MAPBIOMAS
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Appendix

Loss of Vegetation and Secondary Vegetation

Collection 1

Version 1

Document adjusted and translated from the original: ATBD Brazil

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1. Overview

This document describes the methodology applied to generate the annual maps of vegetation and secondary vegetation loss, produced using the annual land cover/use maps (LULC) provided by MapBiomas Ecuador Collection 3 (Methodology of the Annual Maps of land cover and use Ecuador). A time series of the dynamics of the natural vegetation cover of the entire Ecuadorian territory covering the period 2001-2024 was produced, through the identification of patterns of classification trajectories at the pixel level.

2. Methodology

Previous adjustments were made before proceeding with the process of obtaining the vegetation loss and secondary vegetation data. With the purpose of reducing temporal inconsistencies and reducing noise from the classifications of the annual land cover and use maps. The following filter was applied to the final result of these maps. To do this, tools implemented in Google's Earth Engine platform were used:

Post-integration Temporal Filter

The temporal filter inspects the value of each classified pixel in relation to the value of that pixel in consecutive temporal classifications. To do this, it uses a one-way moving window that takes into account sequences of classifications (a 3-year sequence was used for this process) and identifies temporary transitions that are not allowed. The temporal filter is applied to each pixel of all years in the collection.

2.1 Input Data: Vegetation Loss and Secondary Vegetation

The main objective of this method is to identify natural vegetation loss and regeneration events after a period of land use, regardless of the specific vegetation/land use classes in question. Therefore, the 21 classes of the original legend of the MapBiomas Ecuador dataset were grouped into three generic groups: Anthropic, Natural and Not Included (Table 1). The time series (1999 - 2024) was used as input data for the trajectory analysis algorithm described in the next section of this paper.

Table 1 - Diagram of the grouping of the classes of the annual time series LULC of MapBiomas Ecuador Collection 3.

Added Class	Original Classes Included	Raster Value
Anthropic	Silviculture, Mosaic of uses, Urban infrastructure, Mining, Other Anthropic Non-Vegetated Areas, Aquaculture, Banana.	1
Natural	Forest, Open forest, Mangrove, Flooded forest, Non forest wetland, other non-forest natural formation, Grassland, Andean herbaceous and shrubby Vegetation,Flooded Andean Herbaceous.	2
No included	Beach, Dune or Sand Spot, River, Lake or Ocean, Glacier, Rocky Outcrop, Other Natural Non-Vegetated Area	7

