resources and their interaction with LULC classes
- Monitoring agriculture and pasture expansion
- Monitoring natural disasters
- Tracking infrastructure expansion and urbanization
- Identifying desertification processes
- Supporting regional planning
- Managing protected areas
- Modeling land-use changes
- Modeling infectious disease risks
- Modeling climate change

2. Overview and Background Information

2.1. Context and Key Information

This section addresses complementary contextual and critical information relevant to understand the MapBiomas products and methods used in the map collections.

2.1.1. MapBiomas Network

MapBiomas is a collaborative network of NGOs, universities, and technology startups committed to mapping land use and land cover changes across Brazil. Each organization plays specific or multiple roles, contributing to the project's overall development and each biome and cross-cutting theme (Agriculture, Pasture, Coastal Zone, Mining, and Urban Area) has a lead organization (a complete list of organizations can be found in Annex I).

2.1.2. Remote Sensing Data

The imagery dataset used in the MapBiomas 10 m Collection 4 was the harmonized collection of Sentinel-2 sensor MultiSpectral Instrument (MSI) (https://sentiwiki.copernicus.eu/web/s2-mission), accessible via Google Earth Engine and produced by the European Spatial Agency (ESA).

2.1.3. Google Earth Engine and MapBiomas Computer Applications

MapBiomas data processing is based on Google technology, which includes image processing in cloud computing infrastructure, programming with Javascript and Python via Google Earth Engine, and data storage using Google Cloud Storage. Google defines Google Earth Engine as: "a platform for petabyte-scale scientific analysis and visualization of geospatial datasets, both for public benefit and for business and government users."

The MapBiomas project has developed the following computer applications based on Google Earth Engine:

• Javascript codes - these scripts were written directly in the Google Earth Engine Code Editor. The classification, post-classification and map integration of MapBiomas 10 m Collection 4 were written in Javascript.

• Python scripts - This code category was used to optimize image processing of large datasets in Google Earth Engine. In addition, the image mosaicking and statistical analysis were all performed in Google Earth Engine Python API. The python API also is used to train and predict deep learning models, as U-Net.

• Dashboard (https://plataforma.brasil.mapbiomas.org/) - The web platform of the MapBiomas initiative presents LULC annual maps of MapBiomas 10 m Collection 4, and its graphs and statistics (https://plataforma.brasil.mapbiomas.org/coverage/coverage_coverage_10m). Besides the MapBiomas 10 m LULC data , the MapBiomas dashboard presents other products/modules, such as MapBiomas 30 m Collection 11 (Landsat) LULC, transitions temporal analysis, deforestation, secondary vegetation, agriculture, pasture, fire, mining, soil, water, degradation, urban mappings, besides the new modules atmosphere and climate risk. All maps, data, and methodological documents of the MapBiomas Collections are open and freely available to download, and more information about the MapBiomas initiatives are available in the website (http://mapbiomas.org/en).

2.2. Historical Perspective: Existing Maps and Mapping Initiatives

2.2.1. Global Land Use and Land Cover Data

Mapping initiatives at the global scale complement national land use and land cover (LULC) mapping efforts. Early global mapping initiatives were developed by the U.S. Geological Survey (USGS) and the University of Maryland, which produced some of the first global land cover and tree cover datasets from AVHRR imagery at approximately 1-km spatial resolution (Hansen et al., 2000). Subsequently, USGS developed the MODIS Land Cover Type Product (MCD12Q1), providing annual global land cover maps at 500-m spatial resolution since 2001 (Friedl et al., 2010; Sulla-Menashe & Friedl, 2018).

The European Space Agency (ESA) launched the GlobCover project, generating global land cover maps from MERIS imagery at 300-m spatial resolution for the periods December 2004–June 2006 and January–December 2009 (Arino et al., 2012). Building on this effort, the ESA Climate Change Initiative (CCI) Land Cover project produced annual global land cover maps at 300-m spatial resolution from 1992 to 2015 (Defourny et al., 2017).

Advances in Landsat-based mapping enabled the production of higher-resolution global products. The National Geomatics Center of China (NGCC) developed GlobeLand30, a global land cover product at 30-m spatial resolution for the years 2000, 2010, and 2020 (Chen et al., 2014; Chen et al., 2017). Around the same period, the Finer Resolution Observation and Monitoring of Global Land Cover (FROM-GLC) initiative produced the first global land cover map at 30-m resolution based on Landsat imagery for circa 2010 (Gong et al., 2013). The initiative subsequently evolved to generate updated global land cover products using both Landsat and Sentinel imagery (Gong et al., 2019).

The Global Forest Change (GFC) dataset, developed by the Global Land Analysis and Discovery (GLAD) laboratory at the University of Maryland, represented another major advance in global monitoring. Derived from Landsat imagery at 30-m spatial resolution, GFC provides annual information on forest cover loss and gain worldwide from 2000 onwards (Hansen et al., 2013). Beyond GFC, GLAD has developed additional global monitoring products, including datasets on cropland extent, tree canopy cover, and near-real-time land cover change detection based on Landsat and Sentinel imagery (Potapov et al., 2022; Turubanova et al., 2023).

Japan Aerospace Exploration Agency (JAXA) also contributes to global land monitoring through its annual Forest/Non-Forest (FNF) maps derived from ALOS PALSAR and PALSAR-2 mosaics at 25-m spatial resolution, available from 2007 onwards (Shimada et al., 2014).

More recently, global land cover mapping has benefited from the increasing availability of Sentinel imagery. The Copernicus Global Land Service produced annual global land cover maps at 100-m spatial resolution for 2015–2019 (Buchhorn et al., 2020). ESA subsequently released the WorldCover products for 2020 and 2021 at 10-m spatial resolution based on Sentinel-1 and Sentinel-2 observations (Zanaga et al., 2021; Zanaga et al., 2022).

The integration of cloud computing and artificial intelligence has further advanced global LULC monitoring. Dynamic World provides near-real-time probabilistic land cover classifications at 10-m spatial resolution from Sentinel-2 imagery using deep learning techniques (Brown et al., 2022). Similarly, the Esri–Impact Observatory Global Land Cover product offers annual global maps at 10-m resolution from 2017 onwards, generated through deep-learning approaches applied to Sentinel-2 imagery (Karra et al., 2021).

Other global products have been produced using coarser spatial resolutions (>500 m) (e.g., Friedl et al., 2010), but are not discussed here because their spatial resolution limits their applicability for assessing and comparing MapBiomas products, which are generated at the 30-m Landsat pixel scale.

Despite significant advances in global LULC mapping, most global products either have limited thematic detail, shorter historical records, or lower classification accuracy at regional scales, highlighting the importance of national and regional initiatives such as MapBiomas for environmental monitoring and policy applications.

