Transforming Organic Waste into Forests

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Abstract

Reforestation and waste management are critical environmental challenges in mining, especially when topsoil is unavailable for reclamation, and incineration of organic waste proves to be an unsustainable option. This study aimed at improving the conditions of barren soils through the application of processed organic waste, creating a technosol that enhances the reclamation of mined areas. The experiment involved processed organic waste applied at three dosages (10, 20, and 40 t/ha) and a control, with five replications in a randomized block design. Guandu beans (Cajanus cajan) were used as an indicator plant. Physical properties (density and total porosity) and chemical properties (organic carbon) were evaluated in the 0–5, 5–10, 10–20, and 20–40 cm soil layers, as well as dry biomass and plant height at 6 and 14 months. The results showed that doses of 20 and 40 t/ha of organic waste significantly increased plant height and dry biomass compared to the control. Statistically, significant differences in organic carbon were observed in the 0–5 cm layer (p-value < 0.05). Although density and total porosity did not respond significantly to the doses of organic matter, treatments with 20 and 40 t/ha of organic waste exhibited better performance in soil recovery. Incorporating 40 t/ha of organic waste into sterile soil had a positive effect on organic carbon. These findings suggest that the application of organic waste, particularly at doses of 20 and 40 t/ha, is promising for increasing soil carbon content and dry biomass production. Furthermore, since 2015, mining has avoided the incineration of over 1165 tonnes of waste, converting it into 303.75 t of soil-enriching organic material, contributing to sustainability, reducing CO_2 emissions, and generating significant cost savings.

Keywords: Rehabilitation of mined areas, Carbon emission reduction, Soil carbon, Organic residue, Technosol.

1. Introduction

Hydro Bauxite & Alumina is a leading company in aluminium and renewable energy, committed to a sustainable future. Its goal is to create viable societies by developing industries that matter to people and society. [1], Hydro Bauxite & Alumina has transformed natural resources into innovative solutions and businesses, creating a safe workplace for 33 000 employees across more than 140 operations in 40 countries.

In Brazil, Hydro operates across the entire aluminium value chain, employing nearly 7000 people. From bauxite extraction and renewable energy generation to alumina refining, aluminium production and extrusion, Hydro supplies essential materials that drive innovation and sustainability in key sectors such as construction, automotive, and packaging.

Paragominas is an important part of Hydro Bauxite & Alumina's strategy as a global supplier of innovative and sustainable aluminium solutions. The mine in Paragominas is responsible for bauxite extraction, located about 70 km from the municipality center, in northeastern Pará, at the Miltônia 3 Plateau [1].

