DETER INTENSO AND FOREST MONITOR: IMPROVING THE ALERTING OF DEFORESTATION IN THE BRAZILIAN AMAZON RAINFOREST

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ABSTRACT

This article presents the development of the Forest Monitor application and its use in the DETER Intenso project, conducted by INPE. DETER Intenso, complementary to the DETER project, aims to improve the production of deforestation and degradation alerts in the Amazon region. This is done through the systematic analysis of images from other sensors, thus increasing the revisit and also the accuracy of alerts through the incorporation of higher resolution sensors. Forest Monitor is the Web GIS developed to give access to these image sources that are found in a cloud computing environment.

Key words – Deforestation alerts, FOREST Monitor, DETER Intenso, cloud computing.

RESUMO

Este artigo apresenta o desenvolvimento da aplicação Forest Monitor e seu uso no projeto DETER Intenso, conduzido pelo INPE. O DETER Intenso, complementar ao projeto DETER, visa aprimorar a produção dos alertas de desmatamento e degradação na região da Amazônia. Isso é feito através da análise sistemática de imagens de outros sensores, dessa forma aumentando a revisita e também a precisão dos alertas através da incorporação de sensores de mais alta resolução. O Forest Monitor é o SIG Web desenvolvido para dar acesso a essas fontes de imagens que se encontram em um ambiente de computação em nuvem.

Palavras-chave – *Alerta desmatamento, Forest Monitor, DETER Intenso, computação em nuvem.*

1. INTRODUCTION

Less than two decades ago, the systematic mapping of Land Use and Land Cover (LULC) at regional, national, or global scales was unusual since it demanded significant financial, computational, and human resources. Governmental institutions conducted most of the initiatives to produce LULC maps from the analysis of remote sensing images that were costly and difficult to obtain [1]. Until 2006, Brazil's National Institute for Space Research (INPE) applied a commercial policy for its China-Brazil Earth Resources Satellite (CBERS) imagery, as did the US Geological Survey (USGS) and the European Space Agency (ESA). Currently, INPE, ESA, USGS, and others have opened their imagery archives, adopting an open and free policy, thus increasing access to vast amounts of Earth observation data [2]. The data volume produced by Landsat, MODIS (Terra and Aqua), CBERS, Amazonia-1, Sentinel (Sentinel-1, 2, and 3) missions reached over 15 PB per day, presenting challenges to explore and extract information from these datasets.

Cloud computing environments are being used to explore the continuously growing of remote sensing imagery. Clouds provide the storage for large volumes of satellite images and also the analytic environments to process them implementing the paradigm of co-locating data with processing infrastructure rather than delivering the data to a local user infrastructure [3]. Following this trend, giant computing companies such as Amazon, Google, and Microsoft invested heavily in the *Big Earth Data segment* offering the conditions to extract information from this enormous volume of data in distinct application categories, including land-use and land-cover (LULC) monitoring. Wulder et al. [4] called these conditions a new era of land cover analysis, information can be operationally generated in an increasingly automated, systematic, and rigorous way. Land cover change monitoring is a data-intensive activity, specially when the goal is to produce near real-time data over large geographical extensions.

The Real-Time Deforestation Detection System (DETER), run by INPE since 2004, maps deforestation and forest degradation over the Brazilian Amazon. DETER analyses low spatial resolution images from sensors with high revisit time, maximising the area monitored and generating daily alerts of modification on the forest coverage [5].

The large amounts of images from multiple sensors in a cloud computing environment motivated the development of *Forest Monitor*, a web-based application used to complement and improve DETER. It is being used to support the *DETER Intenso* (Intense DETER) project in selected areas of the Brazilian Legal Amazon, using images from Sentinel-2, CBERS, and Landsat available in the Amazon Web Service (AWS) cloud platform. This article talks about the technologies and functions of the Forest Monitor and how it is used in the DETER Intenso project.

2. MATERIALS AND METHODS

2.1. DETER

The DETER project is based on an incremental methodology, as illustrated in Figure 1. It aims at mapping disturbances in areas of the natural vegetation. Whenever a new image is available, remote sensing experts download the images and open them in a desktop Geographical Information System (GIS), then delineate new areas of forest degradation or removal. These polygons are also called ”areas of alert”, or simply ”alerts”. Currently, DETER uses images from the Wide Field Imager (WFI) camera onboard CBERS-4, CBERS-04A, and Amazonia-1. This instrument revisits the same area every five days, and generate images with 64 meters of spatial resolution.