2.2.2. National Land Use and Land Cover Data

The RadamBrasil project was the first national initiative to map the vegetation of the entire Brazilian territory. The project was conducted from 1975 to 1980 and was based on airborne radar imagery, visual interpretation, and extensive and detailed fieldwork involving several organizations. The RadamBrasil project produced maps at a 1:250.000 scale (Projeto RADAMBRASIL 1979) , which is still a solid reference for scientific and technical studies about Brazilian vegetation.

After the RadamBrasil project, only the Amazon and Atlantic Forest biomes were being monitored using other systems, so the Minister of Environment launched the natural vegetation map of Brazil in 2004. This map was created as part of the Probio (Projeto de Conservação e Utilização Sustentável da Diversidade Biológica Brasileira) initiative. The Brazilian biome boundaries (IBGE, 2004a) were used as a reference for the national mapping initiative. The Probio project was based on Landsat imagery acquired in 2002, with a minimum mapping unit varying from 40 to 100 hectares and a cartographic scale of 1:250.000. The accuracy assessment was based on digital imagery products at a 1:100.000 scale, with a minimum overall accuracy of 85%. The land cover classes followed the IBGE manual for vegetation mapping (IBGE, 2004b). The Probio project updated forest change mapping for all biomes in the year 2008 and for specific biomes in the years 2009, 2010, and 2011.

In the context of the National Inventories of GHG Emissions and Removals, the Ministry of Science and Technology commissioned the production of land use and land cover maps of Brazil for the years 1994, 2002, 2010 (also 2005 for the Amazon), and 2016. Those maps were produced based on segmentation and visual interpretation of Landsat imagery, identifying the classes of natural vegetation (forest and non-forest), agriculture, pasture, silviculture, urban area, dunes, rock outcrops, mining, and water at the 1:250.000 cartographic scale.

More recently, IBGE published a platform to monitor LULC change in Brazil, making available maps for the years 2000, 2010, 2012, 2014, 2016, 2018 and 2020 on a 1-km resolution and featuring the classes of forests, savannas, agriculture, pasture, urban areas, water, and mosaics of those classes.

2.2.3. Regional and Biomes Land Use and Land Cover Data

There are also other reference LULC maps at the biome scale and through the cross-cutting themes. For example, the PRODES maps are available for all biomes (https://terrabrasilis.dpi.inpe.br/app/map/deforestation?hl=pt-br) and the TerraClass maps are available for Amazonia and Cerrado (https://www.terraclass.gov.br/). These reference LULC maps for the biomes and cross-cutting themes are cited in respective Appendices.

3. General Methodological Description

The general methodological steps of MapBiomas Brazil 10 m Collection 4 are presented in Figure 2. The first step was to generate annual Sentinel-2 mosaics comprising all images ("COPERNICUS/S2_SR_HARMONIZED") from each year to discriminate the LULC classes across biomes and cross-cutting themes. The second step was to derive all feature space attributes from the Sentinel-2 mosaics and bands from the Satellite Embedding dataset produced by AlphaEarth Foundations ("GOOGLE/SATELLITE_EMBEDDING/V1/ANNUAL") to train one random forest classifier (feature space definition) for each year (Breiman, 2001). Then, training samples were yearly acquired in each biome and cross-cutting theme according to its information availability and statistical needs.

The classification was carried out either using Random Forest, Gradient Tree Boosting or U-Net, depending on the biome or cross-cutting theme (Figure 2). In any case, the output is one LULC map per year for the entire territory based on the training dataset of that year. The Photovoltaic Power Plant class was based on the same input dataset used in MapBiomas 30 m Collection 11, but here resampled to a standardized 10-meter grid, instead of the 30-meter grid in the Collection 11. This dataset was generated using a deep learning-based approach that integrates high-resolution NICFI PlanetScope imagery, U-Net convolutional neural networks, and cloud-based processing in Google Earth Engine (GEE), combined with Google Colab (https://doi.org/10.58053/MapBiomas/DENOGU).

Spatial-temporal filters were applied over the classified data for noise removal and temporal stabilization. Subsequently, the filtered LULC maps of each biome and cross-cutting themes were hierarchically merged (integrated) based on a set of prevalence rules. A spatial filter was once again applied in the integrated LULC maps to create the final 10 m Collection 4 with a minimum mapping unit of 0.25 hectare, after temporal filters application to specifically adjust the temporal consistency of forest plantation and agriculture classes. For the other classes, another temporal filter was applied to eliminate isolated pixels in the time series. MapBiomas Alerta deforestation data was used as an accumulated mask, and when it overlapped with any natural class, it was converted to class 21 (Mosaic of Uses).