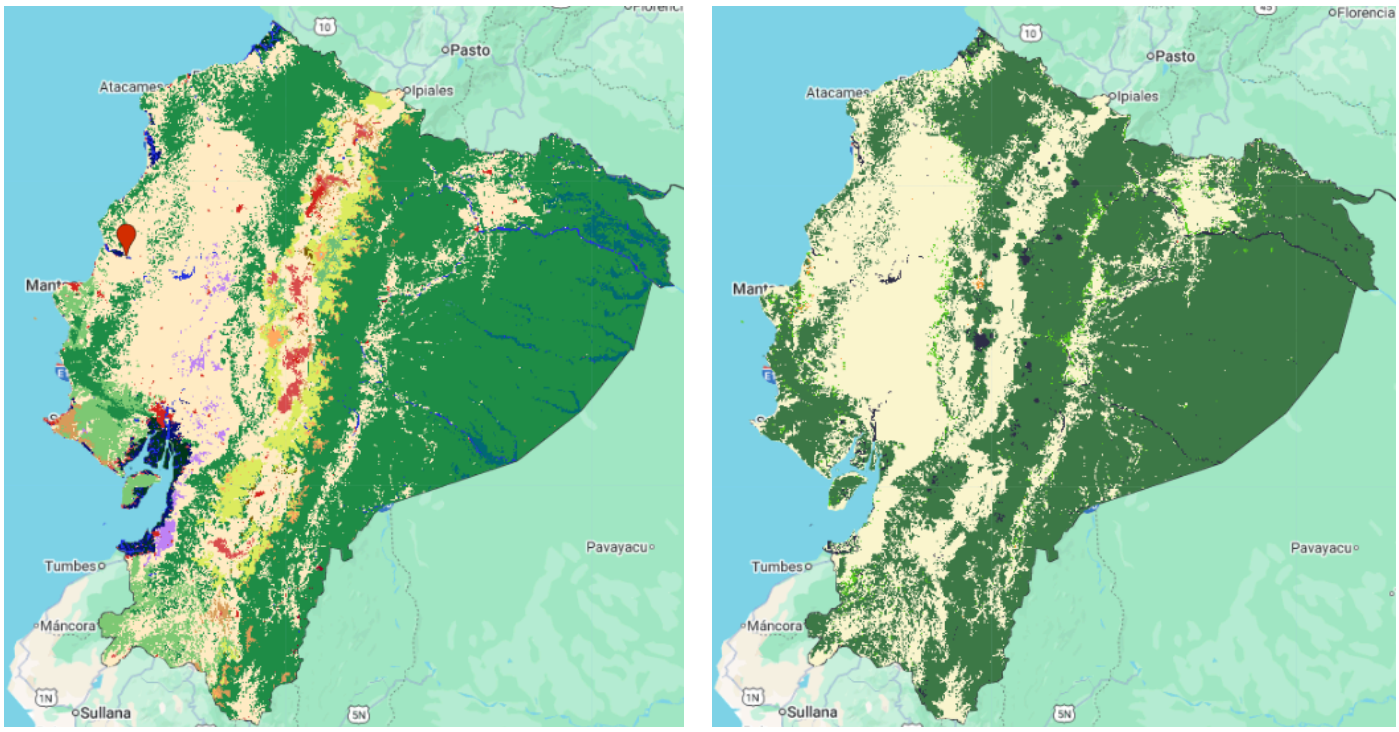


Figure 1. Overview map comparison in mainland Ecuador vs grouped classes

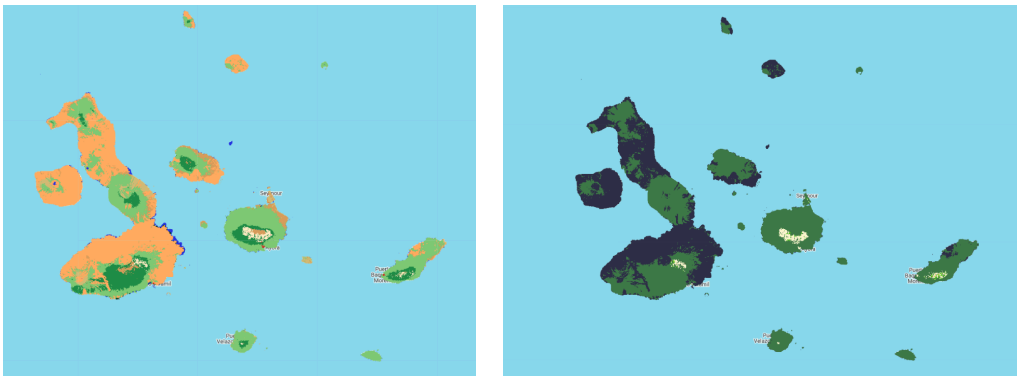


Figure 2. Overview Map Comparison in Galapagos vs Grouped Classes

2.2 Classification trajectory analysis

The analysis of the classification path per pixel was performed within a moving time window while persistence criteria are applied to differentiate between noisy class transitions (e.g., temporal alternations caused by mixed pixels Xie et al., 2020) from transitions consistent with secondary vegetation loss and growth events. For the annual map, the algorithm identifies pixels where there has been a change from the previous year, and then checks to see if the ranking was persistent before and after the transition. The period that a pixel must present a constant classification before and after a class change to be mapped as loss or secondary vegetation, persistence criteria were used.

Changes in input that matched the defined criteria were classified in the respective category of vegetation/secondary vegetation loss. The result has five classes (primary vegetation, secondary vegetation, primary vegetation loss, secondary vegetation loss, and secondary vegetation recovery), in addition to the original three classes of the input data. In the next iterative step, which will produce the following year's map, the output maps from the previous steps are used as a reference for subsequent classification trajectories.

For vegetation loss, persistence criteria were defined within a four-year temporal core: a pixel that was mapped as a loss event in year t if it persisted as Natural for at least two years prior to conversion to Anthropic (i.e., Natural at t-1 and t-2) and persisted as Anthropic for at least one year after conversion (i.e., Anthropic at t and t+1).

