ILLEGAL MINING IN AMAZONIAN INDIGENOUS LANDS: ANALYSIS OF HOTSPOTS AND IMPACTED HOUSEHOLDS

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ABSTRACT

Amazon has the largest tropical rainforest on the planet, where indigenous peoples preserve its biodiversity. However, Indigenous Lands (ILs) are often threatened by the expansion of mining, which endangers the inhabitant's safety. This study proposes identifying hotspots of illegal mining coverage in ILs within Brazil's Amazon biome in 2022. The households affected by this type of extractive activity were described, considering a three-step methodology: i) classification of illegal mining presence in ILs in the Amazon biome; ii) identification of the hotspots of illegal mining cover; iii) description of the affected households in the hotspots. The results revealed the existence of 14 ILs affected by illegal mining. In five ILs there are households located in the hotspots. The geoinformation techniques applied in this study are essential to support actions to prevent and monitor ILs that are likely directed impacted by mining activities.

Key words *— Amazon, Indigenous Lands, Illegal Mining, Hotspots, Households.*

1. INTRODUCTION

The Amazon is the largest biome in the world, responsible for regulating the climate in Latin American countries [1]. Brazil has 64.3% of its total area, with 4 million km^{2,} corresponding to 49% of its territory [2]. This biome faces deforestation threats in areas where biodiversity conservation and socio-economic interests overlap, such as mining on protected lands [3]. For millennia, indigenous people (IP) have conserved the forest landscapes of the Amazon in Brazil [4]. According to Brazil's Federal Constitution, Indigenous Lands (ILs) are territories demarcated to guarantee IPs the right to the exclusive use of the occupied lands [5]. Despite being considered protected areas by law and guaranteeing the physical and cultural well-being of IPs in Brazil, ILs are susceptible to changes in environmental policies in favor of the exploitation of mineral resources [6].

According to the Brazilian Mining Institute (IBRAM), the mining sector contributed 80% of Brazil's trade balance [7]. The mineral abundance and diversity that make Brazil one of the world's largest exporters of mineral resources are to be found in the Amazon, which is home to more than 220 specific IPs [8]. As such, the country faces socio-economic, cultural, and environmental pressures like the Bill 191/2020, which aims to regulate mining in ILs, promoted by the 2019-2023 government [9].

Combining remote sensing and census survey data allow the monitoring of socio-environmental conflicts with mining activities [2]. For example, TerraClass project, based on remote sensing analysis over deforested areas [10]. The Brazilian Institute of Geography and Statistics (IBGE) provides data from the Population Census [11], including the National Register of Addresses for Statistical Purposes (CNEFE), which is a national database of georeferenced addresses of the country's households [12].

In the context of growing concerns about the advance of illegal mining activities in the Amazon within ILs, some questions remain unanswered: 1) Which ILs are affected by mining coverage in the Amazon? 2) How are the mining hotspots distributed within these ILs? 3) Is there a resident population near these hotspots? This article aims to identify the hotspots indicative of the presence of mining in ILs within the Amazon biome to characterize the households affected by this type of illegal mining activity, using LULC and census data of 2022.

2. MATERIAL AND METHODS

2.1. Classification of the presence of illegal mining in ILs across the Amazon biome

The polygons of ILs within the Amazon biome were selected as study areas [11] (Figure 1). Next, the 2022 LULC data [10], in raster format, was processed by selecting the "Mining" class and transforming it into vector format (polygon) to calculate the presence of mining cover (PM) in the Amazon ILs (Eq. 1) [13].

$$PM = \frac{A_M}{A_T} \times 100\% \quad (1)$$

Where:

PM: Presence of mining cover;

A_M: Mining area;

A_T: IL total area

2.2. Identification of illegal mining hotspots

To characterise the critical points of the mining processes, maps were developed for each IL identified based on the Kernel density methodology. This exploratory interpolation technique generates a density surface for visual identification purposes. The kernel density calculation was based on the quartic kernel function (Eq. 2) [14], [15].

$$k\,(h) = \frac{3}{\pi} \times (1 - h^2)^2 \qquad (2)$$

Where:

$k\,(h)$: Kernel density;

h: Distance between a point and its neighbors.

The value of 250 m, used in previous studies [14], was defined for h to generate an exploratory interpolation with a density surface adapted to the extension of each IL.