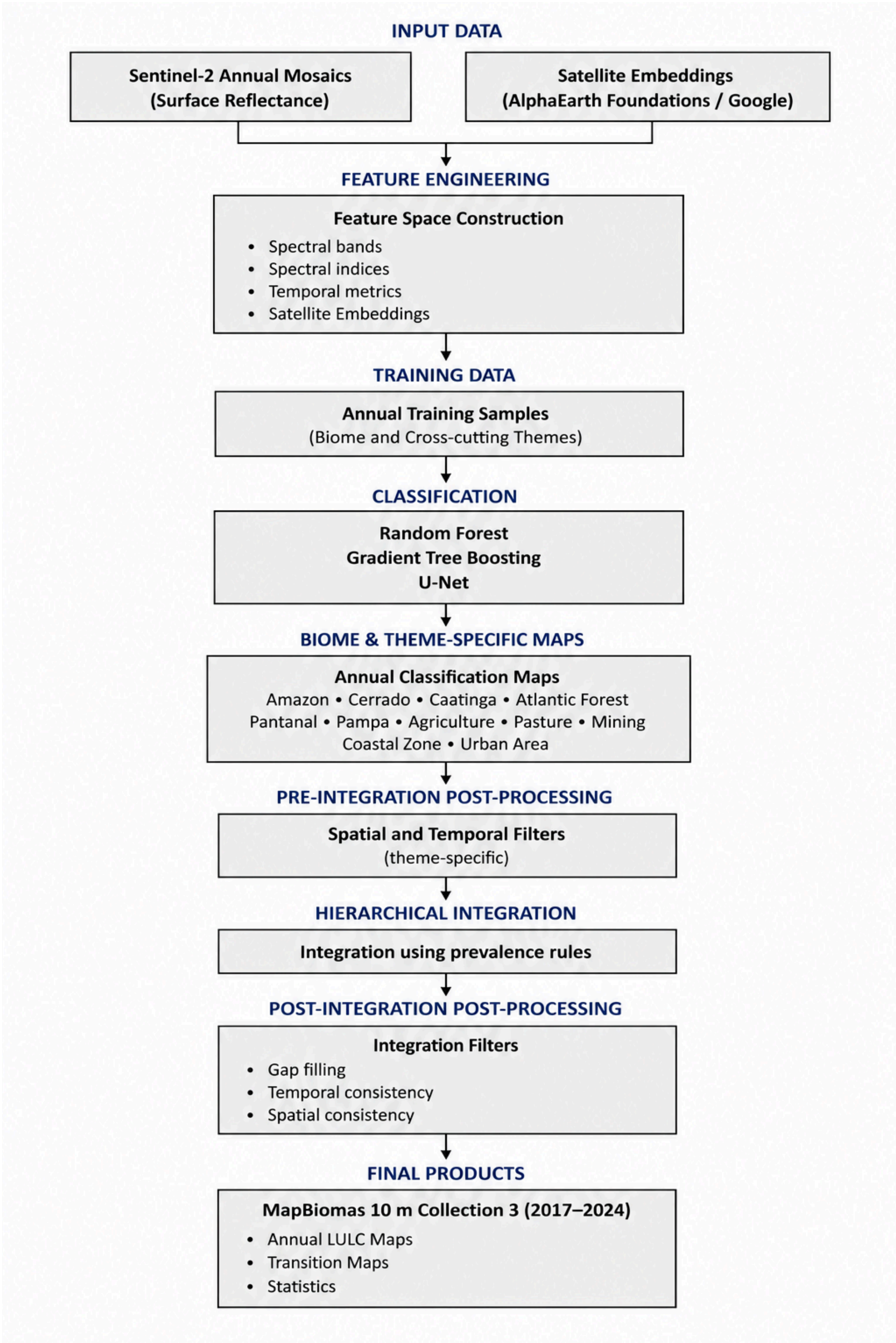

Figure 2. General methodological steps of MapBiomas Brazil 10 m Collection 4.

3.1. Sentinel-2 Mosaics

All biomes generated cloud-free Sentinel-2 composites based on specific time windows to optimize the spectral contrast and improve with the discrimination of LULC classes. Cloud and shadow removal was performed using the cloud probability band in combination with the GEE median reducer. The cloud probability layer helps identify pixels affected by clouds or related artifacts, improving data reliability. The median reducer selects the median pixel value from the image stack over time, effectively excluding extreme values such as very bright pixels (e.g., clouds) and very dark pixels (e.g., shadows), resulting in more stable and consistent mosaics.. In both Collection 2 and 3 of MapBiomas 10 m, harmonized Collection of Sentinel-2 Level 2A surface reflectance images were used as the primary input for classification. Collections 3 and 4 also included bands from the Satellite Embedding dataset produced by AlphaEarth Foundations ("GOOGLE/SATELLITE_EMBEDDING/V1/ANNUAL").

In Collection 2, the cross-cutting themes (Pasture, Agriculture, Urban Area, Coastal Zone, and Mining) processed Sentinel-2 mosaics per scene basis. To reduce noise and improve the mosaic quality, a tool was developed to evaluate the images individually, excluding uninformative images (excess cloud cover).

In Collections 3 and 4, all the biomes (Amazon, Cerrado, Caatinga, Atlantic Forest, Pampa, and Pantanal), used annual mosaics generated by MapBiomas and satellite embeddings as additional bands. Cross-cutting themes adopted different strategies depending on their characteristics. Agriculture used customized annual mosaics combined with embeddings, while Pasture relied on annual mosaics built from a 6-month temporal window (before and after the target year) with on-the-fly processing. Urban areas were mapped directly using embeddings. Coastal Zone and Mining used mosaics generated from 8-bit composites. For the Photovoltaic class, mosaics covering the full period from 2017 to 2025 were used to support detection in Collection 4.

3.2. MapBiomas feature space

The feature space for LULC classification is composed of original Sentinel-2 bands (blue, green, red, red edge 1, red edge 2, red edge 3, red edge 4, swir 1 and swir 2), reflectance index (NDVI, NDDI, NDWI, SAVI) per year and Satellite Embeddings from AlphaEarth Foundations/Google. In addition, statistical reducers were used to generate temporal features such as:

- Median: median of the pixel values within the defined stack of images
- Median_dry: median of the quartile of the lowest pixel NDVI values

- Median_wet: median of the quartile of the highest pixel NDVI values
- Amplitude: amplitude of variation of the index considering all the year's images
- stdDev: stdDev of the pixel values within the defined stack of images
- Min: the lower annual value of the pixels of each band
- Max: the higher annual value of the pixels of each band

Each biome and cross-cutting theme executed a feature selection algorithm to choose the most appropriate subset of variables to train the respective classifier (Random Forest, Gradient Tree Boost or U-NET).

3.3. Legend

The MapBiomas 10 m Collection 4 classification scheme is a hierarchical system comprising three categorical levels (Table 2). At Level 1, there are five classes: 1) Forest, 2) Herbaceous or shrubby vegetation, 3) Farming, 4) Non-Vegetated Area, and 5) Water. Level 2 has 25 classes across the five classes of the first categorical level. Agriculture (3.2) is the only class with further subdivisions down to the third categorical level, separating perennial and temporary crops. The Collection 4 of MapBiomas 10 m comprises 26 LULC classes.

Table 2. Classes of land use and land cover of MapBiomas 10 m Collection 4 in Brazil.

ID	COLLECTION 4 CLASSES	NATURAL/ ANTHROPIC	LAND COVER/ LAND USER	BIOMES/ THEMES
1	**1. Forest**	NATURAL	COVER	-
3	1.1. Forest Formation	NATURAL	COVER	BIOMES
6	1.2 Floodable Forest	NATURAL	COVER	BIOMES
4	1.3. Savanna Formation	NATURAL	COVER	BIOMES
7	1.4. Flooded Savanna (beta)	NATURAL	COVER	BIOMES
5	1.5. Mangrove	NATURAL	COVER	BIOMES
49	1.6. Wooded Sandbank Vegetation	NATURAL	COVER	BIOMES
10	**2. Herbaceous or shruby vegetation**	NATURAL	COVER	-
12	2.1. Grassland Formation	NATURAL	COVER	BIOMES
77	2.2. Herbaceous and Shrub Formation	NATURAL	COVER	BIOMES
11	2.3 Wetland	NATURAL	COVER	THEMES
84	2.4. Salt Marsh (beta)	NATURAL	COVER	BIOMES
50	2.5. Herbaceous Sandbank Vegetation	NATURAL	COVER	BIOMES
32	2.6. Hypersaline Tidal Flat	NATURAL	COVER	BIOMES
29	2.7. Rocky Outcrop	NATURAL	COVER	BIOMES
14	**3. Farming**	ANTHROPIC	USE	-
15	3.1. Pasture	ANTHROPIC	COVER/USE	THEMES
18	3.2. Agriculture	ANTHROPIC	USE	THEMES
19	3.2.1. Temporary Crop	ANTHROPIC	USE	THEMES
36	3.2.2. Perennial Crop	ANTHROPIC	USE	THEMES
9	3.3. Forest Plantation	ANTHROPIC	USE	THEMES
21	3.3. Mosaic of Uses	ANTHROPIC	USE	BIOMES
22	**4. Non Vegetated Area**	NATURAL/ ANTHROPIC	COVER/USE	-
23	4.1. Beach, Dune and Sand Spot	NATURAL	COVER	THEMES
24	4.2. Urban Area	ANTHROPIC	USE	THEMES
30	4.3. Mining	ANTHROPIC	USE	THEMES
75	4.4 Photovoltaic Power Plant	ANTHROPIC	USE	THEMES
91	4.5. Wind farm (beta)	ANTHROPIC	USE	THEMES
25	4.6. Other non Vegetated Areas	NATURAL/ ANTHROPIC	COVER/USE	BIOMES
26	**5. Water**	NATURAL/ ANTHROPIC	COVER/USE	-

