MAPBIOMAS
ECUADOR

Land Cover and Land Use

Flooded forests - Transversal Map

Algorithm Theoretical Basis Document (ATBD)

Collection 4.0

Version 1.0

October 2026

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How to cite
W. Holguín, K. Terán, F. Garcés, C. Cabrera & S. Cevallos. (2026). Algorithm Theoretical Basis Document (ATBD) MapBiomas Ecuador - flooded forests Transversal Theme, Collection 4.0, Ecuador Appendix.

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1. Introduction

The mapping of flood cover, especially flooded forests, in the Amazon region is one of the great challenges at MapBiomas Ecuador. The first advance in this challenge was achieved in previous collections of Amazonia, concentrating efforts, as a pilot area, in the Peruvian territory and using the tools available to the team in those editions.

The algorithms developed for the annual classification of flood zones in MapBiomas Ecuador (1985-2025) incorporated specific work areas and the use of national reference maps, which makes this issue a cross-cutting aspect within the project.

This approach takes advantage of the Landsat tiles generated for the General Map of the 4.0 Collection, using the same parameters of image periods, sensors, cloud cover, and exclusion of annual scenes. However, bands related to the Tasseled Cap index were added in its three components: *Brightness, Greenness, and Wetness*. Of all the available variables, the most representative were selected for each class. In total, a set of 26 variables (including Landsat bands, spectral indices, and topographic variables, with median and 25th percentile reducers) was used to train the Random Forest classifier.

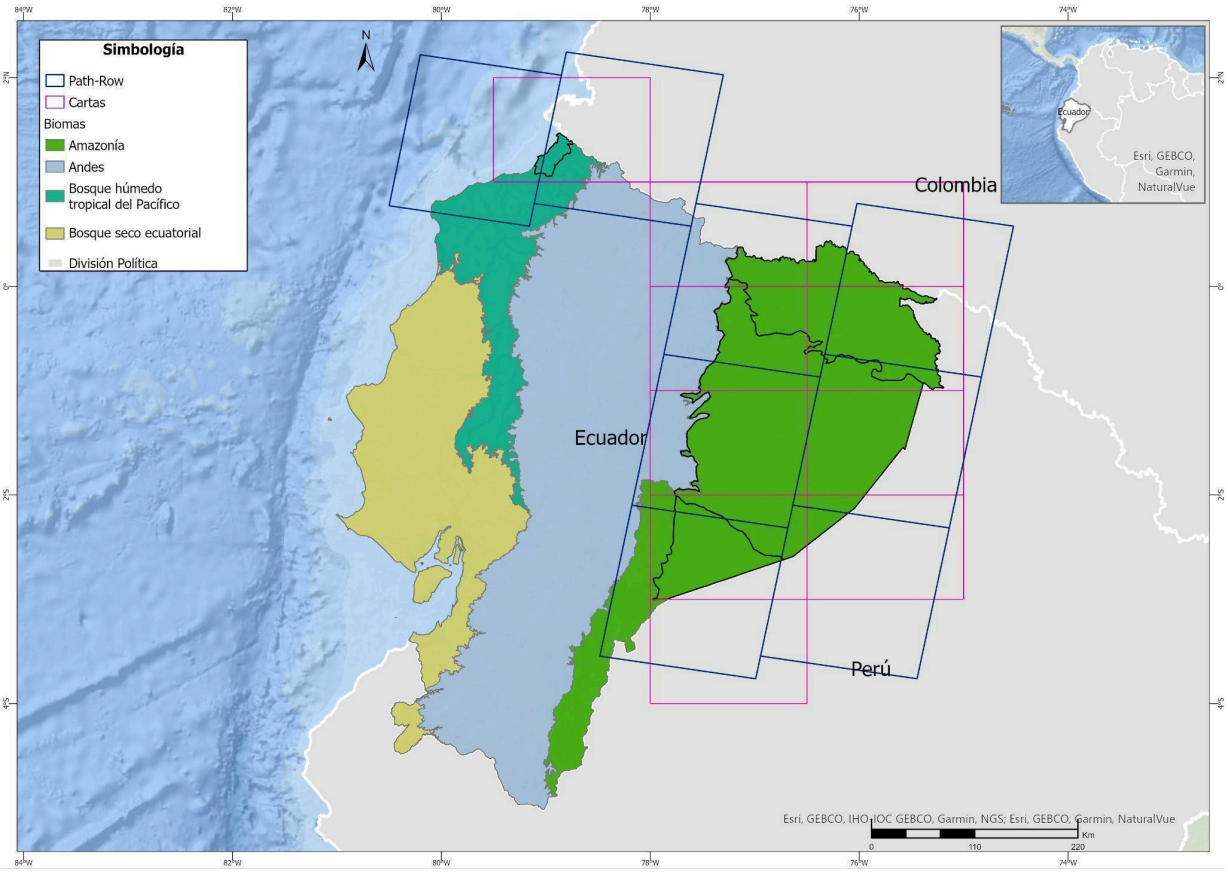

***Figure 1**. Study area.*

The entire process was structured in three main stages: (I) definition and construction of the satellite mosaics, (II) classification of the mosaics and (III) application of post-classification filters. Each of these stages included several steps, such as the collection of reference data, the definition of sampling areas and the performance of preliminary test classifications. The detailed outline of the classification process is presented in Figure 2.

