

ST08 - Using Artificial Intelligence in Process Automation for the Detection of Land Use Change by Removal of Vegetation

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Abstract

Bauxite mines are usually located within in properties of great extension. In such contexts, it is challenging to monitor changes in vegetation, and hence to guarantee that external agents do not perform deforestation. Using satellite images and GIS (Geographic Information System) is an efficient way to monitor large areas, although some expertise is needed to work with these systems, and it demands time to process the satellite images and evaluate them against polygons where removal of vegetation is authorized, as well as against protected areas. To optimize the efforts applied to this monitoring, and make it more preventive and efficient, we have prepared an automated flow in GIS that:

- receives data (satellite images + protected areas + polygons authorized for removal of vegetation + field inspections);
- processes and analyzes data through artificial intelligence;
- organizes the results in online dashboards (monitoring suppression progress in authorized areas + alert dashboards for deforestation in protected or unauthorized areas);
- sends notifications to personnel about probable events to be checked in the field.

This flow can be used for the detection of changes in vegetation in any large areas, it promotes directed inspections on the ground, and it helps preventing unauthorized vegetation removal, whether in bauxite mining areas or in other contexts.

Keywords: Deforestation, Remote sensing, Automation, Deforestation monitoring, Geographic Information System (GIS).

1. Introduction

Large industries and production chains depend on ores as an input for the manufacture of their products. This requires complex mining activities that involve large investments, planning, and the extraction of non-renewable resources. Its impacts are both positive, in terms of economic and social development, and negative, as the extraction of finite resources has an environmental cost [1].

Brazil is one of the countries with the greatest potential in mineral resources on the planet, with about 55 types of minerals already explored [2]. In Brazil's Northern region, especially the state of Pará, mining occurs at a considerable scale thanks to the investments made by large mining companies.

Paragominas is a municipality that has a great stock of bauxite, which is being mined by Mineração Paragominas S.A (MPSA), a company of the Norsk Hydro Brazil group. MPSA uses

the strip mining method, which basically consists of four steps. First, the vegetation is removed, and a layer of soil (typically called topsoil) is mined separately for rehabilitation purposes. Then, the overburden layer is excavated, stacked, and stocked. At that moment, the bauxite is mined and loaded on trucks to be transported to the beneficiation plant. After the bauxite removal, the overburden layer returns to the pit and is leveled before receiving the topsoil for the rehabilitation processes [3].

Thus, bauxite mining according to the strip mining method requires the removal of vegetation of large areas and, unlike the mining process of some other ores, is carried out in the open. In the process, large strips of land are extracted and subsequently recovered [4, 5]. Because of the extension of the areas, the necessary monitoring programs that guarantee that the land cover changes occur as prescribed by Brazilian legislation are particularly challenging to implement.

In addition, within the area where MPSA is active, there are also areas under environmental protection, where removal of vegetation is not allowed, such as Legal Reserve Areas and Permanent Preserved Areas, as defined by the Brazilian Law N. 12.651/2012 [6]. Like the operational areas, these environmental protected areas are large and hard to monitor.

Remote Sensing, Geoprocessing and Artificial Intelligence tools have been widely used to monitor large areas. These tools can provide periodic and consistent land surface data, identifying removal of vegetation by detecting changes in land use. This type of tool is already considered a key instrument in global monitoring and one of the main tools used to understand changes in land cover [7, 8, 9].

Considering the MPSA context and with the aim of automatizing the monitoring of environmental programs, the main motivation of this “Change Detection” project was to create a smart, unified, collaborative, and automatic system to detect land use changes by removal of vegetation. The system aims to monitor such activities, in order to guarantee that removal of vegetation only occurs in areas where it is allowed, and to monitor protected areas or areas where removal of vegetation is not allowed.

2. Study Area

The project area is the MPSA mine area and the Pipeline and Transmission Line Easement Track. The pipeline is the device used to transport the bauxite pulp to the alumina refinery located in Barcarena. And the Transmission Line is necessary to provide energy for the pipeline to work. Both are within the Hydro Paragominas concession, and they are part of the area that is being monitored, like the mine itself.

The MPSA mining area consists of two bauxite deposits on contiguous plateaus referred to as Miltonia 3 (M3) and Miltonia 5 (M5), situated in the municipality of Paragominas, in the northwestern region of the State of Pará, in Northern Brazil. The geographic coordinates of the mine are 2° 59' 51" S; 47° 21' 13" W, as shown in Figure 1.