33	5.1. River, Lake and Ocean	NATURAL	COVER	BIOMES
31	5.2. Aquaculture	ANTHROPIC	USE	THEMES
27	6. Not Observed	NONE	NONE	-

3.4. Classification

The classification procedures and post-integration filtering routines applied to each Brazilian biome and each cross-cutting theme in MapBiomas Collection 4 are documented in dedicated appendices, one per biome (Amazon, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal) and one per cross-cutting theme (e.g., Agriculture and Forest Plantation, Mining, Coastal Zone, Urban Areas, Pasture, Photovoltaic Solar Plants, Wind Farms).

4. Integration and Post-classification

4.1 Integration

The maps of each biome and of cross-cutting themes were integrated on a pixel-by-pixel basis through the hierarchical overlap of each mapped class, following prevalence rules defined by experts. Certain prevalence rules may show exceptions for one or more classes. Some classes present specific prevalence rules or exceptions in certain biomes or regions. The prevalence rules and its exceptions are listed in Annex II.

4.2. Filters on Integrated Maps

In the integrated maps eight spatial and temporal filters were applied as follows:

1) Spatial filter that removes areas smaller than 0.25 hectare using the mode of a 4-pixel kernel;

2) Temporal filter to complete the initial years of forestry;

3) General temporal filter with a 3- and 4-year window to remove temporal noise;

4) Specific temporal filter for Agriculture;

5) Specific temporal filter for Pasture;

6) Spatial filter using the MapBiomas Alerta polygons to replace areas mapped as natural classes with 21 - Land Use Mosaic (in the case of the Amazon and Pantanal, with 15 - Pasture);

7) Transition filter to avoid changes between natural and anthropogenic areas with fewer than 6 pixels each year;

8) Spatial filter to remove noise up to 0.25 hectares in a 4 pixel kernel, and the simple mode applied in a 1 pixel kernel.

4.3. Statistics

Zonal statistics of the mapped classes were calculated for different spatial units, such as the biomes, states, municipalities, watersheds, protected areas (including indigenous lands and conservation units) and can be found in https://brasil.mapbiomas.org/en/estatisticas/. Data on transitions between classes, number of classes and number of changes for each pixel and stable areas throughout the time series are also available in the MapBiomas Platform (https://plataforma.brasil.mapbiomas.org/).

5. Accuracy Assessment

5.1 Accuracy assessment overview

MapBiomas 10 m Collection 4 features a land cover and land use (LULC) map at 10 m spatial resolution, produced from Sentinel-2 surface-reflectance imagery combined with AlphaEarth Embeddings. Because area estimates and change analyses derived from such a map are only as trustworthy as the map itself, an independent accuracy assessment is an essential component of the product. This chapter documents that assessment: the sampling design, the response (reference-labelling) design, the analysis, and the preliminary results for the six Brazilian biomes.

The assessment follows the internationally accepted good-practice framework for estimating area and assessing the accuracy of land-cover maps (Olofsson et al., 2013, 2014). In line with that guidance, the map is evaluated with a probability sample stratified by map class, a reference classification of higher quality than the map, an error matrix expressed in terms of area proportions, and error-adjusted area estimates reported together with confidence intervals. Following Pontius and Millones (2011), the Kappa coefficient is not used; the assessment instead reports overall, user's and producer's accuracies, which have direct and unambiguous interpretations.

5.2 Sampling design

The reference sample uses a stratified random design in which the strata are defined by crossing the six Brazilian biomes (Amazônia, Caatinga, Cerrado, Mata Atlântica, Pampa and Pantanal) with the five Level-1 classes of the MapBiomas legend: Forest, Herbaceous & Shrubby Vegetation, Farming, Non-vegetated Area, and Water. Within each of the 30 strata, 50 sample units were allocated, giving a total of 1,500 reference points. Equal allocation per class ensures that even spatially rare classes (for example, Water or Non-vegetated area) are represented by enough units to estimate their accuracy reliably.

During preparation of the strata, edge pixels were removed by applying a 10 m internal buffer along every class boundary. This step keeps sample units inside spatially homogeneous patches and avoids assigning a single reference label to a mixed pixel that straddles two classes, which would otherwise inflate apparent error for reasons unrelated to the classifier. The mapped area of each stratum was tabulated so that the stratum weights required by the estimator — the share of the mapped landscape belonging to each map class within each biome — are known exactly.

5.3. Response design

Each of the 1,500 sample points was interpreted by an analyst and assigned a single Level-1 reference class. Interpretation relied on two complementary sources. First, the Sentinel-2 time series from 2017 to 2025 was inspected as an annual sequence of false-colour composites, which reveals the seasonal and inter-annual trajectory of the target and helps distinguish, for example, natural herbaceous vegetation from cropland. Second, recent high-resolution imagery from Google Earth was consulted to confirm the class label on the ground at fine spatial detail. The reference classification is therefore of substantially higher quality than the map being evaluated, as required by good practice.

The output of the response design is an error (confusion) matrix for each biome, cross-tabulating the map class against the reference class for the 250 points of that biome. These matrices are the raw material for all subsequent statistics.

5.4. Analysis

Because the sample is stratified by map class with unequal inclusion probabilities across strata, the sample counts are converted into estimated area proportions before any accuracy or area statistic is computed. Each cell of a biome's matrix is weighted by that stratum's mapped-area weight, following Equation 1 of Olofsson et al. (2014). From the resulting population matrix the analysis computes overall accuracy, user's accuracy (the complement of commission error) and producer's accuracy (the complement of omission error) for each class.

