Selection of Key Plant Species for the Rehabilitation of Areas with Constructed Soils after Bauxite Mining in the Amazon Region

Jonilton Paschoal [1], Vicente Sousa [2], Letícia Silva [3] and Igor Gonçalves[4]
1. Environment Manager
2. Environment Analyst
4. Forest Engineer
Mineração Paragominas S.A (Hydro Paragominas), Paragominas/PA, Brazil
3. Forest Engineer of Egis - Engenharia e Consultoria Ltda, Cotia-SP, Brazil
Corresponding author: jonilton.paschoal@hydro.com

Abstract

This study selected nine plant species that presented resilient behavior to environments classified as difficult areas for vegetal recovery in constructed soils after bauxite mining, due to low nutrients availability, which are necessary for the plant development. The selected species are native from the amazon biome and are produced in Hydro Paragominas' nursery. Hydro Paragominas is part of the Norsky Hydro group, located at the municipality of Paragominas, state of Pará, North Brazil. In this bauxite mine, forest recovery over mined areas is performed since 2009. The work aims to implement natural mimetics by starting ecological succession in the environment where natural regeneration will be induced, or selected species will be planted. In 2020, by applying literature criteria based on the species ecological group, for the classification of pioneer species through interactive data visualization software product developed by Microsoft, it was possible to select species produced in Hydro Paragominas' nursery. On field observation was held to verify areas rehabilitated from 2009 to 2014, where those species were planted or had grown spontaneously through natural regeneration. Amongst 63 species listed on Power BI, nine pioneer species from the Amazon region, were selected: Parkia platycephala Benth, Inga edulis Mart, Inga laurina (Sw.) Willd, Inga alba (Sw.) Willd., Hymenaea courbaril L., Clitoria fairchildiana R.A. Howard, Byrsonima verbascifolia (L.) DC., Byrsonima crispa A.Juss., Cecropia pachystachya Trécul. This study suggests the larger seedlings production of the nine species selected for the plantation on areas yet to recover, which will help preventing leaching and erosion processes in rehabilitated areas.

Keywords: Mined areas rehabilitation, Pioneer species, Nutrient deficient areas, Bauxite mining, Rehabilitation of degraded areas.

1. Introduction

As humanity evolves with the help of scientific research and technology, geological knowledge advances with discoveries of new mineral deposits. These discoveries have a positive influence on Brazil's economy promoting industrial advance [1]. About 80 minerals are mined in Brazil, attending both domestic and foreign markets [2].

Currently, 11 substances are responsible for 99.7% of the sector production value, as in: aluminum (bauxite), copper, chromium, tin, iron, manganese, niobium, nickel, gold, vanadium, and zinc [1]. The combined production reached the value of 193.5 billion reais in 2020. The Brazilian Aluminum Association - ABAL [3] carried out a survey on the world's consumption of domestic aluminum, founding out a significant increase of 1,583.9 thousand tons; this amount represents a raise in 10.9% compared to 2020 and is now recorded as the largest volume in market research history, since in 1972. Brazil occupies the 4th position among the world's largest producers of bauxite, 3rd position in largest mineral reserve and 3rd place among the largest alumina producers [4]. Besides, Brazil hosts high-quality bauxite deposits [5].

The State of Pará stands out for locating 90% of the bauxite deposits in Brazil (Pinheiro et al. 2016). Paragominas and Juruti are the municipalities that have the largest bauxite deposits in Pará [1].

As much as the mining sector contributes positively to Brazil's economic balance, mining companies are not exempt from legal obligations. Legislation has been improving; for example, mining projects are obliged to submit its Mine Closure Plan during the licensing process, including a rehabilitation plan for degraded area [6].

According to Law No. 6,938 of 1981 that established the National Environmental Policy [7], the interested party is responsible to provide adequate indemnification (when suitable) and to rehabilitate the altered area. Decree No. 97.632/1989 also determines that "*Rehabilitation shall aim the return of the degraded site to a functional form, in accordance with a pre-established plan for land use, to achieve environmental stability*" [8].