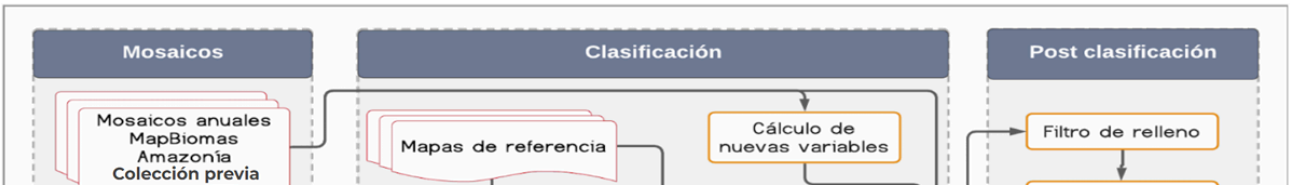

Figure 2. *Methodological diagram for the identification of flood covers.*

2 Definition and construction of satellite mosaics

The mosaics used to identify flood cover are the same ones generated for the general map of the MapBiomas Ecuador 4.0 Collection. As detailed in the General ATBD, the mosaics are constructed from the Landsat imagery available in the Google Earth Engine collections for the study area, using the world's millionth charts as a unit of work (Figure 1). The best quality scenes that cover the largest possible area per chart are selected and the *Cfmask and CloudScore* algorithms are applied for cloud and shadow masking.

Each mosaic is formed with 151 bands (detailed in the General ATBD) that include, in addition to the satellite's own bands, derived spectral indices that use the following aggregation methods[1]:

- Median (_median): Median per pixel of the images corresponding to the optimal mapping period defined for each year[2].
- Median dry season (_dry): Median per pixel of images located in the 25% percentile per year of NDVI.
- Median wet season (_wet): Median per pixel of images located in the 75% percentile per year of NDVI.
- Amplitude (_amp): Annual amplitude per pixel.

[1] These aggregation methods were applied to the chart-selected Landsat imagery and all spectral indices derived from them.

[2] Each country evaluated and defined an optimal period of the year taking as criteria: 1) the availability or coverage of data, 2) the spectral contrast between classes and 3) the phenological characteristics of the vegetation cover at different times of the year. This period was applied to calculate the bands that used the "median" reducer, while for the other bands that used other reducers, the totality of images available in the calendar year was considered.

- Standard deviation (_stdDev): Annual standard deviation per pixel.
- Minimum (_min): Annual minimum per pixel.
- Maximum (_max): Yearly minimum per pixel.

The selection of scenes and construction of the final tiles is carried out using the following parameters as a reference, stored as metadata in each asset constructed:

- ID: Unique identifier for the region.
- Year: Year (1985 to 2025) to which the mosaic corresponds.
- Letter: Letter ID
- Start and end date: Dates used for the selection of images from the collections available in Google Earth Engine.
- Sensor: Sensor identifier (L5: Landsat 5 TM, L7: Landsat 7 ETM+, L8: Landsat 8 OLI, L9: Landsat 9 and LX: Combination of scenes from Landsat 5 and Landsat 7.)
- Cloud Cover: Maximum allowable percentage of cloud cover. Scenes that exceed that percentage were excluded from tile creation.
- Blacklist: List of scenes considered to be of poor quality, which are excluded from the construction of the mosaic.

All generated tiles are stored as a Google Earth Engine imagery collection.

2.1. Definition of flood zones

From the mosaics or charts generated for each country, in this case for Ecuador, those that correspond to the flood zones are selected. To do this, vector layers from various sources are used in order to establish the limit of the floodable areas that will be classified (see Table 1, Figure 3). All the tiles or charts located within these areas are used to generate the classifications, while those outside of them are excluded from processing.