Mapped class areas are then adjusted for classification error. The error-adjusted area of a class is $\hat{A} = A \cdot \hat{p}$, where $\hat{p}$ is the estimated proportion of the reference landscape belonging to that class, and each estimate is accompanied by a 95% confidence interval obtained from the stratified variance estimator (Equations 9–11 of Olofsson et al., 2014). The national (Brazil-wide) figures are obtained by treating all 30 biome-by-class strata as a single stratified design: each stratum is weighted by its mapped area as a share of the national total, so the national overall accuracy is the area-weighted combination of the biome results rather than a simple average of them (Stehman, 2014).

5.5. Preliminary results

All six biomes have been assessed, yielding a national area-weighted overall accuracy of 91.8% (95% confidence interval 89.5–94.1%) over the approximately 851.5 million hectares mapped. Overall accuracy by biome ranges from 95.8% in the Pampa and 95.4% in the Amazônia to 85.0% in the Cerrado and 82.3% in the Pantanal (Figure 3). This gradient largely reflects landscape composition: biomes dominated by a single, spectrally distinct class (dense forest in the Amazônia, managed grassland and cropland in the Pampa) are mapped more accurately than the structurally heterogeneous, transitional landscapes of the Cerrado and Pantanal.

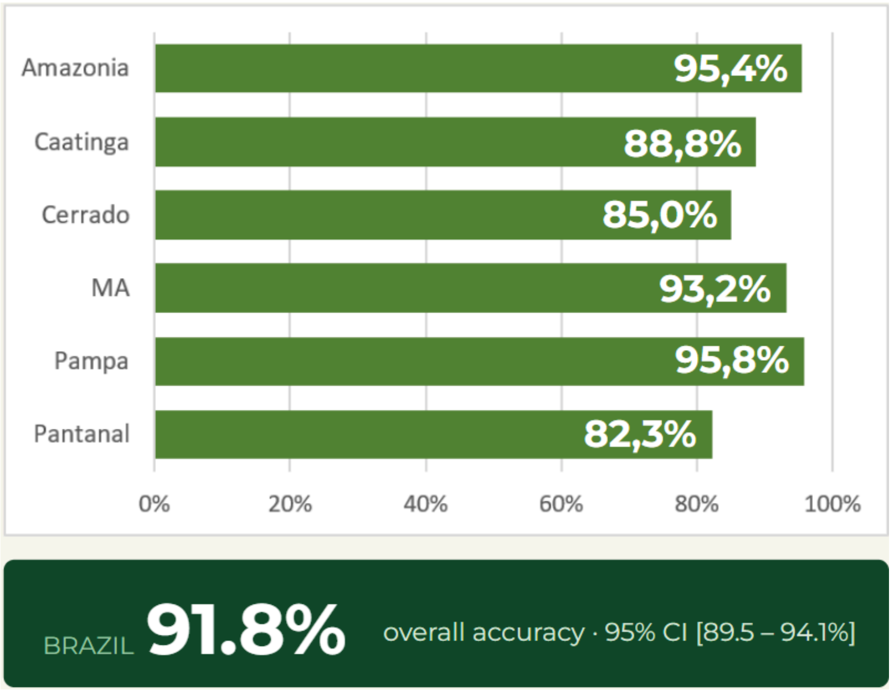

Figure 3. Overall accuracy of MapBiomas 10 m Collection 4 by biome, with the national area-weighted mean (dashed line) at 91.8%. The horizontal axis is truncated at 78% to separate the biomes.

The national confusion matrix (Figure 4) confirms that the two dominant classes, Forest and Farming, are classified reliably, with most sample units falling on the diagonal. The principal confusion occurs in the Herbaceous & Shrubby class, which is exchanged with both Forest and Farming — an expected difficulty in transitional savanna and grassland landscapes — and in the off-diagonal exchange between Non-vegetated area and Farming.

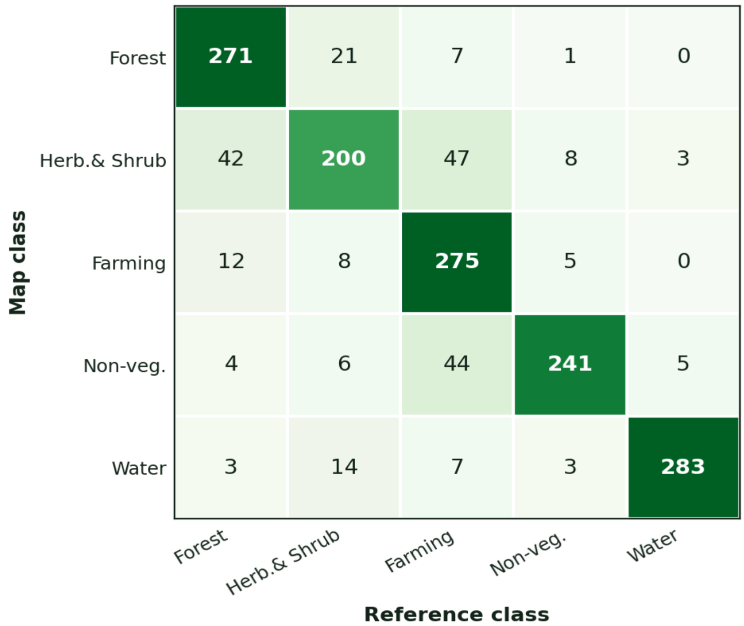

Figure 4. National confusion matrix of MapBiomas 10 m Collection 4 (1,500 reference points; sample counts). Rows are the map class, columns the reference class; diagonal cells are agreements. Colour intensity is scaled by row proportion.

Per-class accuracies and error-adjusted areas for Brazil are summarised in Table 3. Forest and Water are the strongest classes (user's and producer's accuracy at or above 94%), and their error-adjusted areas differ only marginally from the mapped values. The weakest classes are Herbaceous & Shrubby (71% user's, 65% producer's) and Non-vegetated area (79% user's but only 46% producer's, indicating substantial omission); these two classes also carry the widest confidence intervals and account for most of the difference between mapped and error-adjusted area (Figure 5).

Table 3. National per-class user's and producer's accuracy, error-adjusted area with 95% confidence interval, and mapped area.