The region of Paragominas presents a humid tropical climate with regular precipitation, with dry periods lasting from June to November, and a rainy season with high nebulosity from December to May. The local microclimate depends on the vegetative variations since this is an area in transition between native forest and pasture areas. Agriculture is an activity of great influence in the region. The expansion of agriculture can raise temperatures and reduce the relative humidity of the air [10, 11].

The project area is in the Amazon biome, which encompasses 9 (nine) countries. Amazon is the largest biome in area of Brazil, occupying 49.5 % of its territory. In addition, it is of great importance in terms of global biodiversity, hydrology, and climate [12, 13, 14].

The MPSA's operations comprise an integrated production system that includes mining, beneficiation, and transport of bauxite pulp through a 244 km-long pipeline that crosses seven municipalities of the State of Pará (PA), mostly underground. Close to the path followed by the pipeline, there is also 236 km-long power transmission line to supply the plant with the required electricity. A Pumping Station (PS2) is located in Tomé-Açu/PA. The pipeline and the transmission line transport the bauxite pulp to the municipality of Barcarena, where it is used as the raw material to produce alumina.

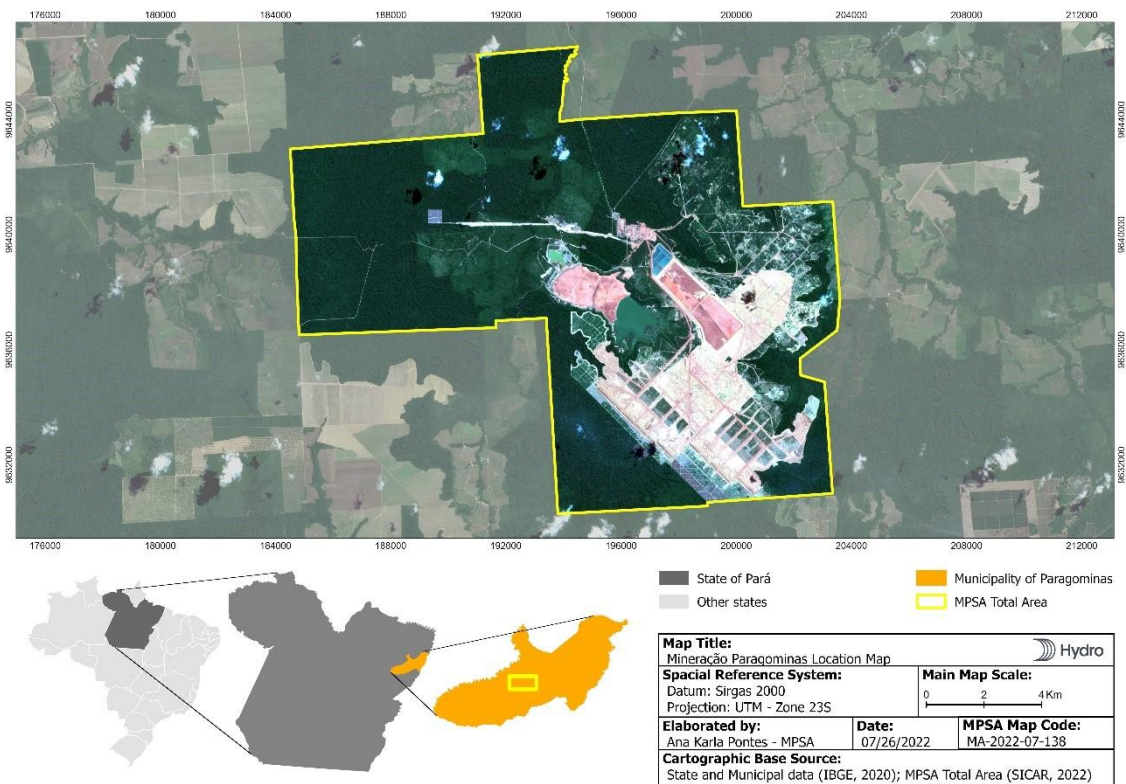


Figure 1. Mineração Paragominas location map.

3. Methods

In order to detect land use changes by removal of vegetation, an environmental risk analysis of the suppression process was performed. The analysis included the identification of the current context, the environmental risks, and the future context.

The result provided enough information for the authors to create a smart, unified, collaborative, and automatic system to detect changes, to issue alerts for field inspections, to create a suppression verification checklist, and to send e-mails to managers to report detected and confirmed removal of vegetation in the field.

The system was created in the ArcGIS platform with the assistance of the Imagem team (Esri Official Distributor in Brazil).

4. Results

The system for detection of land use change by removal of vegetation follows 8 (eight) steps, all described below.

