BX18 - Optimization of the Environmental Recovery Process - An Alternative for Rehabilitating Failures in Recovered Areas

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Abstract

The Program for the Recovery of Degraded Areas - PRAD is one of the most challenging processes for a bauxite mine. After executing environmental recovery activities in large mined areas, some locations may present less satisfactory results, becoming areas of exposed soil (islands without vegetation), which occur due to factors related to the terrain conditions. This work aimed to make a new methodology of area recovery feasible, specifically targeting the islands without vegetation with satisfactory coverage like the other areas rehabilitated after mining. The objective is to return to society a forest as close as possible to those found in the Paragominas region in Pará. The initially proposed technique for the recovery of islands without vegetation was nucleation, a methodology that reuses the residue generated in vegetation suppression and disposed of in already-mined areas. However, the logistics of transport, equipment availability, and mainly safety stimulated the search for a different operational strategy. The analysis focused on a methodology for recovering mined areas that corresponded to environmental expectations. The development of the new soil preparation methodology provided favorable conditions for vegetation development in the fault islands, achieving the initial objective of fully rehabilitating the degraded areas.

Keywords: Environmental restoration, Sustainability, Safety, Process optimization, CO_2 emission reduction.

1. Introduction

With the evolution in research and technology, geological knowledge advances exponentially with new discoveries of metallic mineral deposits. In Brazil, mining occurs more frequently in ecologically important regions, such as tropical forests, savannahs, mangroves and coastal areas, given the great diversity of ecosystems in this country. These discoveries positively influence the country's economy, in addition to promoting advances in the industrialization process [1].

The Brazilian mineral production consists of 89 % of its total value of metallic substances, moving R$ 312.9 billion. Among this total, the expressive participation of 80.1 % of iron stands out and aluminum assumes the participation of 1.74 % in the commercialized production scenario, having as base year 2021, according to the national mining agency - ANM [2]. Even with the positive balance for the Brazilian economy and its productive potential with high quality bauxite reserves, mining activities are not exempt from legal and environmental obligations. During the licensing process, it is necessary to propose strategies for mine closure, a mandatory step for the approval of mining projects in Brazil, undergoing approvals and inspections by the competent environmental agencies, in order to obtain the authorization for mineral exploitation. Among the strategies is the Degraded Areas Recovery Plan - PRAD [3].

Mineração Paragominas S. A. - MPSA, a company of the Norsk Hydro group, a Norwegian company integrated in aluminum production and with a global presence, is among the main producers of bauxite, the raw material for aluminum, in Brazil [4]. The exploitation of the mineral has increased in response to the global demand for aluminum. The Brazilian Aluminum Association - ABAL [3] - conducted a survey on global aluminum consumption and found that there was an increase of 10.9 % in relation to 2020, reaching the highest volume ever recorded since the beginning of the survey, the year 1972. After the extraction of the ore of interest, the areas are available for the beginning of the environmental recovery process [5].

Each site that must be vegetated has its specificity and, therefore, a more appropriate recovery technique. It is necessary to seek alternatives according to the specific characteristics of each area, thus obtaining satisfactory results. As recovery practices for areas altered by open-pit mining activity on flat lands, the most used alternatives and techniques are: direct planting with native tree species and natural regeneration [6].

The MPSA has also implemented a third technique, nucleation [7]. According to environmental legislation, mining companies are required to restore degraded areas after the extraction of minerals of interest has ceased [4]. In anticipation of social commitments and with the aim of restoring ecological functionality and enabling the reintegration of affected ecosystems, MPSA has undertaken to recover within a maximum period of three years the mined areas. One of the challenges in this scenario is to simultaneously develop innovations for the recovery of degraded areas, considering the sustainability of the mining activity itself, reducing costs and ensuring the mitigation of negative environmental impacts caused by mineral exploration [8].

2. The Project Area

The project area is located on the bauxite deposit belonging to the Norwegian group Norsk Hydro (3° 15' 38"S e 47° 43’ 28” W) a 70 km of the seat of the municipality of Paragominas (2° 59' 42" S - 47° 21' 10" O), Northeast region of the State of Pará - Brazil [9]. The MPSA mine is composed of two bauxite deposits on contiguous plateaus called Miltonia 3 (M3) and Miltonia 5 (M5), Figure 1.

