

SUPPLEMENTARY MATERIALS

Filters applied in MapBiomass Uruguay Collection 2

Gap-filling filter (GAP)

In some cases, the absence of information in individual pixels or small pixel clusters — due to satellite errors or persistent cloud cover — leads to missing data, resulting in gaps in the final map. To address this issue, a gap-filling filter was applied to complete or fill in missing or “no data” pixels. These pixels were replaced using the closest available classification along the temporal sequence. For example, if data were missing for the 2020 map, the corresponding pixel was filled using the classification from 2021. If no future reference year was available, the pixel was assigned the most recent valid class from previous years. The only situation in which a pixel would remain unclassified is if it consistently lacked data across the entire study period (1985–2023), which is considered highly unlikely.

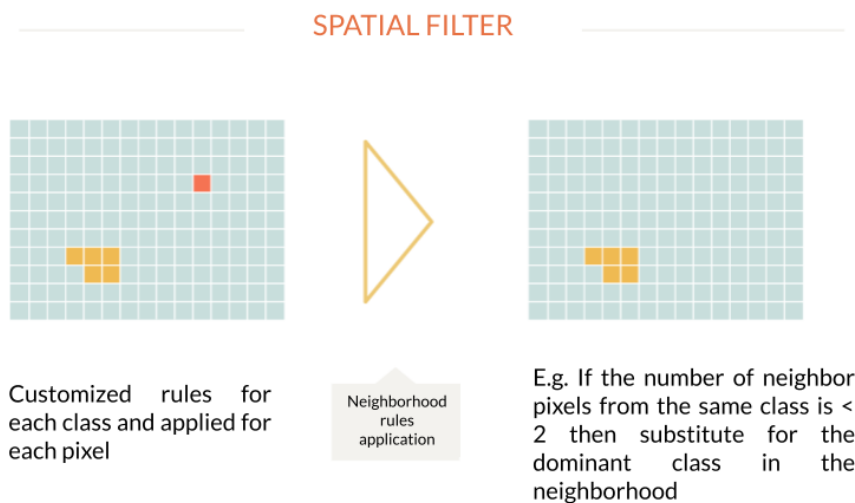
Spatial filter

A spatial filter was applied to reduce the “salt-and-pepper” effect commonly observed in pixel-level classifications (Figure 1). This step is essential for removing isolated pixels likely resulting from classification errors. A focal mode filter was used, applying a 3x3 pixel neighbourhood (1-pixel radius) with a square kernel. This filter replaces the value of each pixel with the most frequent category (i.e., the mode) within its neighbourhood.

To avoid altering large homogeneous areas and preserve the spatial coherence of classes, a mask based on the Google Earth Engine (GEE) `connectedPixelCount` function was used. This function identifies contiguous pixels that share the same value. Only pixels belonging to clusters of six or fewer pixels (~0.5 ha) were selected, under the assumption that such clusters represent classification noise. Finally, the original classification image was merged with the filtered image, such that only pixels within the mask were modified. This procedure was repeated for all years in the time series (1985–2023), generating a new multiband image where each band represents a year with the corrected classification.

Figure 1. Generic example of the spatial filter to eliminate the salt and peppers effect.

Figura 1. Ejemplo genérico del filtro espacial para eliminar el efecto sal y pimienta.