2.2.3. Description of the affected households present at the hotspots

Data from the CNEFE household census 2022 (address face) [12], were superimposed on the polygonal surface of the hotspots identified in the previous phase. ILs with no households in areas affected by mining were identified. ILs with at least one household were described according to the type of locality (indigenous villages, alluvial mining settlements) and the average number of residents.

3. RESULTS

3.1. Illegal Mining in ILs in the Amazon Biome

We identified 14 ILs with mining coverage out of 315 ILs in the Amazon biome. The ILs were classified according to the presence of illegal mining cover (PM) as shown in Figure 1.

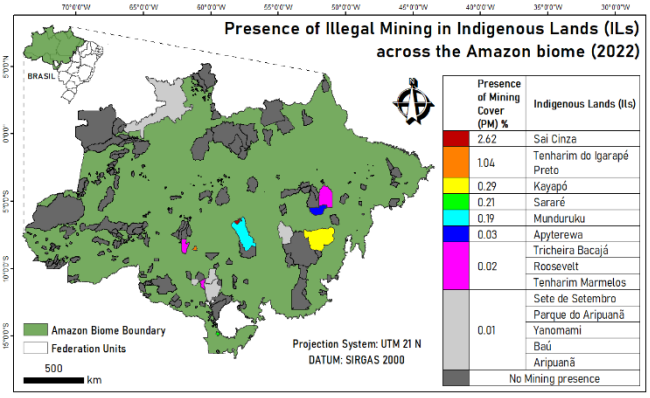


Figure 1. Classification of Indigenous Lands in the Amazon Biome according to the Presence of Illegal Mining in 2022.

3.2. Illegal Mining Hotspots Inside ILs

The maps shown in Figure 2 represent the Kernel density surface result and follow the descending order of the PM (Figure 1). The legend expresses the minimum and maximum values for the intensity of mining cover in each IL.

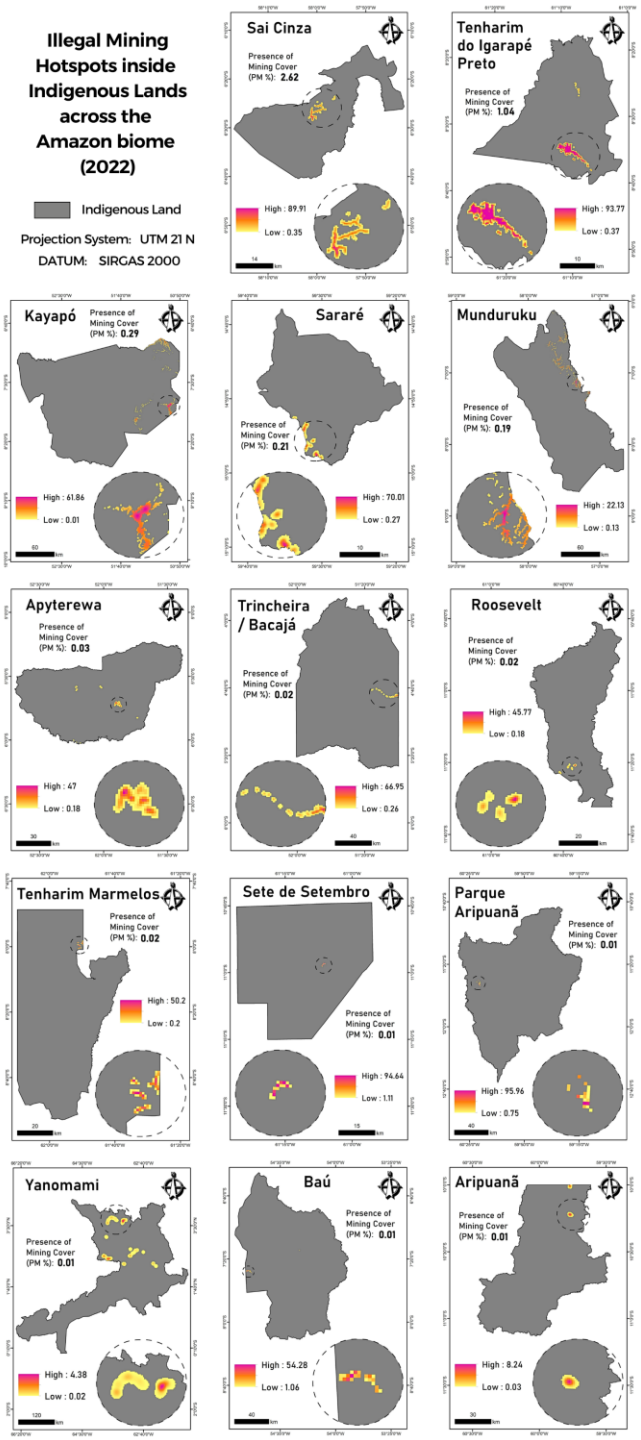


Figure 2. Maps of Illegal Mining Hotspots in ILs across the Amazon biome until 2022.