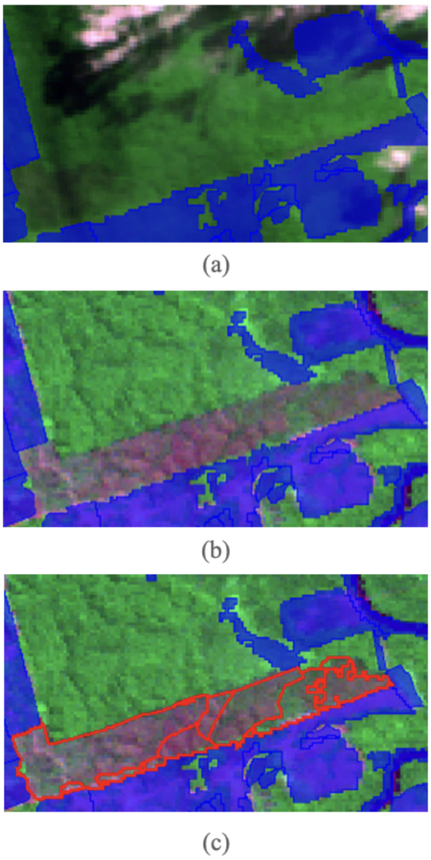

Figura 1: DETER methodology: (a) a Landsat image from 2019-06-04. In blue, deforested areas previously detected; (b) a Landsat image from 2019-07-17 for the same area; (c) a set of DETER alerts mapped during this period.

The spatial resolution of the WFI sensor allows the mapping of alerts with at least 3 ha [5]. The DETER Intenso project aimed at executing a more intensive monitoring by observing the same area more frequently, using images from other sensors that, combined, provide a more frequent revisit. It also aims at detecting smaller alerts through the analysis of images with higher spatial resolution, thus decreasing the alerts' minimum area.

Alerts from DETER and DETER Intenso are qualified as *deforestation*, *mining*, *fire scar* or *selective logging*. They are also annotated with attributes extracted from their spatial intersection with other information layers, such as the maps of conservation areas, municipality boundaries, and the Rural Environmental Registry (CAR). CAR is a national electronic public register, mandatory for all rural properties that integrates the environmental information of rural properties for environmental diagnosis [6].

The DETER alerts are used in the strategic planning of law enforcement activities by government agencies such as the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA), state environmental agencies, and others. The alerts are stored in a spatial database and sent out using INPE's TerraBrasilis portal or geographical web services like the Web Map Service (WMS), the Web Coverage

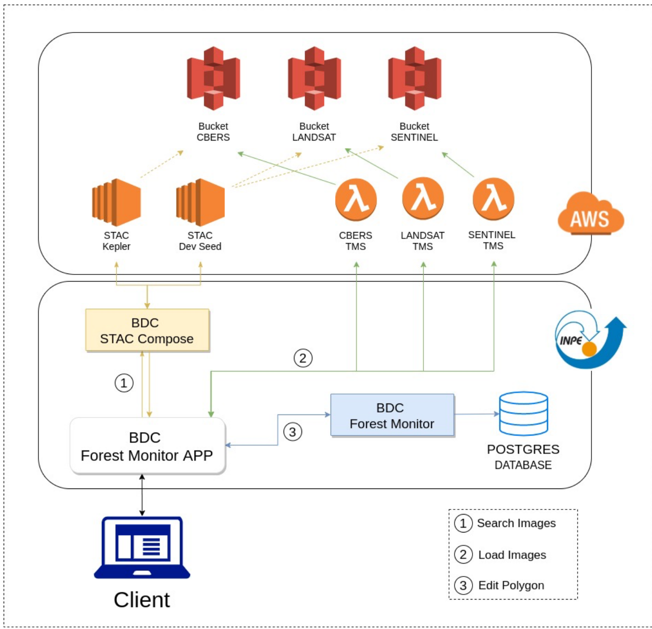

Figura 2: The Forest Monitor Architecture.

Service (WCS), and the Web Feature Service-Transaction (WFS-T), which are all open standards proposed by the Open Geospatial Consortium (OGC).

2.2. FOREST MONITOR

Forest Monitor is the Web GIS application used in DETER Intenso. It is operated by visual interpreters, specialists in remote sensing and land change detection. An interpreter locks an area of interest, selects the latest images for that area, creates a color composition that enhances forest alteration and deforestation, and delineate the alerts. Vector editing tools and image processing tools are available in the application interface. Forest Monitor is the only tool used in the entire process. Figure 3 shows the application interface. Figure 2 shows the Forest Monitor architecture, which is composed of three tiers: (1) data source: image buckets, metadata, and services running in the AWS; (2) services: application, database, and services running at INPE; and (3) client: the web application running in the user's web browser.