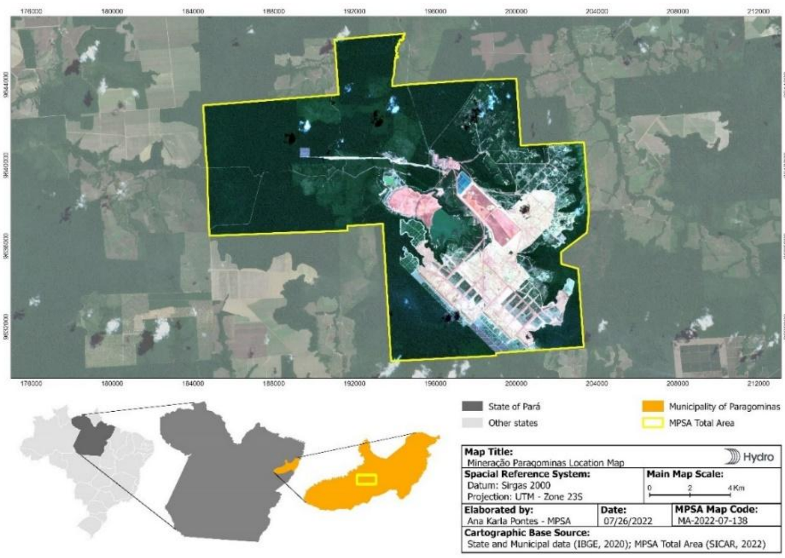

Figure 1. Mineração Paragominas location map.

The mining method adopted by MPSA is strip mining, an open-pit mining technique very characteristic of ores deposited close to the surface with sequenced advancement of area and increased DMT (average transportation distance). The process begins with the plant suppression activity and then the topsoil is transported to the already mined areas that will be rehabilitated by the nucleation method. The sequence of mining activities takes place with the removal of the overburden (between 2 and 18 m) and the extraction (~2 m) and transportation of the ore until it enters the beneficiation process. After bauxite extraction, the terrain is leveled to receive the topsoil (~30 cm layer). And it is spread on its surface [10] as in the illustrated summary, Figure 2.

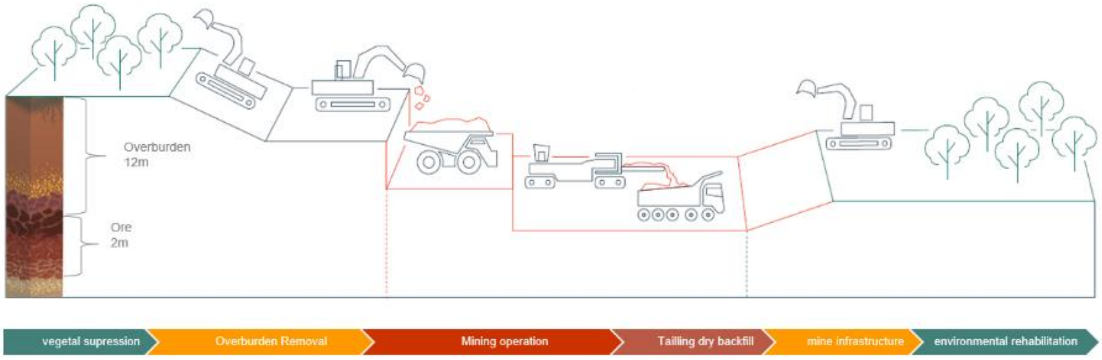

Figure 2. Illustration of the bauxite mining process.

Based on the Environmental Control Plan - PCA of MPSA, which determines the monitoring of vegetation in areas that are in the process of ecological recovery (PLANO DE RECUPERAÇÃO DE AREAS DEGRADADAS - PRAD, 2006) and in the search to achieve the "State of the Art" in environmental restoration, monitoring is carried out - survey and classification of areas that have not achieved the expected result. These sites have deficiencies in their ecological recovery process. To perform this analysis, the MPSA uses the Normalized Difference Vegetation Index - NDVI methodology, in short, it is a form of area mapping, which uses remote sensors to determine the conditions of the vegetation [10]. Figure 3 highlights polygons identified with anomaly in environmental recovery.