Table 1. Reference layers used for the project. Source: Own elaboration

Reference	Source
Global Wetlands Map Produced by the Sustainable Wetland Mitigation and Adaptation Programme (SWAMP)	CIFOR, USAID and CGIAR - FTA https://www2.cifor.org/global-wetlands/
Global wetland map from surface water imagery and groundwater limitations.	A. Tootchi, Anne Jost, and Agnès Ducharne. 2018 https://doi.pangaea.de/10.1594/PANGAEA.892657?format=html#download
Terrestrial Ecosystems (WWF)	https://www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world
Remote sensing of the distribution and extent of wetlands in the Amazon basin. Amazonian floodplain forests. Springer	Melack JM, Hess LL; 2010. pp. 43–59
A classification of major naturally-occurring amazonian lowland wetlands. Wetlands.	Junk WJ, Piedade MTF, Schöngart J, Cohn-Haft M, Adeney JM, Wittmann F 2011; 31: 623–640.
AR Flooded Wetlands and Vegetation, Amazon Basin: 1995–1996. ORNL Distributed Active Archive Center	Hess LL, Melack JM, Novo EMLM, Barbosa CCF, Gastil M. LBA-ECO LC-07 JERS-1 S; 2015.
Land cover in the Colombian Amazon. Scale 1:100,000. Year: 2012, 2014, 2016, 2018. Melack JM, Hess LL; 2010. pp. 43–59	http://geoservicios.ideam.gov.co/geonetwork/srv/spa/catalog.search; jsessionid=97B6F80606F3D7E735B92FA7456F174E#/metadata/285c4d0a-6924-42c6-b4d4-6aef2c1aceb5

Ecosystem Map Biophysical modeling, interpretation of satellite images (2010-2012) and field validation.	MAAE, 2012 (https://www.ambiente.gob.ec/wp-content/uploads/downloads/2012/09/LEYENDA-ECOSISTEMAS_ECUADOR_2.pdf)