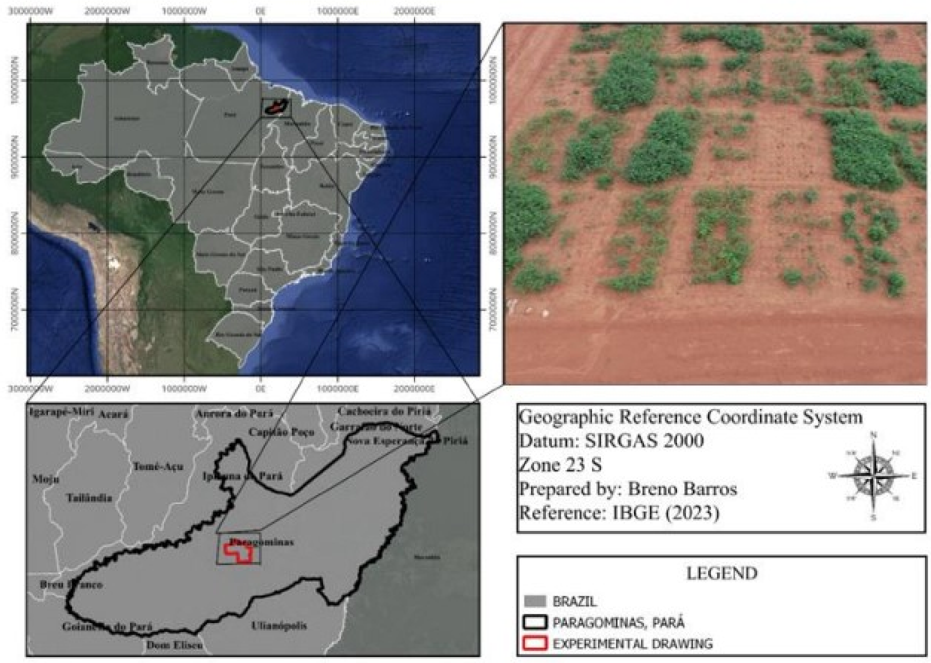

Figure 1. Location of Paragominas Mining – Hydro, according to IBGE (2023).

Hydro Bauxite & Alumina brings an innovative initiative for mined land rehabilitation: Technosol, a project that transforms organic waste, that would otherwise be incinerated, into nutrient-rich material for sterile soils (overburden), called "organic cake" [1].

The Paragominas operation began in 2007 and currently moves about 16 Mtpa, with an annual production of 11.4 Mt of bauxite. The material is transported through a 244-kilometer pipeline to Barcarena — the first in the world designed for this purpose. By 2024, the company had promoted the environmental rehabilitation of 3467 ha [1].

Currently, Hydro Bauxite & Alumina uses three techniques for mined land rehabilitation: (1) Traditional Planting, involving seed collection, seedling production, and planting; (2) Induced Natural Regeneration, involving the transport and spreading of organic soil in the area to be rehabilitated; and (3) Nucleation, involving the transport of organic soil and forest residues (branches and roots) to the areas to be rehabilitated. All these techniques rely on the use of organic soil, a natural and limited resource.

This more favourable environment contributed to greater plant species growth, as it promoted suitable conditions for aeration, nutrient availability, and root system development [26].

However, the recovery of chemical and physical properties at greater depths in technosols may require more time due to the absence of organic sources and ongoing pedogenetic processes.

It can be highlighted that the formation of technosols from residual soils of bauxite mining, combined with organic matter sources derived from the operation's own waste, such as those generated in the dining facilities, proved to be an effective and efficient strategy to improve the growth conditions of Cajanus cajan and restore the biome of mined areas. This technique, based on the concepts of ecological engineering, represents a viable alternative from both economic and environmental perspectives for the rehabilitation of areas altered by mining, where residual soils typically exhibit low physico-chemical quality.

Furthermore, the use of this approach contributes to the reduction of CO_2 emissions, since the organic waste used is no longer incinerated. The success of this strategy led Hydro Bauxite & Alumina to expand the production of organic cake to two additional units in Brazil.

Another relevant point in the bauxite supply chain is that other major mining companies in the sector have adopted technologies similar to Tailings Dry Backfill, aiming to reduce the construction of new dams. Since mining companies plan in advance, they are likely to face challenges with areas no longer required for dam installation and lacking topsoil to initiate environmental recovery. In this context, the use of technosols emerges as an effective alternative to address these challenges.

Among the tested doses, 20 t/ha of dehydrated organic matter proved to be the most effective and efficient option. It provided significant gains in plant height and dry biomass yield, similar to the higher dose of 40 t/ha, but with half the input cost. This makes R20 the recommended dose for large-scale application in post-mining soil rehabilitation projects, offering the best balance between biological performance and economic viability. Unlike standardized industrial inputs, there is no "supermarket" where Technosol can be purchased – it must be carefully created in the field. Identifying the appropriate proportion is essential to ensure sustainability, optimize the use of limited organic material, and maximize the impact of land reclamation efforts. This pursuit of efficiency recalls Greco-Roman architecture, when massive columns were built due to a lack of knowledge about material resistance. In similar fashion, this study helps "calculate the column's diameter" – that is, to technically calibrate the amount of organic amendment required to support vegetation growth and ecological recovery. Knowing how much to apply is as crucial as the application itself. Like spreading butter on bread, the challenge is to apply the same amount more evenly over a larger area. This work provides concrete data to help the mining and aluminium industries apply that principle with technical precision.

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