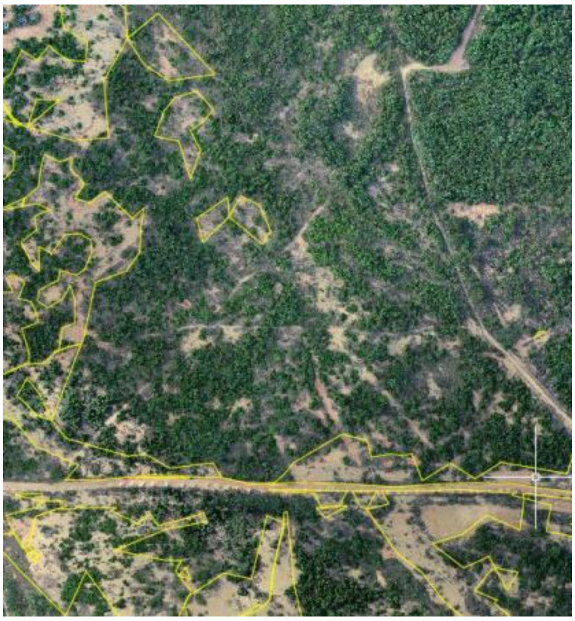

Figure 3. Monitoring of the area after 5 years.

3. Methods

The work was carried out in an area undergoing environmental recovery after bauxite mining. After evaluating the monitoring of the recovered areas, 83 hectares with vegetation anomalies were classified in 2021. This means that the company needed to return to these sites and act to recover them. Initially, it was determined that the nucleation technique would be used, which consists of creating nuclei or islands of vegetation with species with the ecological capacity to recover the environment, in a way that facilitates the occupation of this area by other species [11]. In the MPSA, these cores are formed by branches and roots from plant suppression and organic soil.

Initially, it was determined that the nucleation technique would be used, which consists of the disposal and surface reuse of organic soil and woody residues such as branches and roots. Material from plant suppression rich in nutrients and seeds is transported to degraded areas and accommodated in the form of islands or nuclei with the aim of creating small habitats and inducing environmental heterogeneity [11]. Seen from above, the nucleated areas with organic soil and zigzag branches resemble a chessboard and these groupings give the technique its name.

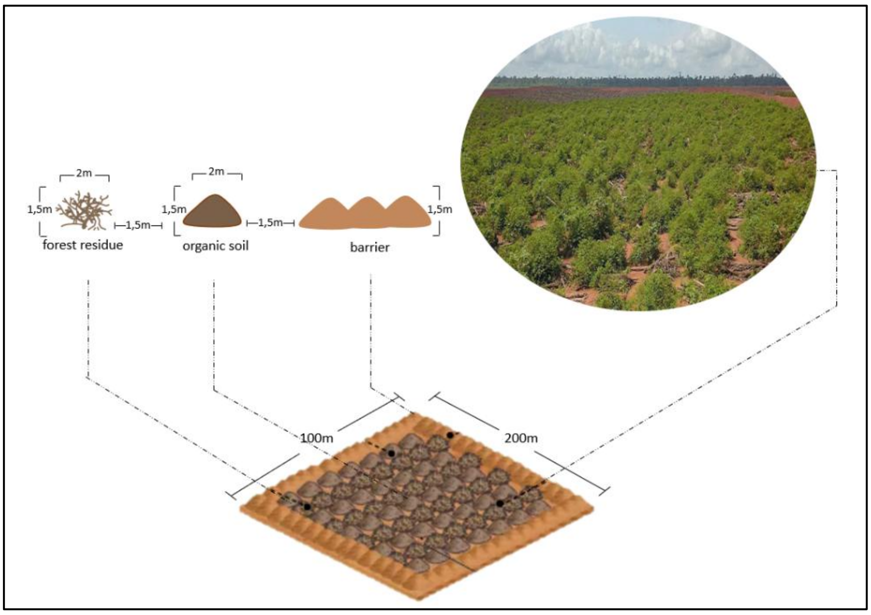

Figure 4. Cores arranged in a zig zag pattern.

The nuclei create shelter and the decomposition of the material is an attraction for the fauna that through the visitation of these areas, contributes with the deposition of dispersed seeds of new species that provides a more suitable environment for the emergence of other species [11]. Nucleation favors the density of vegetation cover, collaborating with the process of forest restructuring and registering positive results. One of the characteristics of this technique is the transportation of forest residue between the areas of plant suppression to the degraded areas, and therefore the need for a fleet of equipment destined for this activity.