Source: Own elaboration

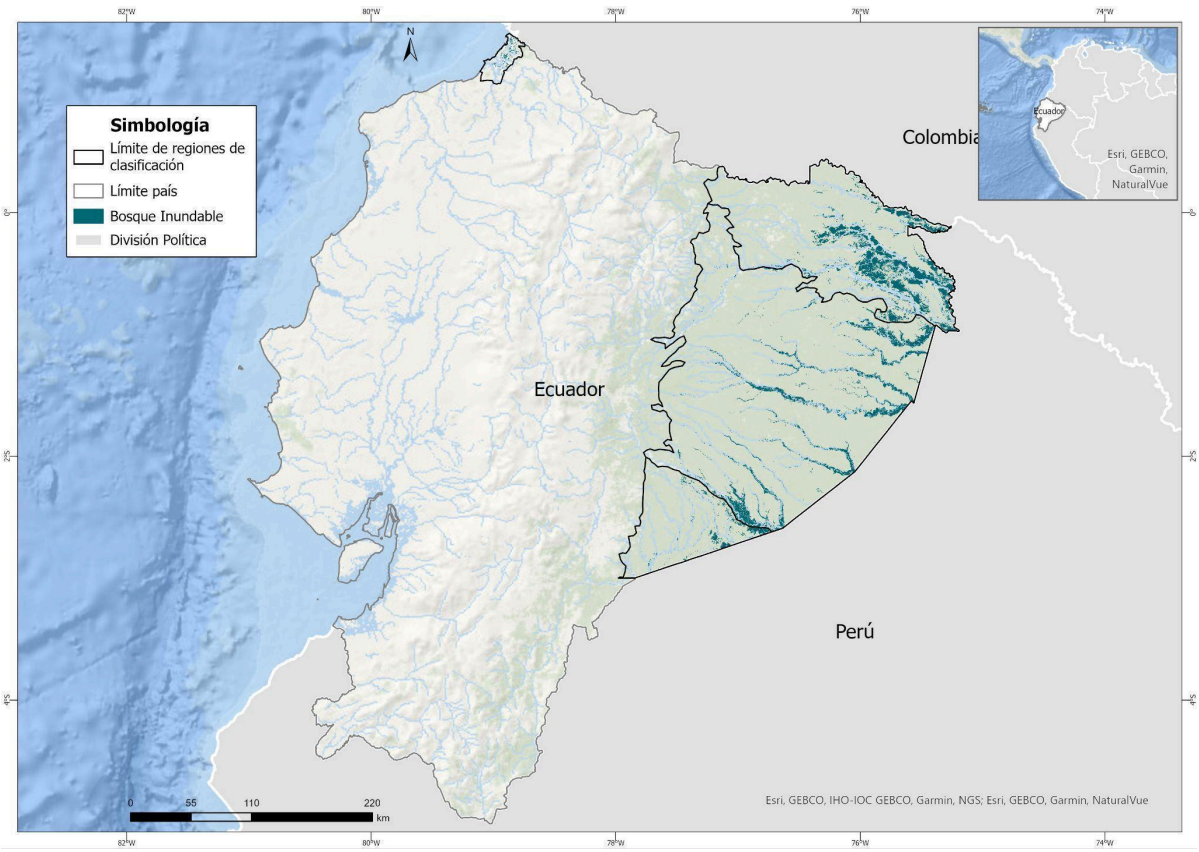

Figure 3. *Delimitation of classification regions based on reference maps.*

2.2. Selection of classification variables

From the regional mosaics generated, preliminary classification tests are carried out to reduce the number of variables necessary for the final classification. Based on the results of these tests, the Tasseled Cap spectral indicators (T-cap brightness, T-cap greenness and T-cap wetness) are included in the classification process, as well as the topographic bands (altitude, slope, slppost) derived from the SRTM elevation model. These additional data are useful for detecting different phenological stages and vegetation types. In total, 26 variables are used to implement the classification, the details of which are presented in Table 2.

Table 2. Variables for the classification of flood cover in Collection 4.0, MapBiomas Ecuador

Band	Description	Reducer
blue	Blue band value	Medium
Green	Green band value	Medium
Network	Red Band Value	Medium
nir	Near-infrared (NIR) band value	Medium
SWIR1	SWIR1 Band Value	Medium
Swir2	SWIR2 Band Value	Medium

NDFI	Normalized Difference Fraction Index	Medium
Ndfib	Adaptation of the NDFI for the Andes	Medium
Good game.	Fractional abundance of green vegetation	Medium
GVS	Shade-normalized green vegetation	Median, 25% drier percentile
NPV	Fractional abundance of non-photosynthetic vegetation	Medium
Shade	Fractional abundance of shade within	Median
evi2	Modification of the Improved Vegetation Index (EVI)	Median, 25% drier percentile
NDVI	Normalized Difference Vegetation Index	Median, 25% drier percentile
ndwi_gao	Normalized Difference Water Index (GAO)	Median, 25% drier percentile
ndwi_mcfeeters	Normalized difference water index (mcfeeters)	Medium
Mndwi	Normalized difference water index	Medium
Savi	Soil-adjusted vegetation index	Median, 25% drier percentile
Sefi	Savannah Ecosystem Fraction Index	Median, 25% drier percentile
Matchmaking rating	Modular Mangrove Recognition Index	Medium
T-cap brightness*	Tasseled Cap that adjusts brightness values on the floor	
T-cap greenness	Tasseled Cap that adjusts greenness values in vegetation	
T-cap wetness	Tasseled Cap that adjusts humidity values	
slope	Pending	
SLPpost	Stratified Slope	
altitude	Altitude	

Source: Authors, 2026

*Kauth, R. J. and Thomas, G. S. (1976) developed coefficients that enhance the information contained in the spectral bands (Landsat) and generated formulas they referred to as "Tasseled Cap" (TC), represented in three bands: Brightness is associated with variations in soil reflectance, Greeness is correlated with vegetation vigor, and Wetness is influenced by bands in the mean IR and has to do with plant and soil moisture

3 Classification

From the selected mosaics or charts (see previous section of this manual), a supervised classification is carried out based on the Random Forests algorithm (Breiman 2001). The processing is carried out entirely on the Google Earth Engine platform, and the results are stored as a collection of images on the same platform. The detection of cover focuses on the identification of two main classes present in the flood zones of the region: 1) Floodable forest and 2) Natural non-forest formation (savannah) floodable. The classification process is carried out separately for both covers, considering only two possible classes in each case: the class of interest (flooded forest or non-forest flooded formation) and the Not Observed class (everything that does not correspond to the class of interest).

3.1. Identified classes

3.1.1 Flooded forest (ID 6)

In this paper, flooded forest is defined as any continuous area of predominantly natural tree cover, greater than half a hectare (approximately more than 6 Landsat pixels or 0.5 ha), which is seasonally or permanently flooded. This definition is based on national bibliographic references (Instituto Sinchi, 2009; Wittmann et al., 2002; Ministry of Environment of Ecuador, 2012; MINAM, 2019, among others).