Class	User's	Producer's	Adjusted area (ha)	95% CI (± ha)	Mapped (ha)
Forest	94%	95%	**490,348,066**	± 18,506,497	499,264,861
Herbaceous & Shrubby	71%	65%	**60,925,025**	± 11,162,620	55,854,303
Farming	93%	93%	**269,190,604**	± 17,066,287	270,260,362
Non-vegetated	79%	46%	**11,882,927**	± 5,474,224	6,971,127
Water	96%	96%	**19,140,326**	± 1,146,528	19,136,296

Class	User's	Producer's	Adjusted area (ha)	95% CI (± ha)	Mapped (ha)
Brazil (total)	**—**	**—**	**851,486,949**	**—**	**851,486,949**

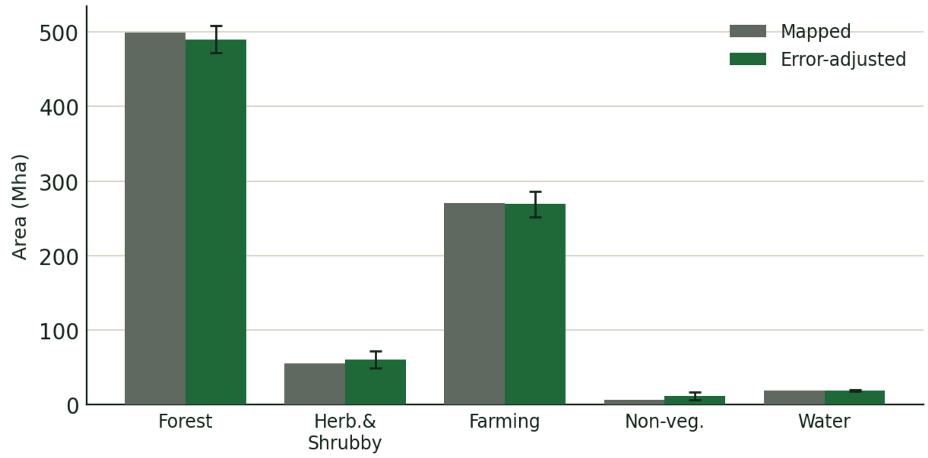

Figure 5. Mapped versus error-adjusted area by class at the national level (Mha). Error bars show the 95% confidence interval of the adjusted area.

5.6. Concluding remarks of accuracy assessment

At 91.8% national overall accuracy, the 10 m Collection 4 LULC map meets the expectations for an operational land-cover product, and its error-adjusted class areas remain close to the mapped areas for the dominant Forest and Farming classes. The assessment also localises where the map is weakest — the transitional Herbaceous & Shrubby and Non-vegetated classes, and the Cerrado and Pantanal biomes — which is precisely the information needed to prioritise future mapping improvements. A specific caveat is documented for the Pantanal: reference interpretation used the median annual mosaic rather than the maximum-inundation mosaic used in classification, so part of the apparent Water error reflects a difference in reference basis rather than a true map error; accounting for this raises the biome's overall accuracy from 82.3% to about 82.9%.

These results are preliminary and will be consolidated as interpretation is finalised. The confidence intervals reported here capture sampling variability only; they do not include interpreter or geolocation error, which good practice recommends evaluating separately.

6. Map Collections and Analysis

Aiming to provide data with higher spatial resolution than in the MapBiomas 30-m collections, in 2023 MapBiomas launched the first collection in beta version of the LULC annual maps of Brazil at 10 meters resolution using Sentinel-2 satellite images covering the period from 2016 to 2022 (period of availability of Sentinel) and 18 LULC classes, named as the initiative MapBiomas 10 m. This new dataset allowed the inclusion of more detailed information in the mapping, for example, in rural properties, urban areas infrastructures and riparian forest in Permanent Preservation Areas (APP) along rivers and springs.

The second collection (beta) of MapBiomas 10 m, launched in 2025, covered the period of 2016 to 2023 and 21 LULC classes, including three new classes: Floodable Forest in the Amazon, Aquaculture and Apicum (hypersaline tidal flat) in the Coastal Zone. This collection applied similar methods and the same legend of the LULC classes of the MapBiomas Collection 9 (up to the third level of the legend). Seeking to continually improve methods and update the collection, maps from 2016 to 2022 were reprocessed and the year 2023 was mapped with the same spatial resolution, which resulted in the MapBiomas 10 m Collection 2 (beta). The shorter time series (from 2016 to 2023) decreased the temporal consistency of the Sentinel-2 mapping compared to the longer time series of Landsat mapping.

The third collection (beta) of MapBiomas 10 m, launched in May 2026, covers the period from 2017 to 2024 and includes 22 LULC classes, with the addition of a new class: Photovoltaic Power Plant (beta). Unlike the two previous collections, this version does not include the year 2016, as the Satellite Embedding from AlphaEarth Foundations/Google is only available from 2017 onwards. These embeddings were used as additional bands to improve the classification. In addition, the platform provides LULC transition data and temporal analyses (e.g., number of classes, number of changes, and stable areas). In Pantanal, the class Mosaic of Uses (21) was included, defined as farming areas that may include abandoned pastures, early regeneration stages, and peri-urban smallholdings.

In the fourth Collection, launched in August 2026 and covering the period from 2017 to 2025, four new classes were mapped: Wind Farms (beta), Flooded Savanna (beta), and Herbaceous and Shrub Formation, and Salt Marsh (beta), totaling 26 classes. For the other classes, the same methods used for Collection 3 were generally applied, with specific changes regarding biomes that are described in the respective appendices. Table 1 summarizes the main characteristics and methodological evolution across the three MapBiomas 10 m collections.

Table 1: Overview of the MapBiomas 10m collections.

MapBiomas 10 m	Collection 1	Collection 2	Collection 3	Collection 4
Publication date	2023	April 2025	May 2026	August 2026
Time series	2016-2022	2016-2023	2017-2024	2017-2025
Number of classes	18	21	22	26
Main methods	Random Forest	Random Forest, U-net	Random Forest, U-net, Embeddings	Random Forest, U-net, Embeddings

7. Practical Considerations

The fourth collection of MapBiomas 10 m presents high resolution, updated and detailed information encompassing 26 classes of LULC in the Brazilian territory from 2017 to 2025. The shorter time series compared to the MapBiomas 30 m data represents a challenge for temporal consistency, which is being addressed through the use of temporal filters. The main steps of the methodology reproduces the solid technical expertise acquired during the 10 years of MapBiomas 30 m data production. Generating data using parameters, variables, and training samples specific to each biome and cross-cutting theme - defined by experts on the territory or mapped land-use class - results in a distinctive product with great potential for diverse applications.

Furthermore, the use of Satellite Embeddings from AlphaEarth Foundations/Google brought innovation and technological advances necessary to the continuous improvement of MapBiomas data. The methodology is fully replicable and all scripts are available in the MapBiomas GitHub repository (https://github.com/mapbiomas/brazil-all-initiatives). Validation against independent reference points is a gap that needs to be filled and will enable a detailed identification of the data's strengths and weaknesses.

8. Concluding Remarks and Perspectives

The algorithms developed for pre-processing and classifying Sentinel-2 imagery hold promise for expanding the possible applications of MapBiomas LULC maps. Thanks to Google Earth Engine and open source technology, it is possible to access and process large-scale satellite imagery datasets such as the one generated by the

MapBiomas project. The replication of this type of project is viable for other areas of the planet. The MapBiomas initiative has expanded to all South American countries and Indonesia. In addition, the MapBiomas team will keep improving the following collections in subsequent years. The open-access MapBiomas LULC dataset allowed several scientific publications in Brazil and abroad. Policymakers and stakeholders also use the dataset for public policies and decision-makers in the country.