Unlike loss, secondary vegetation is not an event that can be observed from the differences in consecutive annual LULC maps. Rather, it is a gradual process that spans several years and whose duration is controlled by several ecological factors: the type and duration of the previous land-use regime, the abundance of propagule sources in the landscape (i.e., fragments of natural vegetation), climate, and topography, among other variables that can vary widely at scale across biomes (Aide et al., 2000; Ferreira et al., 2015; Sobrinho et al., 2016; Uriarte et al., 2010).

Therefore, a trajectory analysis was performed considering three different persistence criteria (i.e., considering three different time nuclei). The evaluation of each version was based on knowledge of how vegetation growth varies according to different climate regimes, vegetation types and land-use regimes in the past. The three sets of persistence criteria for identifying secondary vegetation pixels in year t were:

- **a)** Persistent classification as Anthropic for at least two years prior to conversion (i.e., Anthropic at t-1 and t-2) and persistence as Natural for at least three years after transition (i.e., Natural at t, t+1, and t+2);
- **b)** Persistent classification as Anthropic for at least two years prior to conversion (i.e., Anthropic at t-1 and t-2) and persistence as Natural for at least five years after transition (i.e., Natural at the period t to t+5);
- **c)** Persistent classification as Anthropic for at least two years prior to conversion (i.e., Anthropic at t-1 and t-2) and persistence as Natural for at least seven years after transition (i.e., Natural at the period t to t+7).

Since the persistence criteria for both vegetation loss and secondary vegetation growth imply a two-year period before conversion to verify consistent class changes, the start of the output time series is set in 2001. This choice is due to the fact that in 1999 and 2000 we found greater consistency of data at the country level, given that previous years there was a lack of satellite images in several sectors.

Pixels that showed class changes between Natural and Anthropic (or vice versa) but did not follow the defined rules were reclassified to correctly represent land cover/use in the next step of the iterative algorithm (i.e., when analyzing the next year in the series).

Figure 1 provides an overview of the processes through which information from MapBiomas' annual LULC time series is used to map vegetation and secondary vegetation loss. The seven classes representing vegetation dynamics or stability that are derived from the trajectory analysis of the original input dataset:

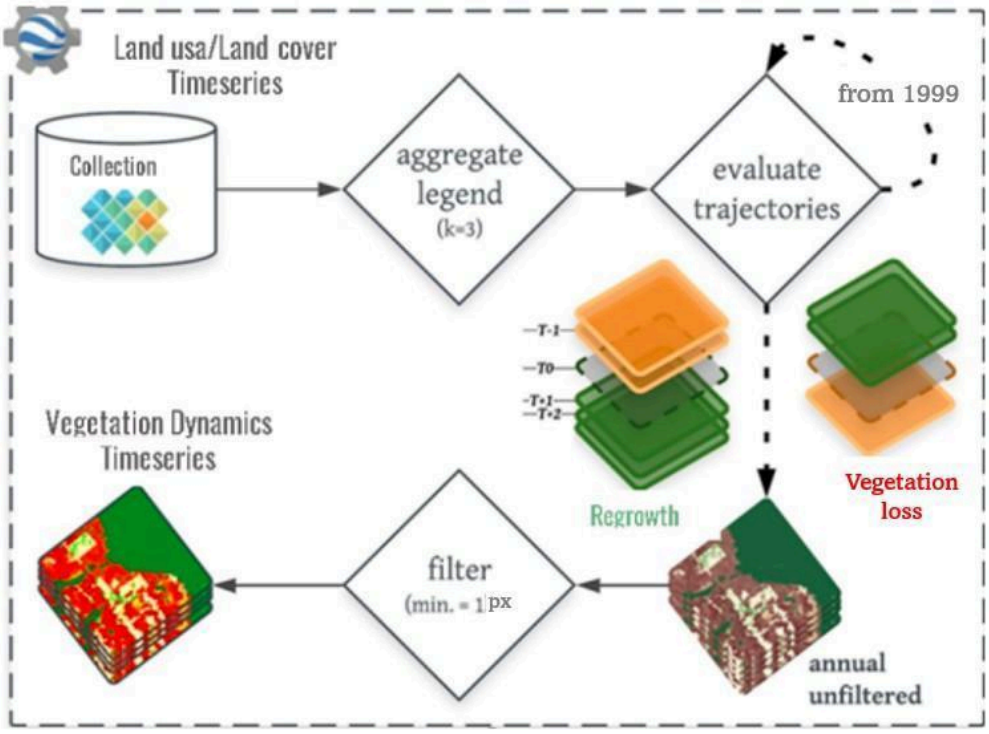


Figure 1 - Summary of the steps required to map vegetation dynamics using a LULC annual time series as input, following the method presented:

- The first step is to aggregate the 21 LULC classes from the original datasets into three classes (Natural, Anthropic, and Not Included).
- In the second step, the pixel path of the resulting aggregate annual time series is analyzed to identify changes consistent with the defined persistence criteria.
- For a pixel to be identified as secondary vegetation, it must be classified as Natural in the current year of analysis (pixel with dashed green border; T0), in (at least) the following two years (green pixels; T+1 and T+2) and also be classified as Anthropic in the two years immediately prior to the year of analysis (yellow pixels, T -1 and T -2, yellow pixels).
- For a pixel to be identified as vegetation loss (i.e., Primary Vegetation Loss or Secondary Vegetation Loss) it must be classified as Anthropic in the current year of analysis (pixel with a discontinuous yellow border; T0), in the following years (yellow pixels; T+1) and also be classified as Natural (Primary Vegetation or Secondary Vegetation) in the two years immediately prior to the year of analysis (green pixels; T-1 and T-2).
- The process is carried out iteratively from the 2001 map (the 1999 and 2000 input maps are used to check the persistence criteria) and the result is an annual time series with seven classes, which can represent a land cover type or a class change: Primary vegetation (cover), Secondary vegetation (cover), Anthropic (cover), Regeneration (change), Loss of primary vegetation (change) and Loss of secondary vegetation (change).

- The post-processing of the annual time series resulting from the trajectory analysis consisted of a two-step spatial filter that removes small, isolated pixel patches. A 12-pixel spatial filter was used to eliminate noise.

1.1. Classification Scheme

The final annual maps produced using trajectory analysis contain seven classes, which may represent a land cover type or a class change event: Primary vegetation (cover), Secondary vegetation (cover), Anthropic (cover), Regeneration (change), Primary vegetation loss (change), and Secondary vegetation loss (change). The definition of these classes and the persistence rules related to each of them are shown in Table 2.

Table 2 - Description of the mapped classes in the annual time series of vegetation dynamics produced by the presented method.

Class	Description	Ruler	Raster Value
Anthropic	A pixel classified as anthropic in the input dataset and unchanged in the year of analysis.	None.	1
Recovery of secondary vegetation	Areas that have a history of Anthropic use followed by change to natural vegetation specifically in the year of analysis (year of first change to natural class).	Persistent classification as Anthropic for at least two years prior to the year of analysis and persistent classification as Natural for three/five/seven years after conversion.	5
Primary Vegetation	Natural vegetation that persists from the beginning of the series (1999) to the year of analysis. All natural vegetation classes in the input dataset were considered.	Persistent classification as Natural in the input dataset, from the start of the series to the year of analysis.	2

Vegetation Secondary	Areas that present a history of Anthropic use followed by change to natural vegetation prior to the year of analysis.	Classified as natural in the input dataset in the year of analysis and classified as secondary vegetation in the previous iterative step (i.e., in the map drawn up for the previous year).	3
Loss of Vegetation Primary	Areas that change of Primary to Anthropic Vegetation in the year of analysis.	Persistent classification as Primary Vegetation in the maps prepared in stages previous iterative (i.e., previous years), for at least two years, followed by persistent classification as Anthropic in the input dataset for three/five/seven years, including the year of analysis.	4
Loss of Vegetation Secondary	Areas that change from Secondary to Anthropic Vegetation in the year of analysis.	Persistent classification as Secondary Vegetation in the maps prepared in stages previous iterative (i.e., previous years), for at least two years, followed by persistent classification as Anthropic in the input dataset for three/five/seven years, including the year of analysis.	6
Others	Areas mapped in the input dataset as other classes that are not anthropic or natural. Among others, it includes the classes of River, Lake and Ocean, Glacier, Aquaculture.	Classified as Other at any point in the input dataset.	7

1.2.Post-processing

A spatial filter of 0.5 hectares was used for the entire analyzed series, where all pixels with vegetation growth throughout the time series (i.e., classified as Secondary vegetation at least once) were accumulated in a single layer, and the same was done with vegetation loss. Patches (i.e., connected

pixels of the same class) that contained less than a threshold within each mask were removed. These pixels were reclassified according to the fashion in their spatial vicinity (considering a three-by-three-pixel window).