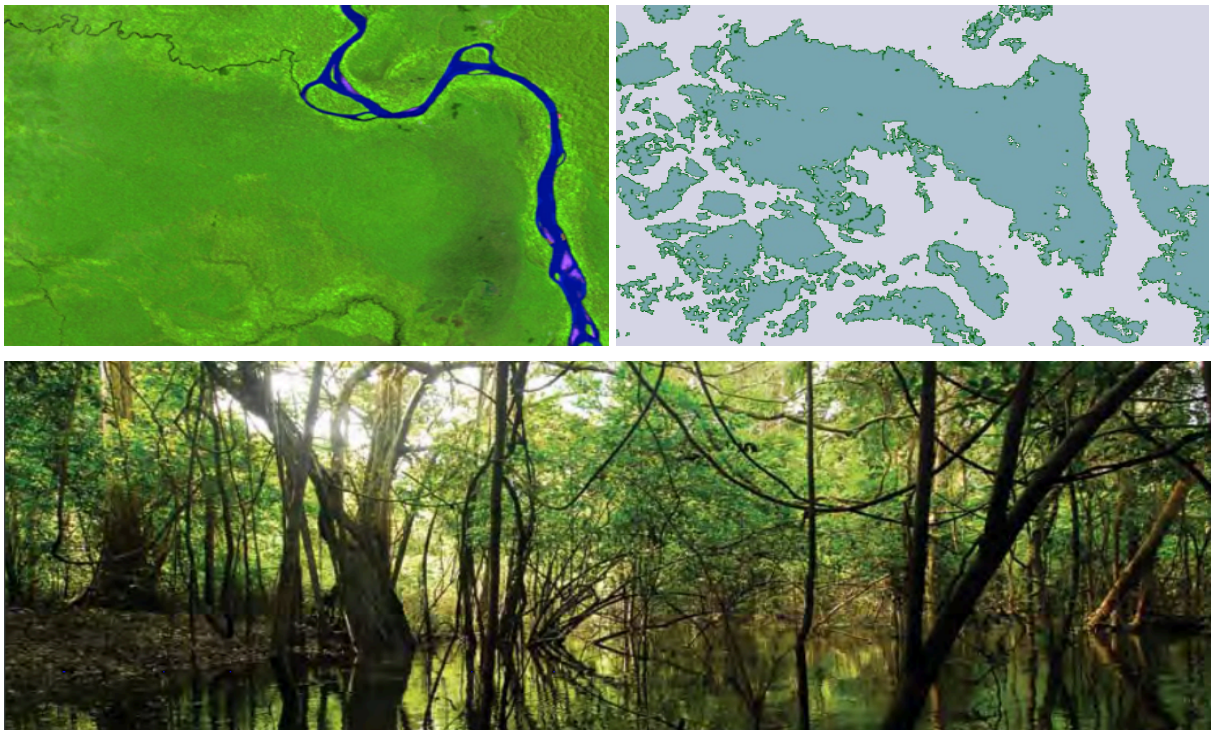

Figure 4. *Reference images for the Flooded Forest class. Top left: Landsat tile (RGB), Top right: Cover classification (Flooded Forest legend, Areas without flooded forest). Bottom: landscape photograph.*

3.1.2 Non-forest floodable natural formation (ID 11)

The natural non-forest floodable formation classified in this project includes all areas of natural herbaceous or shrubby vegetation that are subject to periodic or permanent flooding. For this definition, sources such as the Sinchi Institute (2009), Wittmann et al. (2002), Ministry of Environment of Ecuador (2012), MINAM (2019), among others, are taken into account.