Environmental recovery is a multidisciplinary process that aims to achieve excellence and aggregate knowledge in Ecology, Forestry, Soil Science, Economics and Social Sciences, among others [9]. As practices for mined areas rehabilitation, the most used techniques are No-till with fast growing native tree species and Natural Regeneration [10]. The possibility of selecting species, by the no-tillage method of seedlings, is a fundamental factor for ecological restoration practices, which is an enabler for including species from different ecological groups and conservation status [11].

Located in the State of Pará, Brazil, Hydro Paragominas started to execute its Degraded Areas Recovery Plan (PRAD) in 2009, following the guidelines defined on the company's Environmental Impact Assessment (EIA) [12]. Reforestation techniques were resumed in traditional planting and natural regeneration induction, and in 2013 the company started to perform a third technique named as nucleation.

To improve rehabilitation practices, in 2020, a study was conducted aiming to select the most successful species that were found in the rehabilitated areas, focusing on the patches with poor vegetation cover. Species selection is a fundamental factor capable to determine multiples outcomes; in this way, it is important to consider the possibilities of different ecological groups and conservation status [11]. The results are meant to determine in which species the investments in seedling production should be directed, since those species would have high potential to favor the advance of the forest succession process in environments with low availability of nutrients, such as constructed soils after bauxite mining.

2. Experimental

The work was carried out in Paragominas, northeast region of Pará [13], at Hydro Paragominas' site (3° 15' 38"S and 47° 43' 28" W). The soil is characterized by a predominance of Dystrophic Yellow Latosol, medium to very clayey texture, according to the soil classification [13]. The Dystrophic Yellow Latosol are soils of low fertility (naturally), low cation exchange capacity - CTC and low levels of base saturation [15]. In addition, the soil presents high weathering, they are deep, drained soils, with very low natural fertility. It has a subsurface described as a thick horizon B latosol, with low content of easily alterable primary minerals [16].

In 2020, Hydro Paragominas carried out a quality assessment on 1,363.28 ha of rehabilitation areas, whose reforestation techniques were applied between 2009 and 2014. Of this total, using the Normalized Difference Vegetation Index - NDVI in satellite image, were identified 170.79 ha with poor vegetation cover and/or presence of exposed soil [17] (Figures 1 and 2).