9. References

Arino, O., Ramos Perez, J.J., Kalogirou, V., Bontemps, S., Defourny, P., & Van Bogaert, E. (2012). Global Land Cover Map for 2009 (GlobCover 2009). ESA Living Planet Symposium.

Breiman, L. Random forests. (2001). *Machine learning,* v. 45, n. 1, p. 5-32 .

Brown, C.F., Brumby, S.P., Guzder-Williams, B., et al. (2022). Dynamic World, Near Real-Time Global 10 m Land Use Land Cover Mapping. Scientific Data, 9, 251.

Buchhorn, M., Smets, B., Bertels, L., et al. (2020). Copernicus Global Land Service: Land Cover 100m Collection 3. Remote Sensing, 12, 1044.

Chen, J., Chen, J., Liao, A., et al. (2014). Global land cover mapping at 30 m resolution: A POK-based operational approach. ISPRS Journal of Photogrammetry and Remote Sensing, 103, 7–27.

Chen, J., Ban, Y., & Li, S. (2017). China: Open access to Earth land-cover map. Nature, 514, 434.

Defourny, P., Bontemps, S., Lamarche, C., et al. (2017). Land Cover CCI Product User Guide Version 2. ESA Climate Change Initiative.

Friedl, M.A., Sulla-Menashe, D., Tan, B., et al. (2010). MODIS Collection 5 global land cover: Algorithm refinements and characterization of new datasets. Remote Sensing of Environment, 114, 168–182.

Gong, P., Wang, J., Yu, L., et al. (2013). Finer Resolution Observation and Monitoring of Global Land Cover: First Mapping Results with Landsat TM and ETM+ Data. International Journal of Remote Sensing, 34, 2607–2654.

Gong, P., Liu, H., Zhang, M., et al. (2019). Stable classification with limited sample: Transferring a 30-m resolution sample set collected in 2015 to mapping 10-m resolution global land cover in 2017. Science Bulletin, 64, 370–373.

Hansen, M.C., DeFries, R.S., Townshend, J.R.G., & Sohlberg, R. (2000). Global land cover classification at 1 km resolution using a decision tree classifier. International Journal of Remote Sensing, 21, 1331–1364.

Hansen, M.C., Potapov, P.V., Moore, R., et al. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. Science, 342, 850–853.

IBGE. *Mapa de biomas do Brasil (escala 1:5.000.000).* Rio de Janeiro: IBGE. Mapa e nota técnica. 2004a.

IBGE. *Mapa de biomas do Brasil (escala 1:5.000.000).* Rio de Janeiro: IBGE, 2004b.

Karra, K., Kontgis, C., Statman-Weil, Z., et al. (2021). Global land use / land cover with Sentinel-2 and deep learning. IGARSS 2021 Proceedings.

Olofsson, P., Foody, G. M., Herold, M., Stehman, S. V., Woodcock, C. E., & Wulder, M. A. (2014). Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment, 148, 42–57.

Olofsson, P., Foody, G. M., Stehman, S. V., & Woodcock, C. E. (2013). Making better use of accuracy data in land change studies: Estimating accuracy and area and quantifying uncertainty using stratified estimation. Remote Sensing of Environment, 129, 122–131.

Pontius, R. G., Jr., & Millones, M. (2011). Death to Kappa: Birth of quantity disagreement and allocation disagreement for accuracy assessment. International Journal of Remote Sensing, 32(15), 4407–4429.

Potapov, P., Turubanova, S., Hansen, M.C., et al. (2022). Global maps of cropland extent and land cover using Landsat and Sentinel imagery. Remote Sensing of Environment, 281, 113236.

Projeto RADAMBRASIL. (1979). Comissão Executora do Projeto Radambrasil: informações básicas 1. Rio de Janeiro: Departamento Nacional da Produção Mineral, 1979. 48 p. In: IBGE. Desbravar, conhecer, mapear: Memórias do Projeto Radam / RadamBrasil / IBGE, Gerência de Biblioteca e Acervos Especiais. - Rio de Janeiro: IBGE

Shimada, M., Itoh, T., Motooka, T., et al. (2014). New global forest/non-forest maps from ALOS PALSAR data (2007–2010). Remote Sensing of Environment, 155, 13–31.

Souza, C.M., Jr.; Z. Shimbo, J.; Rosa, M. R.; Parente, L. L.; Alencar, A.; Rudorff, B. F. T.; Hasenack, H.; Matsumoto, M.; G. Ferreira, L.; Souza-Filho, P. W. M.; De Oliveira, S. W.; Rocha, W. F.; Fonseca, A. V.; Marques, C. B.; Diniz, C. G.; Costa, D.; Monteiro, D.; Rosa, E. R.; Vélez-Martin, E.; Weber, E. J.; Lenti, F. E. B.; Paternost, F. F.; Pareyn, F. G. C.; Siqueira, J. V.; Viera, J. L.; Neto, L. C. F.; Saraiva, M. M.; Sales, M. H.; Salgado, M. P. G.; Vasconcelos, R.; Galano, S.; Mesquita, V. V.; Azevedo, T. (2020) Reconstructing Three

Decades of Land Use and Land Cover Changes in Brazilian Biomes with Landsat Archive and Earth Engine. *Remote Sensing,* v. 12, 2735. https://doi.org/10.3390/rs12172735.

Stehman, S. V. (2014). Estimating area and map accuracy for stratified random sampling when the strata are different from the map classes. International Journal of Remote Sensing, 35(13), 4923–4939.

Sulla-Menashe, D., & Friedl, M.A. (2018). User Guide to Collection 6 MODIS Land Cover (MCD12Q1).

Turubanova, S., Potapov, P., Tyukavina, A., et al. (2023). Ongoing advances in global land-cover and land-change monitoring from the GLAD laboratory. Remote Sensing, 15, 2784.

Tyukavina, A., Stehman, S. V., Pickens, A. H., Potapov, P., & Hansen, M. C. (2025). Practical global sampling methods for estimating area and map accuracy of land cover and change. Remote Sensing of Environment, 324, 114714.

Zanaga, D., Van De Kerchove, R., Daems, D., et al. (2021). ESA WorldCover 10 m 2020 Product User Manual.

Zanaga, D., Van De Kerchove, R., De Keersmaecker, W., et al. (2022). ESA WorldCover 10 m 2021 Product Validation Report.