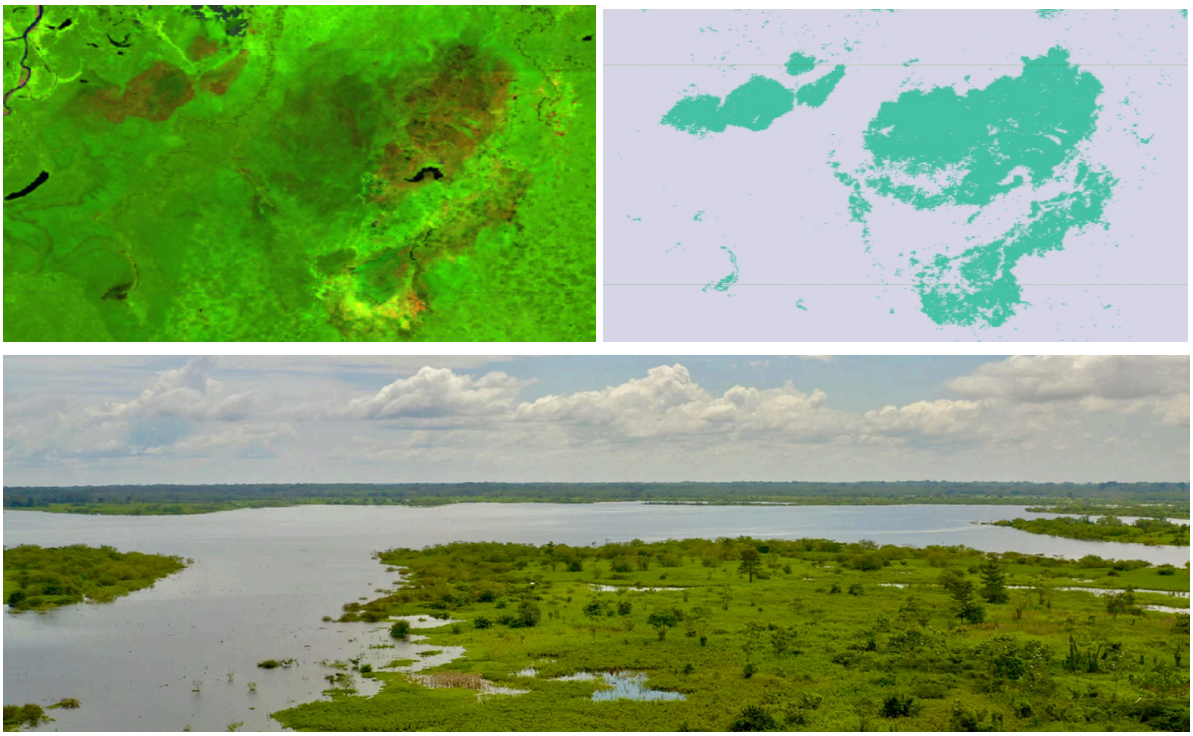

Figure 5. *Reference images for the flooded forest class. Top left: Landsat mosaic (RGB), Top right: cover classification (Legend Floodable forest a) floodable, Areas without non-floodable formations). Bottom: landscape photograph.*

3.2 Training Samples

The training samples used for the classification were generated on the area of intersection between the stable pixel layer of collection 6 MapBiomas Amazonia (1985 - 2025) and the flood cover reference maps (Table 2a and 2b). Stable pixels are defined as those whose coverage class is repeated in all the years of the series covered by collection 6.

Table 2a. Floodplain Forest Reference Maps

Reference	Bolivia	Colombia	Ecuador	Guyanas	Peru	Come
Accumulated Flooded col3	Yes	Yes	Yes	Yes	Yes	Yes
Stable Flooded col3	Yes	Yes	Yes	no	Yes	no
Cifor-2017	Yes	Yes	Yes	Yes	no	no
WCS_100m	Yes	Yes	Yes	no	no	no
Tootch i- 2017	Yes	no	no	no	no	no
Global Flood Plain 250M-2019	no	Yes	Yes	Yes	Yes	no
National reference	no	Yes	Yes	no	Yes	no

Table 2b. Reference maps of non-forest formation in wetlands

Reference	Bolivia	Colombia	Ecuador	Guyanas	Peru	Come
Accumulated Flooded col3	**Yes**	**no**	**Yes**	**Yes**	**Yes**	Yes
Stable Flooded col3	Yes	no	Yes	no	no	Yes
Cifor-2017	no	no	Yes	no	no	no
WCS_100m	no	no	no	no	no	no
Tootch i- 2017	no	no	Yes	no	no	no
Global Flood Plain 250M-2019	no	no	no	no	no	no
National reference	no	Yes	Yes	Yes	Yes	no

In the case of Ecuador, the stable pixels of the floodable covers are selected from the classes of Collection 6 of Amazonia, shown in Table 3. The pixels corresponding to the "non-floodable" areas are generated from the intersection between the reference maps of each country and the stable pixel layer of the rest of the covers. In addition, a function is implemented to exclude or include sample areas based on geometries, in order to avoid errors derived from inconsistencies in the reference layers.

Table 3. Coverage of the 6 MapBiomas Amazonia collection used to obtain the image of stable pixels for flood zones. Source: own elaboration

Country	Collection 6 Cover Lines (IDs) Used to Identify Flooded Forests	Collection 6 Covers (IDs) Used to Identify Non-Forest Floodable Formations
Ecuador	3	13

