# Performance evaluation of forest disturbance maps for selective logging monitoring in the Brazilian Amazon

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## 1. Introduction

Forest degradation is characterized by the gradual and partial removal of the forest, resulting from the selective logging of trees and forest fires (Fearnside, 2005; Rappaport et al., 2018). As one of the processes that most affect the Amazon, forest degradation is responsible for climate change on different scales, forest fragmentation, changes in carbon emission rates, reduction of ecosystem services and loss of biodiversity (Montibeller et al., 2020). It is estimated that degradation affects the Amazon on a large scale and already exceeds deforestation (Matricardi et al., 2020). Studies on this process have increased in Remote Sensing, but the current uncertainties represent an obstacle to understand the consequences of the carbon cycle and climate change (Senior et al., 2017; Longo et al. 2020; Vancutsem et al., 2021).

The patterns of selective logging on satellite imagery are commonly observed by roads and trails into the dense forest (regular or irregular geometric pattern), logging decks used as storage of extracted timber and gaps in the forest canopy related to tree felling (Pinheiro et al. 2016; Dupuis et al., 2020). Selective logging, mainly illegal, contributes to the forest's susceptibility to fire due to the opening of the forest canopy (Fearnside, 2005). The challenge of mapping this degradation driver lies in the need for images of high spatial and temporal resolution (Finer et al., 2014; Welsink et al., 2023). Subtle patterns in change of cover (Longo et al., 2020) and quick recovery by vegetation, in the case of low-intensity logging, represent the difficulty of monitoring this driver. Furthermore, it is common to integrate forest degradation estimates as a subsection of deforestation (or methodologies that do not divide the two processes), although they are distinct processes that generate damage of different magnitudes to vegetation in the long term.

Bringing reality to the Brazilian Amazon, it is estimated that degradation affects the Amazon on a large scale and already exceeds deforestation (Matricardi et al., 2020). However, although some initiatives represent great forest degradation monitoring systems, they still run into operational limitations. There are many factors that limit accurate large-scale selective logging mapping, such as limited availability of high spatial and temporal resolution imagery, lack of clarity about the conceptual distinction between deforestation and forest degradation, uncertainties about the nature and extent of selective logging in vegetation as diverse as the Brazilian Amazon.

Our goals in this work are to: (1) review three mapping initiatives: Tropical Moist Forests (Joint Research Centre) (Vancutsem et al., 2021), Global Forest Change (Global Land Analysis and Discovery, University of Maryland) (Hansen et al., 2013) and DETER-B (National Institute for Space Research, Brazil) (Diniz et al., 2015); (2) verify what these products generate for Brazil in terms of estimation and extension of the phenomena for the Brazilian Amazon and subsequent comparison of data generated; and (3) present that there are uncertainties and limitations of the estimates raised by the analyzed products and the need for more operational and precise initiatives.

## 2. Methods

First of all, a systematic review of each mapping initiative will be carried out (TMF, GFC and DETER-B), analyzing the parameters on which each model operates and what are the similarities and differences between the selective logging mapping approaches, both conceptual and operational.

The next step consists of generating and organizing maps and estimates of each initiative for the extension of the Brazilian Amazon. The aim is to gather the spatial data on selective logging generated by them and compare. The maps will be generated relating to the surveys of each mapping initiative.

The comparison between the maps and estimates will assume the data generated by DETER-B as the truth, since it is the initiative that emerged in Brazil (INPE) and the monitoring of Amazon vegetation are mainly carried out by government agencies that consider the estimates generated by DETER-B as the official reference. Cross-referencing of maps and estimates will be carried out using the following methods:

(1) fuzzy similarity method using the Dinamica EGO software to precisely assess the spatial similarity between maps, considering cell neighborhoods. Drawing inspiration from earlier works by Costanza (1989) and Pontius (2002), the method distinguishes errors based on location and quantity. This approach proves pivotal for analyzing spatial patterns and agreement among categorical maps.

(2) disagreement indices based on cross-tabulation were applied to evaluate selective logging between different binary maps (e.g., logging or not) (Krüger, Lakes, 2015). This methodology develops uncertainty measures for the probability surface following the disagreement approach of Pontius and Millones (2011).

## 3. Results

The expected results consists on: (1) tables containing estimatives of selective logging detection from TMF, GFC and DETER-B; and (2) maps that show the spatial intersection between the three predictions.

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