The planning for nucleation execution in the 83 mapped hectares with a transport distance of more than ten kilometers dimensioned a fleet of 65 equipment between trucks, loading equipment, support equipment and crawler tractors and, therefore, 65 people directly involved in the operation of machines. In addition, approximately 100 hectares of areas for vegetation suppression were identified for the opening of roads for the construction of safe access to the "failure areas" (name given to the areas identified with the need for intervention that resembles the terrain where the vegetation cover has generated a failure or bare area) and maneuvering areas for the tipping of trucks.

The analysis studied demonstrated potential risks of accidents and exposure of people in collisions, overturning, trampling and other risks, high negative environmental impact as a result of the accuracy of plant suppression in previously recovered areas in good conditions of vegetation development, in addition to the possible compromise of environmental recovery goals and negative image exposure, therefore.

Through a dedicated team (multidisciplinary group responsible for the development of improvements and strategic decisions related to a process) the change of the recovery technique of the 83 hectares of failure areas was defined. The traditional planting technique deliberated as the most suitable for the scenario described demanded the development of a new method of land preparation due to the characteristics found of high soil compaction, loss of nutrients by the leaching process, absence of vegetation cover and erosive processes caused by surface waters that form small lines along the exposed soil, concentrating a greater amount of water and adding more runoff speed, which causes the loss of coverage of surrounding areas.

The methodology implemented consists of removing the topsoil with a depth of approximately 1 m. For the development of the technique, a crawler tractor (equivalent model Caterpillar D6) is used, Figure 5.

Figure 5. Stages of area preparation with new method.

In this way, the equipment achieves a higher level of soil decompression, in depth and soil restructuring when compared to traditional procedures that use only the rear implement (ripper) that reaches a maximum penetration of 50 cm in the soil.

The new method of soil preparation consists of 5 stages: 1. initial scarification - decompression of soil structures with high level of compaction; 2. cutting - removal of the surface layer to deepen the decompression of the soil; 3. landfill - restructuring of the soil layer; 4. leveling - topographic correction of the slopes of the land with the intention of avoiding erosive processes; and 5. final scarification - decompression of compacted stretches by the energy exerted in the displacement of the crawler tractor.

The 5 stages of the technique developed for the rehabilitation of faults in recovered areas are shown in Figure 6, below.

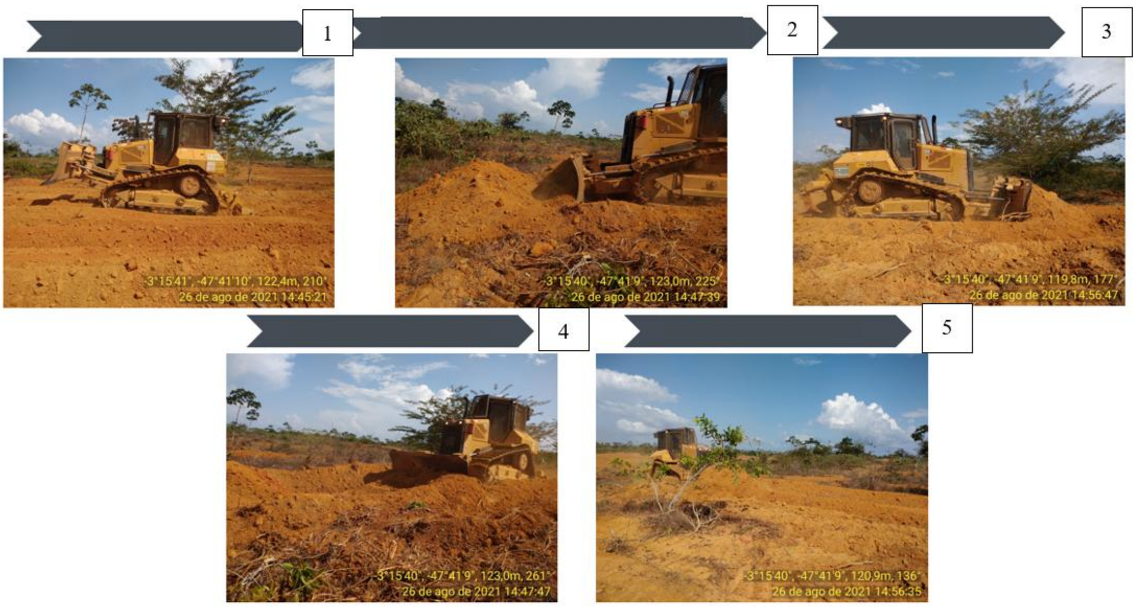

Figure 6. Stages of area preparation with new method.