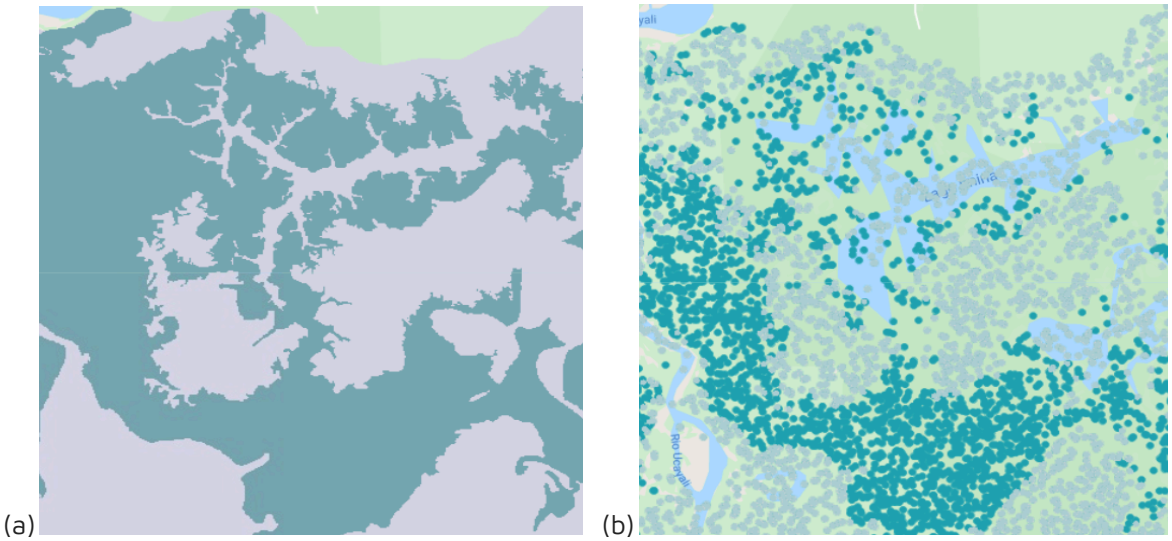

Figure 6. *Training samples (b) randomly drawn for floodable (light blue) and non-floodable (gray) coverage, based on the reference map (a).*

4 Post-classification

Due to the pixel-based nature of the classification method and the work over an extensive time series, a series of post-classification filters are applied. This process includes the application of fill, temporal, spatial, and frequency filters

4.1 Filling information gaps

The sequence of filters begins with filling in information gaps. In a large time series of regions severely affected by clouds, it is common for gaps to occur in the median result. This filter replaces those gaps with the closest temporal classification (see Figure 7). If a value is not available in the previous year, the space is filled with the value of the following year. Therefore, gaps should only exist if a pixel has been permanently classified as "no information" throughout the entire time series.

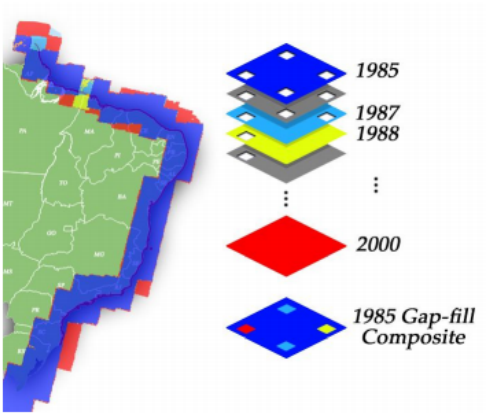

Figure 7. *Example of the mechanism of action of the void-fill filter.*

4.2 Time Filter

After gap filling, a temporal filter is applied. This filter uses sequential classifications in a one-way sliding window of 3, 4, or 5 years to identify temporally inconsistent transitions. Based on general rules (GR), applied to all intermediate years in the series (1986-2024); first-year (PR) rules, applied to 1985; and last-year (RU) rules, applied to 2025, the temporary filter inspects the year of interest and classifies the central pixel according to the criteria set out in Table 4

Table 4. Rules for applying the temporal filter and results.

	Entry sequence					**Output sequence**				
	T-2	**T-1**	**S0**	**T+1**	**T+2**	**T-2**	**T-1**	**S0**	**T+1**	**T+2**
RG		Bi/Fi	No	Bi/Fi			Bi/Fi	Bi/Fi	Bi/Fi	
	Bi/Fi	No	No	Bi/Fi	Bi/Fi	Bi/Fi	No	Bi/Fi	Bi/Fi	Bi/Fi
RP			No	Bi/Fi	Bi/Fi			Bi/Fi	Bi/Fi	Bi/Fi
UK	Bi/Fi	Bi/Fi	No			Bi/Fi	Bi/Fi	Bi/Fi		

Source: Authors.

Where RG is a general rule, applied to all intermediate years (1986 - 2024); RP is a first-year rule, applied only to the year 1985; and RU is a last-year rule, applied to the year 2025. T0 is the year on which the filter is applied, T-n the previous years, and T+n, the following years. Bi: Floodable forest. Fi: Non-forest floodable natural formation, No: Not observed.

4.3 Frequency filter

Another filter available in the sequence is the frequency filter. As shown in Figure 9, this filter considers the occurrence of the class throughout the time series to optimize the classification result.

On the one hand, this filter contributes to completing the classifications in areas covered by clouds that the temporary filter fails to recover. Since the class "Non-forest natural floodable formation" is characterized by a high humidity dynamics over time (increase and reduction of the flooded area), an 80% filter is applied to this class. That is, the information gaps are filled as long as the class maintains a temporal persistence of 29 years or more. As for the "Floodable forest", the value applied is more flexible (60%), since this coverage is more stable over time and was well detected in most regions.

