Original Research Article

Quantification of Root Biomass in Post-Mining Areas in the Municipality of Capitão Poço – PA, Brazil

ABSTRACT

The present work aimed to quantify the concentrations and biomass stock of fine and coarse roots, in three areas in the municipality of Capitão Poço-PA, Brazil. The areas used were degraded area, recovery area and native forest. For soil sampling, 24 trenches were opened, measuring 70 x 70 x 100 cm. In these trenches, soil samples were taken at depths 0-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-80 and 80-100 cm and sieving was carried out. All roots and other underground plant structures that remained in the sieve were collected by manual collection. The roots were separated into two diameter classes: fine roots ≤ 5 mm and thick roots > 5 mm, kiln dried and weighed. In the analysis, higher concentrations of coarse and fine roots were observed in an area of native forest at depths of 0-10 and 10-20 cm. In the areas analyzed in this study, the root density in the topsoil of 0-10 cm was mainly composed of fine roots. In the three areas analyzed in this study, it was observed that from a depth of 10-20 cm there were decreases in the concentrations of coarse roots. The area under recovery approached the area of native forest in the concentration of fine roots, demonstrating possible improvements in soil quality and recovery is probably actually taking place.

Keywords: degraded area, recovery, root stock, underground biomass.

INTRODUCTION

Mining is an exploratory activity of natural resources that modifies the landscape and reduces the resilience of altered areas [1]. This type of activity to this day still occurs often without adequate techniques and effective control, resulting in a situation of degradation in the area where the project is installed as well as in the surroundings. [2].

After the generated exploration, the soils are degraded, which are normally devoid of biomass and organic matter, the deleterious effects of the reduced vegetation cover become even more expressive [3]. Therefore, vegetation cover plays a vital role in protecting this soil, the root system of these species contributes to soil aggregation, possibly reducing phenomena such as erosion and surface sealing [4].

Studies on root biomass in ecosystems are important to assess the storage capacity and potential for carbon emission into the atmosphere due to the removal of vegetation and land use [5]. Root biomass has different representation in different forest formations and its contribution is very significant for the composition of total forest biomass [6]. Roots are important factors in the process of rehabilitation of degraded areas as they stimulate the biological activity of the soil, incorporate sources of different organic compounds, increasing the concentration of organic carbon in the soil and act in its structuring [7].

Thus, this study aimed to quantify the concentrations and biomass stock of fine and thick roots, in three areas: Degraded area, area under recovery and native forest in the municipality of Capitão Poço-PA, Brazil.

MATERIAL AND METHODS

The research was carried out in the municipality of Capitão Poço, state of Pará, in an area destined for the commercial extraction of rolled pebble ore. The location of the area obeys the following geographic coordinates: 1º34´21.85´´S and 47º06´39.91´´W.

In the region, the climate is classified as Am, according to the Köeppen classification. This type of climate presents an annual precipitation of 2,500 mm, average temperature of 26°C and relative humidity between 75 and 89% [8].

The existing vegetation is of the evergreen equatorial forest type or dense and mixed rainforest, in addition to secondary forests in different successional stages, due to the characteristics of land occupation that occurred in the northeast region of Pará. In turn, the soil in these areas belongs to the Latossolo Amarelo class [9].

The study was carried out in three distinct areas: native forest, degraded area, and in recovery with three years, each area presented the following characteristics:

The area has 5.16 ha, which underwent pebble and sand mining for seven years from 2009 to 2016. The exploration of the area initially took place with the total removal of the native vegetation with the aid of machinery such as a crawler tractor, bucket and backhoe, then the extraction of the first layers of soil considered inappropriate. All material removed from the ground was transported to another location, where the processing, which is washing and separation, was carried out. No form of recovery has been carried out in the area, it has been found fallow to date.

