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Soil recovery in a chronosequence of revegetated coal mine spoils in Colombian drylands: a view from the assessment of physical-chemical and biological properties

Jeiner Castellanos-Barliza [a,b,*], Juan Diego León-Peláez [a]

[a] Grupo de Investigación en Restauración Ecológica de Tierras Degradadas en el Trópico, Universidad Nacional de Colombia, Calle 59A 63-20, Medellín 050034, Colombia

[b] Grupo de investigación en Restauración Ecosistémica y Ecología Urbana, Facultad de Ciencias Básicas, Universidad del Magdalena, Carrera 32 #22-08, Santa Marta D. T.C.H., Magdalena 470002, Colombia

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ABSTRACT

Characterizing changes in soil properties is essential to understand the effect of land rehabilitation practices and the mechanisms that drive such changes. The objective of this study was to evaluate the recovery of physical-chemical and biological properties of Technosols with increasing rehabilitation age in a chronosequence of dry forests (7, 10, and 21 years) in the El Cerrejón open-pit coal mine (La Guajira, Colombia). Based on previous studies that demonstrated a greater effect of surface change on the physicochemical properties of soils, composite samples taken at two depth levels (0–3 cm and 3–20 cm) were analyzed for each site. The studied properties improved over time, increasing significantly with respect to non-rehabilitated sites, mainly near the surface (0–3 cm). Particularly, after seven years, the increases in soil N content and soil P solution were significant (32% and 71%, respectively). The increased structural and functional development of the vegetation over time led to increased inputs of organic materials via fine litterfall. Overall, soil organic matter (SOM) ranged from 63 to 89% in the rehabilitated sites compared with a reference mature dry forest. Increased SOM is a key indicator of recovery in degraded mine spoils, as it has an outsized ability to influence other soil properties. This represents a positive result for the revegetation/restoration strategy applied at the El Cerrejón mine.

1. Introduction

Open-pit coal mining represents one of the most important activities in some countries for regional or local economies, nevertheless it has also been shown that its negative impacts can affect these communities, and the environment in general (Martins et al., 2022). Among the most significant impacts are drastic changes in topography and landscape, the destruction of vegetation, loss of biodiversity, alteration of surface hydrological regimes, nutrient cycling, and soil properties (Castellanos-Barliza et al., 2019; Zapico et al., 2021). Topsoil is particularly affected because genetic soil horizons are removed and mixed during extraction (Ngugi et al., 2018). Subsequently, these soils are stored and reused to reconstruct landscapes in the next stages of the rehabilitation process, negatively altering their physical, chemical, and biological properties (Mushia et al., 2016).

The rehabilitation of these post-mining areas has been achieved to a greater extent through the application of revegetation and soil substrate management programs (Bucka et al., 2021; Sudarmadji and Hartati, 2021). In particular, revegetation can be employed by applying various alternatives, initially using herbaceous cover crops or an association of grasses and legumes, and subsequently, mixed plantations of native or exotic fast-growing tree species, timber, and deciduous species, etc. (Gualdrón, 2011; Mukhopadhyay and Masto, 2022; Thakur et al., 2022). These revegetation methods have been shown to reverse degradation processes of some soil properties and improve key soil quality properties such as organic carbon content, microbial biomass, and nutrient availability, leading to an increase in primary productivity at the ecosystem level (Bateman et al., 2021; Bucka et al., 2021; Chaturvedi and Singh, 2017; Hamidović et al., 2013; Parsapour et al., 2018; Zhang et al., 2018b).

The benefit of vegetation on substrate chronosequences in mining waste has been demonstrated by numerous studies worldwide (Buta

* Corresponding author.
E-mail address: jcastellanos@unimagdalena.edu.co (J. Castellanos-Barliza).

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