2.2.1. Data source

To run DETER Intenso, Forest Monitor was implemented to operate on the AWS Amazon Web Services (AWS) cloud platform, using credits from the "Group on Earth Observations GEO) and AWS Earth Observation Cloud Credits Program" [7]. The images used are part of the "AWS Public Dataset Program" an initiative that covers the cost of storage for high-value cloud-optimized datasets, including remote sensing imagery [8].

The imagery collections in AWS are stored in *buckets*, each bucket represents a space of storage, uniquely identified by a name. In this work, three buckets are used: Landsat-8 (`https://registry.opendata.aws/landsat-8/`), Sentinel-2 (`https://registry.opendata.aws/sentinel-2/`), and CBERS-4 (`https://registry.opendata.aws/cbers/`).

The image bucket metadata are described in compliance with the Spatio Temporal Asset Catalog (STAC) [9] specification. The STAC specification is a community driven effort to facilitate the discovery of and access to raster data. Each image bucket has its STAC catalog instance running in the AWS Cloud exposed through a Representational State Transfer (REST) Application Programming Interface (API). The AWS provides an event-driven, serverless computing service called Lambda. This mechanism runs code in response to events and automatically manages the computing resources required by that code [10]. Forest Monitor consumes the images from AWS using Tile Map Service Specification (TMS) servers implemented using Lambda.

2.2.2. *Services*

The polygons edited by users in the Forest Monitor application are stored in a PostgreSQL database with the PostGIS extension [11]. PostGIS is an open-source project compliant with the OGC Simple Features Specification (SFS), allowing the storage and query of vector spatial data using the Structured Query Language (SQL). This database, stored at INPE, contains the application data model, the mapping results generated in DETER and also ancillary data used to aggregate attributes for the alerts.

2.2.3. *Client*

Forest Monitor client, a multi-user application that runs in any web browser, was developed using open source libraries and languages, including JavaScript, Angular, HTML, Python, and Leaflet.js. The Forest Monitor gives interactive access to images from Landsat-8 (30 meter of spatial resolution), CBERS-4 (20 meter), and Sentinel-2 (10 meter) satellites directly from the cloud environment. It allows their visualization as color compositions, with the possibility of contrast enhancement, applied at run time.

3. RESULTS AND DISCUSSION

DETER Intenso began experimental operation in February 2020, producing deforestation alerts in selected critical areas of the ALB, with a $484,000$ km2 extension (see Figure 3).

Between 2021-08-01 and 2022-11-03, the project generated $39,724$ alert polygons covering an area of $8,178$ km^2. DETER Intenso reported an average area of 8 ha per polygon, whereas DETER reported an average of 15 per polygon. As a result, we conclude that combining images with higher spatial resolution and from multiple satellites enhanced the DETER system. An example of alert mapped with Forest Monitor are detailed in Figure 4.

Because it provided access to a large volume of images for observed areas, the Forest Monitor application was critical in supporting this enhancement. Using this application, interpreters can easily select the best image from a large number of images from various sensors and with varying spatial resolutions, with the fewest clouds and cloud shadows. The possibility to access past and current images from various satellites and sensors without having to download and maintain them locally is the primary benefit of using AWS image buckets.

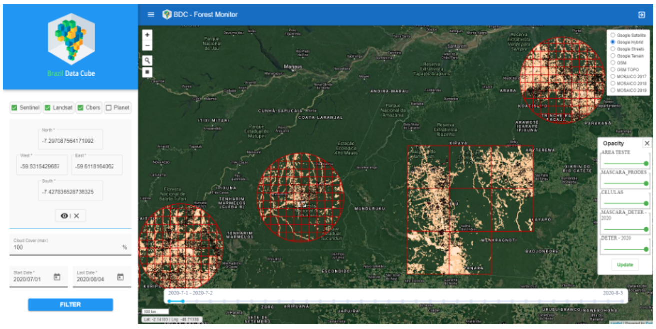

Figura 3: Forest Monitor client interface.

Figura 4: Detail of a DETER Intenso alert.

4. CONCLUSIONS

This article describes the development of the Forest Monitor deforestation mapping platform, which uses cloud computing and web services to access large repositories of Earth observation satellite data. Forest Monitor is the application that INPE uses to run the DETER Intenso project. It enabled the use of more images in near real time detection of forest perturbations. More alerts and more precise alerts are generated with the timely inclusion of more images.

The DETER Intenso project will be expanded to include new observation areas in the future. To do so, factors such as the cost of private cloud computing must be considered.

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