4.1 Environmental Risks Analysis and Actual Context

The first step of this project was to monitor land use changes by removal of vegetation. Removal of vegetation is an inherent step for bauxite extraction. At the MPSA, such removal is only carried out when licensed by the environmental agency, regardless of the location. However, because these are large areas, routine monitoring of the activity is necessary to ensure that removal of vegetation occurs within the authorized terms.

In addition, the MPSA mine is in the rural part of the Paragominas municipality and has environmental protection areas (Legal Reserves and Permanent Preservation Areas) on river slopes, which must be protected in accordance with Federal Law N. 12.651/2012 (Brazilian Forest Code) and MPSA's Term of Commitment N. 1308/2022 of adherence to the Environmental Regularization Program (commitment signed between MPSA and the environmental agency for the protection of these areas).

Considering the risks of occurrence of removal of vegetation in areas where it is not authorized, or in protected areas, the need for the creation of a robust, independent, and automated monitoring system was identified. This need was evidenced in the analysis of the current monitoring system, which was based on sporadic field inspections or actuated in response to complaints.

4.2 Creation of the Users in the ArcGIS Environment

Knowing the necessity, the next step of the project was the creation of the users in the ArcGIS platform. This was an easy step because MPSA's already had the licenses to use the software.

4.3 Upload the MPSA Spatial Data in the ArcGIS Online

The third step was to compile the MPSA spatial data to support the detection of changes in the land cover. The layers uploaded are: the areas where removal of vegetation has been previously authorized, the environmental protected areas (Legal Reserve Areas and Permanent Preserved Areas) and its security buffers, the plateau areas and the plateau security edge buffers, the pipeline and the transmission line easement track, the MPSA's rehabilitation program areas, the MPSA's mining rights areas licensed to mining, the MPSA's property area, the MPSA's infrastructure areas, the MPSA's total area of vegetation removal, the MPSA's historical mining areas, the traditional communities' areas, the MPSA's environmental monitoring points and the MPSA's pipeline maintenance areas. All those layers were used to classify the severity of the removal of vegetation when it occurs.

4.4 Creation of the Land Use and Occupation Classification Model and Change Detection

The third step was the application of a change detection model. To achieve the objective of creating a smart and independent system, the need to use a model was identified.

The land use and change detection classification model is based on Deep Learning techniques and was trained with more than 100,000 samples, using Sentinel-2 data at the L2A processing level and its thirteen bands. The model was created by the Imagem team, MPSA's partner in the project.

The model was trained to read different classes of land use, including "Country vegetation/Undergrowth", "Temporary Cultivation", "Forest". "Permanent Cultivation", "Water Mass", "Anthropic Area", "Exposed Soil /Burned" and "Others (Clouds and Shadows)".

To detect changes over time, the analysis was implemented by always comparing different images: a historical one (always from the previous month) and a current one (from the month under analysis), considering that images are taken monthly.

Before proceeding with classification, it is essential to align one image with the other, ensuring perfect overlap, a process known as image registration. This step ensures the accuracy of subsequent comparisons. With the images duly registered, each one is individually classified using the Deep Learning model. This procedure generates two distinct layers, which reflect land use in the two analyzed periods. These layers are transformed into polygons and after that, an intersection operation is performed to identify the overlapping areas. Next, a filter is performed to identify the differences between the layers, isolating the areas where significant changes have occurred. Finally, the result layer is uploaded in the ArcGIS Online platform.

4.5 Creation of the Removal of Vegetation Monitoring Dashboard

Using the result layer with the identification of changes and the uploaded layers, it was possible to create a severity scale of alerts to be issued when removal of vegetation occurs. The severity classes were defined considering the latest land cover found and the location of the change, based on the overlaps in the uploaded layers. This was a complex step since the severity rating depends on many factors.

Four severity alert classes were created: red, orange, yellow and white classes. The classes are described below:

4.5.1 Red alerts

The red alerts have the highest severity and are generated when changes are identified outside authorized areas (without a license from the Environmental Agency), in environmentally protected areas (Legal Reserves and Permanent Preserved Areas), in the MPSA's rehabilitation program areas or in the MPSA's pipeline maintenance areas. The red alert applies if the land after the change is classified as "*Exposed Soil /Burned*" in the model analysis.

4.5.2 Orange alerts

The orange alerts have high severity and are generated when changes occur in the same areas where the red alerts are identified, but if these areas after the change are classified as "*Country vegetation/Undergrowth*" in the model analysis.