3.3. Affected households at illegal mining hotspots

It Only 5 of the 14 ILs with mining on their land have households within the hotspots. In three ILs, all their indigenous villages ("aldeia) were within mining hotspots (Figure 3). Two ILs were identified with indigenous villages and alluvial mining settlements ("garimpo") within the mining hotspots (Figure 4).

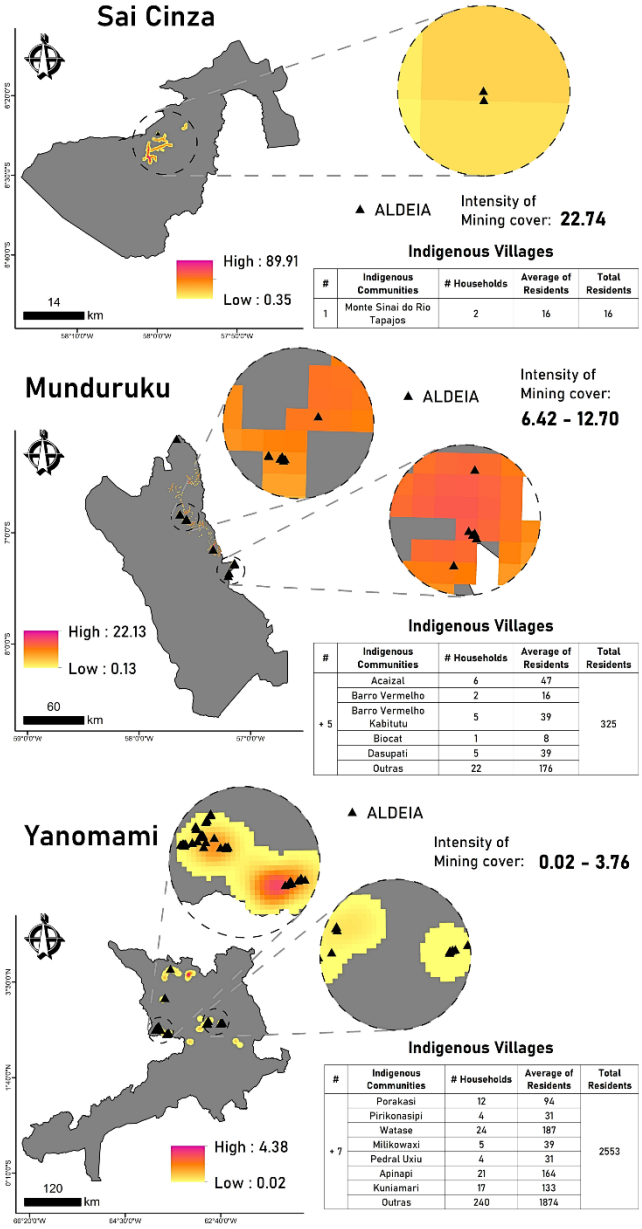


Figure 3. Maps of ILs with only indigenous villages ("Aldeia") within their mining hotspots.

Figures 3 and 4 describe the range of intensity of the mining cover, their indigenous communities, their number of households, and their number of inhabitants for each group of ILs.