2. Conclusions

The method presented here conceptualizes categories of vegetation dynamics based on LULC classification trajectories per pixel, which requires the adoption of some premises. For example, any natural vegetation mapped at the beginning of the input time series is considered Primary Vegetation until it changes to other classes, although some of those areas of natural vegetation cover have already been used before 1999. In addition, mapping of Secondary Vegetation following the presented method is not capable of reporting on the quality of developing vegetation and therefore may represent contrasting ecological processes, such as regeneration, restoration, or biological invasion (e.g., Damasceno et al., 2018; Fernandes et al., 2016; Pinheiro & Durigan, 2009).

Although the quality of the maps produced is closely linked to the accuracy of the input dataset (MapBiomes), a validation protocol is being developed to enable the assessment of the quality of the classification of vegetation dynamics. The main objective is to reduce uncertainties and eliminate biases when estimating the area and accuracy metrics for vegetation dynamics classes that are not prevalent in the territory.

3. Bibliography

- Aide, T. M., Zimmerman, J. K., Pascarella, J. B., Rivera, L., & Marcano-Vega, H. (2000). Forest Regeneration in a Chronosequence of Tropical Abandoned Pastures: Implications for Restoration Ecology. Restoration Ecology, 8(4), 328–338. https://doi.org/10.1046/j.1526-100x.2000.80048.x
- Damasceno, G., Souza, L., Pivello, V. R., Gorgone-Barbosa, E., Giroldo, P. Z., & Fidelis, A. (2018). Impact of invasive grasses on Cerrado under natural regeneration. Biological Invasions, 20(12), 3621–3629. https://doi.org/10.1007/s10530-018-1800-6
- Fernandes, G. W., Coelho, M. S., Machado, R. B., Ferreira, M. E., Aguiar, L. M. de S., Dirzo, R., Scariot, A., & Lopes, C. R. (2016). Afforestation of savannas: an impending ecological disaster. Natureza & Conservação, 14(2), 146–151. https://doi.org/10.1016/j.ncon.2016.08.002
- Ferreira, M. C., Walter, B. M. T., & Vieira, D. L. M. (2015). Topsoil translocation for Brazilian savanna restoration: propagation of herbs, shrubs, and trees. Restoration Ecology, 23(6), 723–728. https://doi.org/10.1111/rec.12252
- Pinheiro, E. D. S., & Durigan, G. (2009). Spatial dynamics (1962-2006) of phytophysionomies in the conservation unit of the Cerrado in southeast Brazil. Revista Brasileira de Botânica, 32(3), 441–454. https://doi.org/10.1590/S0100-84042009000300005
- Rosa, M. R., Brancalion, P. H. S., Crouzeilles, R., Tambosi, L. R., Piffer, P. R., Lenti, F. E. B., Hirota, M., Santiami, E., & Metzger, J. P. (2021). Hidden destruction of older forests threatens Brazil's

Atlantic Forest and challenges restoration programs. Science Advances, 7(4). https://doi.org/10.1126/sciadv.abc4547

- Sobrinho, M. S., Tabarelli, M., Machado, I. C., Sfair, J. C., Bruna, E. M., & Lopes, A. V. (2016). Land use, Fallow period and the recovery of a Caatinga forest. Biotropica, 48(5), 586–597. https://doi.org/10.1111/btp.12334
- Uriarte, M., Schneider, L., & Rudel, T. K. (2010). Land Transitions in the Tropics: Going Beyond the Case Studies. Biotropica, 42(1), 1–2. https://doi.org/10.1111/j.1744-7429.2009.00580.x
- Xie, Z., Pontius, R. G., Huang, J., & Nitivattananon, V. (2020). Enhanced intensity analysis to quantify categorical change and to identify suspicious land transitions: A case study of Nanchang, China. Remote Sensing, 12(20), 1–16. https://doi.org/10.3390/rs12203323