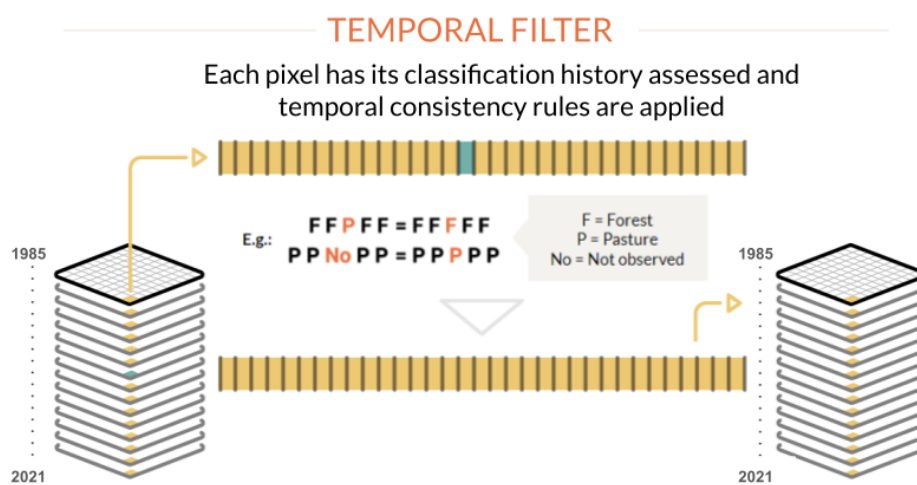


Temporal filter

This filter is applied to improve the temporal consistency of the classifications (Figure 2). Specifically, it allows for correcting inconsistencies in the time series based on a three-year temporal window. Within this period, the filter evaluates the value of each pixel in a given year and compares it with the values from the previous and following years. If the pixel value in the intermediate year differs from those of the adjacent years, it is replaced by the predominant category of the latter, ensuring greater temporal coherence in the classification. For the first year of the series (1985), the analysis is conducted considering the following two years (1986 and 1987), while for the final year of the series (2023), the evaluation is based on the two preceding years (2022 and 2021).

Figure 2. Generic example of the temporal filter using a temporal window of 3 years.

Figura 2. Ejemplo genérico del filtro temporal usando una ventana temporal de 3 años.



Frequency and specific filters

These filters were implemented to eliminate classification errors that persisted after applying the standard filters described previously (spatial and temporal). They operate based on two main parameters: frequency and incidence. Frequency is defined as the number of years in which a specific class appears in the same pixel, while incidence corresponds to the number of times a pixel's classification changes throughout the entire analysed time series.

These filters were applied exclusively to correct errors in certain specific classes (for example, confusion between Native woody vegetation and Forest plantation). The frequency filter works by identifying, for each pixel, a specific combination of classes over 38 years, in order to define a subset of pixels eligible for correction. It then detects and overwrites only those years where false positives occur, using a fixed class value or the mode of the time series, depending on the case.

As an example, a concrete application of this approach is the frequency filter applied in the Sierras del Este region for pixels classified as Native woody vegetation within areas of Forest plantation. This is a clear case of confusion between two classes belonging to the same plant functional type and with a very high spectral similarity. In this case, pixels were selected where the combined frequency of Native woody vegetation, Forest plantation, and grasslands exceeded 90% over the time series. Within this mask, only pixels classified as Forest plantation for more than 15% of the time and as grassland for at least 1% were selected. The rationale behind this correction is that, in most cases, Forest plantation areas originally corresponded to

grasslands in the early years of the time series. Therefore, if a pixel was alternately classified as grassland, Forest plantation, and in some years as Native woody vegetation, the forest classification is likely erroneous. This is because Native woody vegetation in Uruguay tends to maintain significant temporal stability and does not usually transition to Forest plantation in the same way as grasslands do.

Another example of frequency filter application is the correction of classification errors between Swampy areas/flooded vegetation and agriculture (Annual crops) in the Graben de la Laguna Merín region, specifically in areas where agricultural activity caused confusion in classifying Swampy areas/flooded vegetation. In this case, pixels were identified where the combined frequency of Swampy areas/flooded vegetation, grasslands, and Annual crops exceeded 90% over time, and which also exhibited a high incidence of class changes (more than six changes in the time series). Within this mask, pixels where the Annual crop class exceeded 80% of the time were selected. These pixels were reclassified as Annual crop, assigning a fixed class value to ensure temporal consistency. The logic behind this correction lies in the relative stability of the Swampy areas/flooded vegetation class compared to agricultural activity. If a pixel has been alternately classified as wetland and agriculture with a high frequency of changes, the wetland classification is likely incorrect.

Finally, an additional filter was used to mitigate issues arising from shadows cast by mountainous terrain. These filters incorporate topographic features alongside frequency, aiming to correct false positives in the classification of water bodies and Swampy areas/flooded vegetation on shaded slopes within regions of undulating relief. For this purpose, the filter selects all pixels classified as water for at least one year but fewer than 37 years (<95%), or as Swampy areas/flooded vegetation for at least one year but fewer than 35 years (<90%), provided these pixels are located in cliff and slope areas. Identification of these areas was performed by combining slope data, derived from the SRTM elevation model, with the HAND (Height Above Nearest Drainage) database, enabling the definition of zones where the presence of water or wetlands is not expected. In these cases, both classes were replaced by the modal class of the pixel.