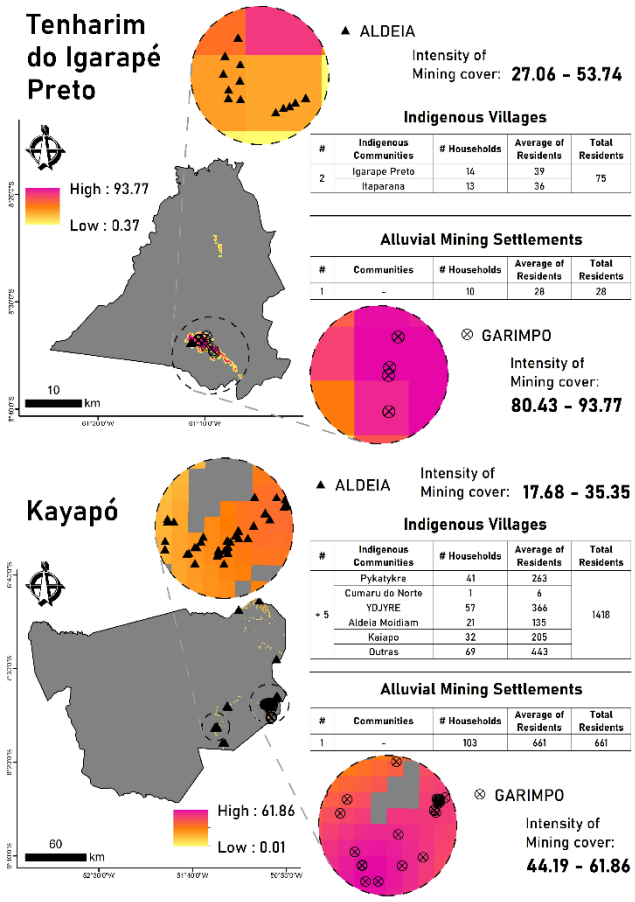


Figure 4. Maps of ILs with indigenous ("aldeia") and alluvial mining ("garimpo") villages within their mining hotspots.

4. DISCUSSION

Mining activity was identified in 14 out of 315 Indigenous Lands in the Amazon biome. The rates of illegal mining ranged from 2.62% to 0.01%, with the Sai Cinza Indigenous Land registering the highest rate, representing 344 ha of its surface. Meanwhile, the lowest rates were recorded in ILs such as Sete de Setembro, Parque do Aripuanã, Yanomami, Baú, and Aripuanã..

Kernel density surfaces made it possible to spatially represent the distribution of mining in the ILs and to visualize the patterns of mining hotspots. The most frequent spatial pattern was the alluvial mining type, which follows the shapes of the main rivers, tributaries, and their banks. This pattern was identified in the Sai Cinza, Tenharim do Igarapé Preto, Kayapó, Mundurukú, TrincheiraBacajá, and Yanomami ILs. The ILs with the highest maximum kernel density values have more intensified mining areas on their land, as in the case of Sete de Setembro, Tenharim do Igarapé Preto, Parque do Aripuanã, and Sai Cinza. These ILs had maximum values of 90%. Meanwhile, the ILs with shallow maximum Kernel density values or close to 20% represent lands with less intense mining, as with the Munduruku,

Aripuanã, and Yanomami ILs.

Only 5 of the 14 ILs with the illegal mining presence have inhabitants within these areas. Of these, only 2 had 'alluvial mining' communities. According to this 2022 representation, Yanomami has the most affected inhabitants, with 2553 belonging to Indigenous communities. The second one was Kayapó, with 2079 inhabitants affected. However, 32% of these belong to the alluvial mining type of locality. The third was Munduruku with 325 inhabitants who live in 'aldeia' type localities. Fourth place is the Tenharim of Igarapé Preto, with 103 residents affected. However, 28 live in 10 households classified as alluvial mining settlements ("garimpo"). Finally, Sai Cinza has two households and 16 inhabitants living within hostpots.

This study answers the research questions raised but also opens the way for future studies. By integrating census and remote sensing data, this study elucidates socio-environmental problems that illegal mining activity causes. It can support government decision-making and legislative actions to protect the environmental, cultural, and social wealth that ILs represent. Because our findings were limited on the indigenous people living within 250 m distant from mining activity, in the future, further investigation is suggested about the indigenous community that live within the watershed where mining activity is placed to understand also possible indirect impact from the mining activity. This is particularly important for alluvial mining activity that directly impacts the rivers.

5. CONCLUSIONS

This study identified the hotspots of illegal mining in ILs within the Amazon biome and characterised the domiciles affected by this activity in 2022. Kernel density determined the intensity of illegal mining within ILs and identified spatial distribution patterns of alluvial mining. By complementing these results with census data, the affected indigenous communities and the mining settlements of those who carry out this extractive activity were located. The results contribute to governmental and environmental decision-making for monitoring mining activities within Indigenous Lands.

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