6. References

1. Departamento Nacional de Produção Mineral – DNPM. Anuário mineral estadual do Pará, 2017., site, https://www.gov.br/anm/pt-br/centrais-de-conteudo/publicacoes/serie-estatisticas-e-economia-mineral/anuario-mineral/anuario-mineral-estadual/para/amest-2017_pa_v1/view (accessed on: 12/10/2021).
2. Alberto Brasil Neto, et al., Natural regeneration for restoration of degraded areas after bauxite mining: A case study in the Eastern Amazon, *Ecological Engineering*, 171, 106392, Brasil, 2021.
3. Associação Brasileira do Alumínio - ABAL: https://abal.org.br/noticia/consumo-de-produtos-de-aluminio-em-2021-registra-o-maior-volume-historico/ (accessed on: 12/10/2021).
4. José Cardoso, et. Al., A indústria do alumínio: estrutura e tendências, *BNDES Setorial*, RJ, n. 33, p. 43-88, mar. 2011 Available at: http://web.bndes.gov.br/bib/jspui/handle/1408/2499 (accessed on: 10/18/2021).
5. Revista do Aluminio. Especial Mineração de Bauxita: como é feita a extração e qual a importância da atividade para o Brasil. Revista do alumínio, ed. 55; set, 2019. Available at: https://revistaaluminio.com.br/especial-mineracao-de-bauxita-como-e-feita-a-extracao-e-qual-a-importancia-da-atividade-para-o-brasil/ (accessed on: 07/15/2021).
6. Paulo Soares, Zuleica Castilhos, Recuperação de áreas degradadas pela mineração no Brasil. In: Jornada do programa de capacitação interna do cetem, 04. Rio de Janeiro, *Anais CETEM/MCTI*, 2015.
7. BRASIL. Constituição. LEI Nº 6.938, DE 31 DE AGOSTO DE 1981. Dispõe sobre o estabelecimento da Política Nacional do Meio Ambiente, da Lei n° 6.938. Brasília, DF: Senado Federal: Centro Gráfico, de 31 de agosto de 1981. Available at: http://www.planalto.gov.br/ccivil_03/leis/l6938compilada.htm (accessed on: 08/13/2021).
8. BRASIL. Constituição. DECRETO NO 97.632, Dispõe sobre a regulamentação do Artigo 2°, inciso VIII, da Lei n° 6.938. Brasília, DF: Senado Federal: Centro Gráfico, de 10 de abril de 1989. http://www.planalto.gov.br/ccivil_03/decreto/1980-1989/D97632.htm (accessed on: 08/13/2021).
9. Instituto Brasileiro de Meio Ambiente e Recursos Naturais Renováveis - IBAMA, *Manual de recuperação de áreas degradadas pela mineração: Técnicas de revegetação*, Brasília, 1990. 13p/S. accessed on: 08/15/2021.
10. Pedro Brancalion, Ricardo Rodrigues e Sergius Gandolfi, Restauração florestal. Oficina de Textos. Em 2015.
11. Rafael Salomão et. Al., Dynamics of natural tree regeneration after strip-mining in the Amazon, *Bol Mus Para Emílio Goeldi Ciências Nat* 85–139, Brasil, 2007.
12. Rodrigo Barbosa, et al, Restoration of degraded areas after bauxite mining in the eastern Amazon: Which method to apply? Available at: https://www.sciencedirect.com/science/article/abs/pii/S0925857422001008?via%3Dihub (accessed on: 06/22/2021).
13. Mineração Vera Cruz S.A. – MVC.: Estudo de Impacto Ambiental - EIA - Lavra e Beneficiamento de Bauxita, Relatório Técnico. Ref.: ALUV-A-001-006.DOC. P. 424 a 429. accessed on: 01/22/2021.
14. Instituto Brasileiro de Geografia e Estatística – IBGE. Localização dos municípios do Brasil. Available at: https://www.ibge.gov.br/busca.html?searchword=Paragominas (accessed on: 02/02/2021).
15. Santos Rodrigues, et. al, Caracterização e classificação dos solos do município de Paragominas, Estado do Pará. Belém: Embrapa, 2003. 51 p. (Série Documentos, n.162)
16. Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA. Os solos do brasil. Available at: https://www.embrapa.br/tema-solos-brasileiros/solos-do-brasil. accessed on: 07/20/2021.

17. Leonardo Tullio, et. al., Formação Classificação e Cartografia dos Solos. Available at: https://www.atenaeditora.com.br/wp-content/uploads/2019/09/E-book-Formacao-Classificacao-e-Cartografia-dos-Solos.pdf. E-book. CAP, 1. P, 17. (accessed on: 08/13/2021).
18. Mineração Paragominas. S. A. PLANO DE RECOMPOSIÇÃO DE VEGETAÇÃO DO PRAD DE 2009 a 2014, 2017. Relatório Técnico. accessed on: 22/01/2021.
19. Jackeline Lorenzo, et. al.; A fitossociologia para recuperar área de lavra, *Revista Ambiente*, vol. 8 (1), 26-34. Brasil. Em 1994.
20. Oliveira Knowles, et. al, Amazonian Forest restoration: an innovative system for native species selection based on phenological data and field performance indices. *The Commonwealth Forestry Review*, 230-243, Porto de Trombetas, Pará, Brasil, em 1995.
21. Melinda Moir, et. al, Restoration of a forest ecosystem: The effects of vegetation and dispersal capabilities on the reassembly of plant-dwelling arthropods. *Forest Ecology and Management*, 217(2-3), P. 294-306. Em 2005.
22. Letícia Silva, Relatório Anual PRAD 2021. Programa de Recuperação de Áreas Degradadas, Programa de Salvamento de Germoplasma e Programa Plantio Compensatório. Mineração Paragominas S.A. Relatório Técnico. Paragominas, PA: Egis – Engenharia e Consultoria. 2022.
23. Walmer, Martins et. al, Survival, growth and regeneration of forest species in mining areas in the Eastern Amazonia. Scientia Plena, Vol. 16, Num. 6. Em 2020.