On the other hand, the filter is also adjusted to identify temporary noises and poor classifications. In contrast to the values used in the previous function, in this case all pixels of "Non-forest floodable natural formation" that do not exceed 20% frequency in the time series are excluded from the classification. For the classification of "Floodable forest", pixels with a frequency of less than 40% are removed.

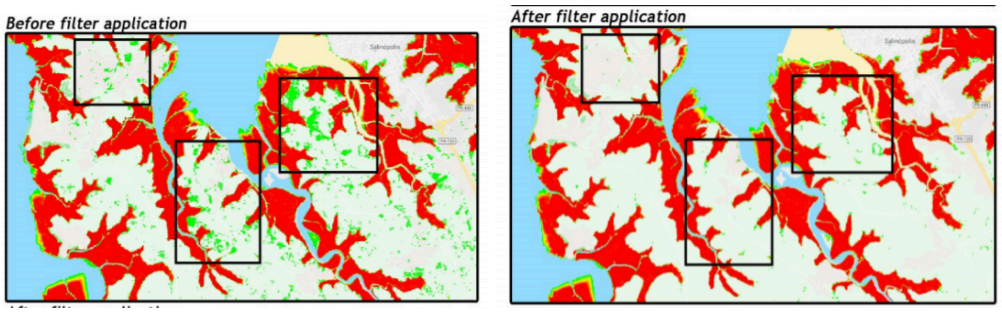

Figure 8. *Effect of Frequency Filter Application*

Note: Areas in green do not comply with the applied frequency rules, therefore they are eliminated from the classification; meanwhile, areas in red do meet the frequency criterion so they remain in the classification

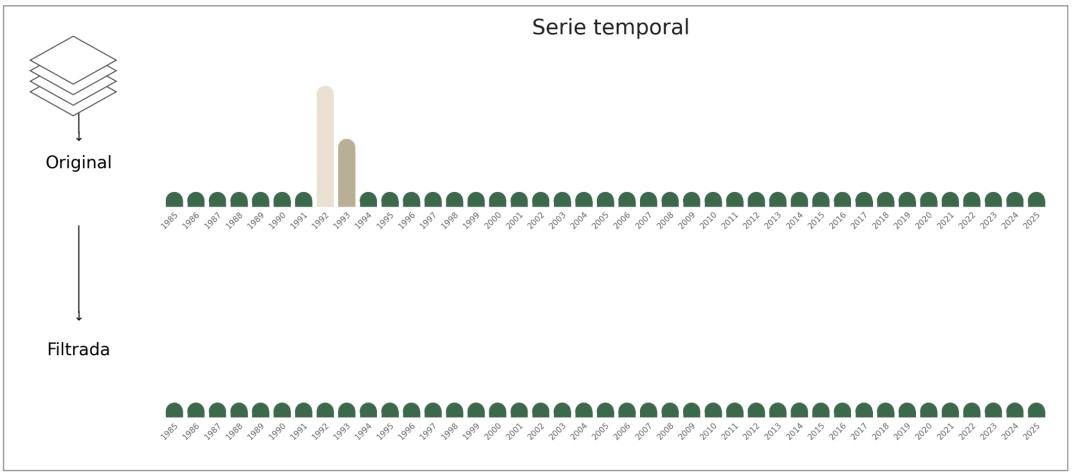

Figure 9. *Effect of the application of the frequency filter. Source: MapBiomas Collection 4, 2026.*

4.4 Spatial Filter

The spatial filter is based on the "connectedPixelCount" function, which identifies the set of pixels (neighborhood) that share the same value. Thus, only pixels that are not connected, according to a predefined minimum number of identical pixels, are defined as isolated and reclassified pixels (see Figure 10). For both classes, the minimum connection established is 6 pixels, which is approximately equivalent to 0.5 hectares.

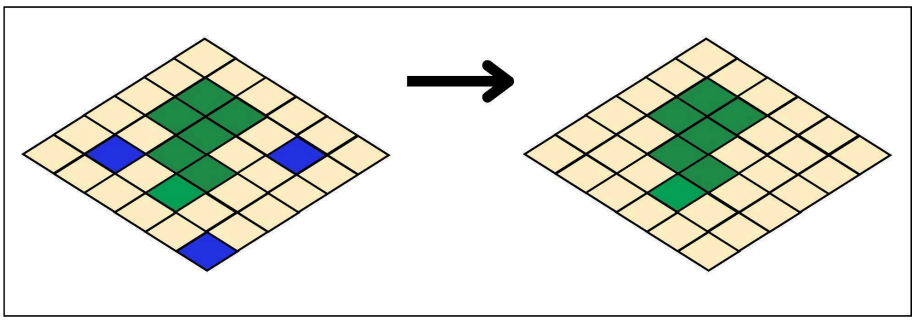

Figure 10. *Effect of the application of the spatial filter.*

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