Furthermore, an orange alert is issued when changes are identified outside the authorized areas but within the MPSA's property area, in the MPSA's pipeline and transmission line easement track, in the MPSA's plateau area, in the security buffers (50 meters around environmental protected areas or MPSA's pipeline maintenance areas), or in the security buffers (40 meters around plateau edges). The orange alert applies if these lands are classified after the change as "*Exposed Soil /Burned*" in the model analysis.

4.5.3 Yellow alert

The yellow alerts have moderate severity and are generated when changes occur in the areas described in the second paragraph on the orange alerts, if these after the change are classified as "*Country vegetation/Undergrowth*" in the model analysis.

Additionally, it is a yellow alert when changes are identified outside security buffers (100 meters around environmental protected areas, plateau edges, or MPSA’s pipeline maintenance areas), if the land after the change is classified as “Exposed Soil /Burned” in the model analysis.

4.5.4 White alert

Finally, the white alerts have low severity, and are identified when changes occur in the areas described in the second paragraph on the yellow alerts, if the lands after the change are classified as “Country vegetation/Undergrowth” in the model analysis.

Figure 2 presents a print screen of the prototype dashboard created. The dashboard has 4 filters in the header: alert class, alert year, alert month, and alert ID. On the left side of the dashboard are 4 alert indicators, pointing out the number of alerts, sorted by severity class, in relation to the total. Right next to the indicators are 2 interactive charts: one showing the number of alerts over time, subdivided by severity class; and one presenting alerts by area type, overlapped with the subdivision by severity class. On the right side, there is an interactive map, which from the outset only visualizes alerts and field inspections, but which is capable of also activating the other layers uploaded in the ArcGIS Online platform. Finally, there is an interactive table presenting the severity classes of alerts, the number of inspections performed, and the number of cases of removal of vegetation confirmed by on-site inspections.

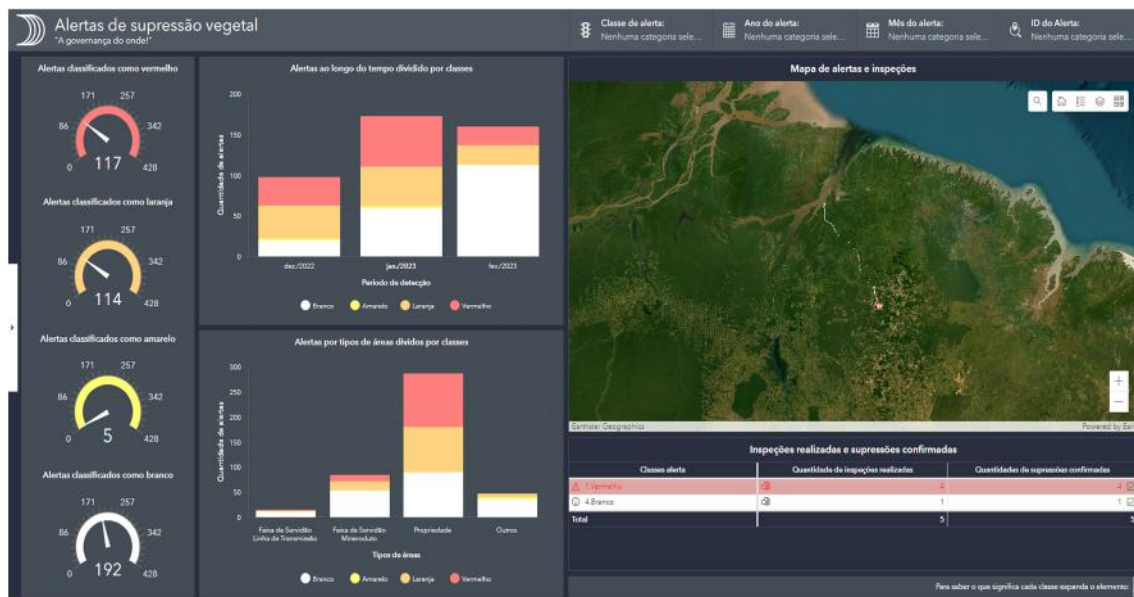


Figure 2. Prototype of the removal of vegetation monitoring dashboard.

The dashboard is automatically updated when it receives the monthly analysis made by the change detection model. This is enabled by a code created with the help of the *Model Builder* tools available in ArcGIS software. This code is responsible for classifying severity, calculating the area, and identifying overlapping indication. Also, the code enables automatic updates.

4.6 Creation of the Suppression Form for Inspection in the Field

When an alert shows up in the Removal of Vegetation Monitoring Dashboard, there is a tool that has been created to guide field inspections to verify whether the suppression really happened.