In order to avoid the compaction process, causing damage to the physical quality of the soil, among them, mechanical resistance to penetration, reduction of macroporosity, water infiltration rate and gas exchange in the soil, favoring susceptibility to water erosion [12].

Figure 7. Left: before. Right: after.

4. Results

4.1 Technical Assessment

As a result, in the structure of the soil we have: 1- Less compaction; 2- Greater water retention in the soil; 3- Elimination of erosive processes. In addition to the selection of the most adapted species for rustic environments, increasing the chances of success of the technique. Figure 8 shows the breakdown of these results.

Soil compaction is defined as the increase in density and decrease in porosity when it undergoes continuous pressure or stress [13]. With less compaction, facilitating the root development of vegetation.

High compaction inhibits soil infiltration, hindering crop development, compromising water and nutrient uptake [14]. With greater retention of water in the soil, increasing water availability for plants in the dry period.

Soil erosion is a major threat to terrestrial ecosystems, sui generis for the sustainable development of agriculture, and represents a serious environmental problem [12]. The elimination of erosive processes, avoiding the loss of material by sedimentation.

Figure 8. Improvements in soil preparation.

Decompaction of the soil reduced the density and increased the surface roughness, hydraulic conductivity and water infiltration rate in the soil [15]. Assisting in the development of the vegetation installed in the area after bauxite mining activity.

4.2 The Use of Equipment

The change of strategy of the method of recovery of areas, made it possible to achieve gains in operational safety with the reduction of 94 % of the number of equipment for execution of the technique. A fleet of 4 crawler tractors prepared the entire mapped area, while the nucleation technic will require 65. The reduction of equipment favored less exposure of people to risks of operational accidents.

4.3 Fuel Consumption

The reduction in the number of equipment needed to carry out the activity made it possible to avoid the consumption of 900 000 L of diesel with the operation of machines, from 2409 to 124 L.

This reduction in consumption avoided 95% of the emission of greenhouse gases (CO_2) into the atmosphere in an annual cycle (6 months of operation) of the activity.

4.4 Vegetation Suppression Activity

The method developed for soil preparation for planting allowed the execution of the activity without requiring plant suppression to open accesses and maneuvering areas for trucks. The suppression activity was eliminated from this process, resulting in less impact and preservation of areas already in the process of advanced recovery.

4.5 Financial Saving

The reduction in the operating cost of the activity caused by the reduction of equipment, contracting of services, reduction of fuel consumption and the number of steps performed ensured a financial expenditure 63 % compared to the execution of the nucleation technique with transportation of more than 10 km. The cost, applied to the same reclamation area, for nucleation that was 12.7 million BRL, reduces to 4.6 million BRL. The savings achieved with the new methodology was around 8 million BRL (~1.5 million USD).

5. Conclusion

The implementation of new methodology for rehabilitation of reclaimed areas with occurrences of fault islands at high transportation distances provided gains in different technical aspects - soil restructuring, reduction of equipment and exposure of people, reduction of fuel consumption and CO_2 emissions, preservation of reclaimed areas in the surroundings, satisfactory rehabilitation of fault islands, as well as financial savings.

The effectiveness of the soil preparation technique with tracked tractor ensured competent performance in the development of planting, the monitoring of the mapped areas shows significant evolution in the growth of vegetation cover. The higher productivity of the new methodology conferred 220 % of the planned target (83.2 ha), 183 ha of recovery of area with deficiency in the development process were executed.

The optimization carried out is in line with the commitment of companies to pursue the industry's decarbonization goals, with the social responsibility of returning fully recovered areas to society and with the search for a more viable and sustainable society. It has the potential to be multiplied or adapted in other mining companies, as well as to inspire new development tests of the environmental recovery process.

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