APPENDICES

Appendix 1 - Amazon biome

Appendix 2 - Atlantic Forest biome

Appendix 3 - Caatinga biome

Appendix 4 - Cerrado biome

Appendix 5 - Pampa biome

Appendix 6 - Pantanal biome

Appendix 7 - Agriculture and Forest Plantation

Appendix 8 - Pasture

Appendix 9 - Coastal Zone

Appendix 10 - Mining

Appendix 11 - Urban Area

Appendix 12 - Infrastructure layers (Transportation, Energy and Mining)

Appendix 13 - Deforestation and Secondary Vegetation

Appendix 14 - Accuracy Assessment

Appendix 15 - Photovoltaic Power Plant

Appendix 16 - Agriculture Module

ANNEXES

Annex I: MapBiomas Network

MapBiomas is an initiative of the Climate Observatory, involving a collaborative network of NGOs, universities and technology companies organized by biomes and cross-cutting themes.

Biomes Coordination:

- Amazon – Institute of People and Environment of the Amazon (IMAZON)
- Caatinga – State University of Feira de Santana (UEFS), Northeast Plants Association (APNE), and Geodatin
- Cerrado – Amazon Environmental Research Institute (IPAM)
- Atlantic Forest – Foundation SOS Atlantic Forest and ArcPlan
- Pampa – Federal University of Rio Grande do Sul (UFRGS) and GeoKarten
- Pantanal – Institute SOS Pantanal and ArcPlan

Cross-cutting Themes Coordination:

- Pasture – Federal University of Goias (LAPIG/UFG)
- Agriculture – Agrosatelite until collection 8. Remap in collection 9.
- Coastal Zone and Mining – Vale Technological Institute (ITV) and Solved
- Urban Area – USP University of São Paulo (Quapá-FAU and FFLCH/Geography) and Federal University of São Carlos (UFSCar - NEEPC).

Technology Partners:

- Google
- EcoStage
- Geodatin
- Ecode

Financing:

- Amazon Fund
- Arapyaú Institute
- Children's Investment Fund Foundation (CIFF)
- Climate and Land Use Alliance (CLUA)
- Good Energies Foundation
- Gordon & Betty Moore Foundation
- Humanize Institute
- Institute for Climate and Society (iCS)
- Montpelier Foundation
- Mulago Foundation
- Norway's International Climate and Forest Initiative (NICFI)
- Global Wildlife Conservation (GWC)
- OAK Foundation
- Quadrature Climate Foundation (QCF)
- Sequoia Foundation
- Skoll Foundation
- Walmart Foundation
- Woods & Wayside International

Institutional Partners:

- Arapyaú Institute
- MapBiomas Support Institute (IAMap)
- WRI Brasil
- AVINA Foundation

General Coordination: Tasso Azevedo (SEEG/OC)

Technical Coordination: Marcos Rosa (ArcPlan)

Scientific Coordination: Julia Shimbo (IPAM)

The project counts on an Independent Committee of Scientific Advice composed by renowned specialists:

- Dr. Edson Eygi Sano (IBAMA)
- Dra. Leila Maria Garcia Fonseca (INPE)
- Dra. Liana Oighenstein Anderson (CEMADEN)
- Dra. Marina Hirota (Federal University of Santa Catarina)

Former members:

- Dr. Gilberto Camara Neto (INPE)
- Dr. Joberto Veloso de Freitas (Federal University of Amazonas)
- Dr. Matthew C. Hansen (Maryland University)
- Dr. Mercedes Bustamante (University of Brasília)
- Dr. Timothy Boucher (TNC)
- Dr. Robert Gilmore Pontius Jr (Clark University)
- Dr. Alexandre Camargo Coutinho (Embrapa)
- Dr. Gerd Sparovek (University of São Paulo)

Technical Partners:

- Institute of Agricultural and Forest Management and Certification - Imaflora (IMAFLORA)
- Energy and Environment Institute (IEMA)
- Socioambiental Institute (ISA)
- Institute for Democracy and Sustainability (IDS)
- The Nature Conservancy (TNC)
- Life Center Institute (ICV)
- WWF Brasil
- Brasil I.O

Annex II: Prevalence rules

MapBiomas 10 m Collection 4 prevalence rules, given by the “Prevalence ID” (from the most to the less prevalent class), used for integrating biomes and cross-cutting themes maps. Since some classes were mapped both as cross-cutting themes and in the biomes, the “Source” column indicates the source of information for that specific rule. “Exceptions” are classes that are prevalent over the listed one in that region.

CLASS ID	CLASS NAME	SOURCE	PREVALENCE ID	EXCEPTION
75	4.4 Photovoltaic Solar Plant	Photovoltaic Solar Plant	1	
30	4.3. Mining	Mining	2	In São Paulo and Mato Grosso states, the cross-cutting class 24 is prevalent
23	4.1. Beach, Dune, and Sand Spot	Coastal Zone	3	
23	4.1. Beach, Dune, and Sand Spot	Biomes	4	
5	1.3. Mangrove	Coastal Zone	5	
31	5.2. Aquaculture	Coastal Zone	6	
32	2.3. Hypersaline Tidal Flat	Coastal Zone	7	
24	4.2. Urban Area	Urban Area	8	
9	3.3. Forest Plantation	Agriculture	9	At Lagoa dos Peixes (Pampa), the classes 3, 11, 12, 29, 33, 49, 50 are prevalent
9	3.3. Forest Plantation	Biomes	10	
29	2.4. Rocky Outcrop	Biomes	11	
20	3.2.1. Temporary crop	Agriculture	12	Where both biomes and MapBiomas Water indicates class 33, class 33 is prevalent
50	2.5. Herbaceous Sandbank Vegetation	Biomes	13	
25	4.4. Other Non Vegetated Areas	Biomes	14	

33	5.1. River, Lake and Ocean	Water	15	
33	5.1. River, Lake and Ocean	Biomes	16	
3	1.1. Forest Formation	Biomes	17	
4	1.2. Savanna Formation	Biomes	18	Outside protected areas in Cerrado the class 15 is prevalent
49	1.5. Wooded Sandbank Vegetation	Biomes	19	
6	1.4. Floodable Forest	Biomes	20	
11	2.1 Wetland	Biomes	21	Outside protected areas in Cerrado the class 15 is prevalent
12	2.2. Grassland Formation	Biomes	22	Outside protected areas in Cerrado the class 15 is prevalent
15	3.1. Pasture	Pasture	23	In Pampa, the Pasture class (19) is converted to class 21 (Mosaic of uses). Outside protected areas in Cerrado Pasture are prevalent in Savanna, Wetland and Grassland classes (4, 11, 12). In Pantanal, agriculture (19 and 41) mapped by the biome stays as agriculture.
21	3.4. Mosaic of Uses	Biomes	24	
36	3.2.2. Perennial crop	Agriculture	25	
25	4.4 Other non vegetated areas	Biomes	26	