For this step, 2 application tools from the ArcGIS platform were used: “Field Maps” and “Survey 1, 2, 3”. The “Field Maps” application was used to create a web map (available offline) with all the data uploaded and the results of the change detection model analysis. The objective of the web map was to guide colleagues in the field to the location of the alert.

The “Survey 1, 2, 3” application was used to create a Removal Form to be used as a tool for data collection in the field. The main objective of that form is to confirm if the removal alert is real and collect data on it (information and pictures).

Both applications are synchronized with the Removal of Vegetation Monitoring Dashboard. So, when one of the tools is updated, all the others receive the updates too.

4.7 Creation of the Removal of Vegetation Inspections Monitoring Dashboard

The seventh step of the project was the creation of the Removal of Vegetation Inspections Monitoring Dashboard to present the data collected in field.

Figure 3 presents a print screen of the prototype dashboard created. The dashboard has 4 filters in the header: alert class, confirmation of removal, inspection number, and alert ID. On the left side of the dashboard are 4 alert indicators, pointing out the number of inspections realized, sorted by severity classes alert. Right next to the indicators are 3 charts that present areas with identified removal of vegetation, kind of environmental occurrence, and environmental impacts detected in the field inspection. Then, besides the charts, there is an interactive map and the details from the Removal Form. Finally, there is the same interactive table as presented in the Removal of Vegetation Monitoring Dashboard.

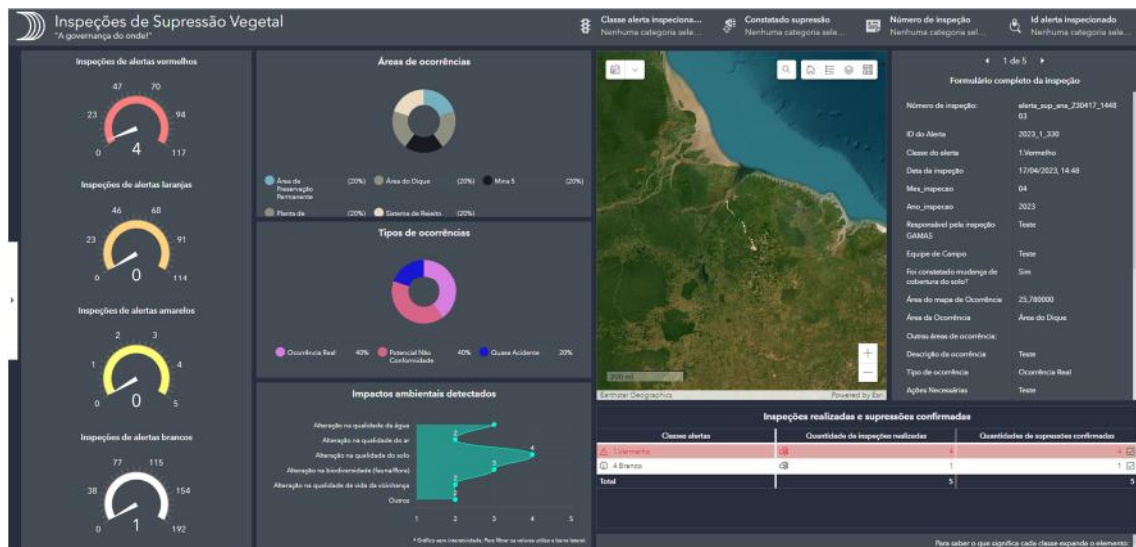


Figure 3. Prototype of the removal of vegetation inspections monitoring dashboard.

4.8 Creation of the Alert Email for Suppression in Protected or Unallowed Areas

The last step of the project was to automatize the sending of an e-mail to managers if removal of vegetation was confirmed in the Removal Form. That step was performed using the Microsoft Power Automate tool connected to the “Survey 1, 2, 3” form.

5. Conclusion

The monitoring system created uses deep learning methods, and the automation of the modelling tool allowed for the monitoring of removal of vegetation at a very high level. The System is

intelligent and able to receive data and classify alerts autonomously. It is connected to the dashboards, field map and inspections form. It is hosted in an interactive, automated, and collaborative platform since it enables data collection in the field and data synchronization in real time.

Using this system allowed for monthly monitoring to detect land use changes in more than 20 000 hectares of MPSA areas, and to carry out targeted inspections of areas with high risks of vegetation removal. In addition to this, it became possible to monitor environmental protection areas, creating a virtual fence around these areas.

The MPSA is committed to protecting environmental protection areas and only perform its operations in authorized areas, and this system is helping to fulfill this commitment in the day-to-day operations.

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