The area has 4.92 ha, had its original vegetation removed for pebble mining and the bioengineered soil recovery technique was applied with a time of three years. The technique used to recover the area was soil bioengineering implemented in 2018, starting with the fencing of the area, for the implementation of the implement, initially the land was manually leveled, with tools (hoe and shovel) and without the use of heavy machinery.
Antes da implantação foi realizada a capina e limpeza da área, com o intuito de retirar possíveis espécies competidoras. Após o preparo da área, foi realizado o plantio de espécies leguminosas como feijão guandú (Cajanus cajan (L.) Millspaugh), mucuna preta
(Stiolozobium aterrimum Piper & Tracy), feijão de porco (Canavalia ensiformis (L.) DC) e crotalária (Crotalaria juncea L), onde as sementes foram inseridas, em uma quantidade de sete gramas a cada quatro metros lineares.

Comment [RG1]: Translate these paragraphs to English

The planting of seeds was used hydrogel in order to increase water retention, and arranged in lines of approximately 50 cm apart, these lines were placed parallel to the direction of solar movement, so that radiation would disperse more homogeneously. Fertilization was administered with 4 kg of N, 50 kg of P2O5 and 40 kg of K2O ha ^{1}, in the form of urea, triple superphosphate and potassium chloride.

At the base of the slope, in order to contain the collapse and drag of sediments, bamboos were used as inert elements as a barrier, in order to reduce the energy of the water through surface runoff. After three years of implementation of the soil bioengineering technique, a floristic survey was carried out in which species with the highest importance value index were found - IVI of the species was 25.16% for *Cochlospermum orinocense* (Kunth) Steud. and 27.84% *Solanum crinitum Lam*.

The area with native forest forest has about 6.4 ha, with fifty years without anthropic intervention. At the site were found species with higher importance value indices (IVI) such as: succuba 8.414% (Himatanthus sucuuba Spruce ex Müll. Arg. Woodson), cumaru 8.119% (Dipteryx odorata Aubl. Willd.), seal 22.993% (Vismia guianensis (Aubl), tatapiririca 32.281% (Tapirira guianensis Aubl.), large ucuuba 9.057% (Virola sebifera Aubl.), inga-xixica 26.082% (Inga alba (Sw.) Willd.), Custard food 18.560% (Lacistema aggregatum) and bird 18.373% (Casearia arborea (Rich.) Urb.).

For soil sampling, 24 trenches were opened, with eight trenches in each area, randomly allocated, in dimensions 70 x 70 x 100 cm. Soil samples were taken from these trenches at depths 0-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-80 and 80-100 cm and subsequently dried in the open air, passed in 2 mm sieve and, finally, carrying out the analyzes in the laboratory.

The quantification of root biomass was performed by separating the roots into two diameter classes using a caliper as follows: ≤5 mm (fine roots) and > 5 mm (coarse roots). For this analysis there was no separation of roots by species and no distinction between live and dead roots. The material was dried in paper packages, dried in a forced circulation oven at 65°C, until reaching constant weight. The weighing, in turn, was performed to obtain the dry mass of the plant components.

The root biomass stocks were calculated in Mg ha-1 for each sampled depth and root biomass stocks in the sampled layers and added to obtain the total root biomass stocks. The determination of biomass stocks was carried out as follows:

$$E_{ST}B_R = (B_R \times D_s \times P)/ 10 \quad (1)$$

Where: ESTBR - root biomass stock in the soil layer (Mg ha-1); BR - soil root biomass concentration (g kg-1); Ds - density of soil in the layer (kg dm-3); and P - sampled depth (cm).

For the statistical analysis, the values obtained were submitted to the Shapiro and Wilk normality tests, and then to the analysis of variance to assess the differences between the mining recovery areas in the soil depths of 0-10, 10-20, 20 -30, 30-40, 40-50, 50-60, 60-80 and 80-100 cm. Then, the data were subjected to the mean comparison test using the Tukey test at 5% significance with the SISVAR statistical software tool [10].

RESULTS AND DISCUSSION

According to the analysis of variance, there were significant differences by the Tukey test at the 5% probability level. In the analysis, higher concentrations of thick roots were observed in an area of native forest at depths of 0-10 and 10-20 cm, as shown in Figure 1, which shows the values of thick root concentrations in the three areas analyzed in this study.

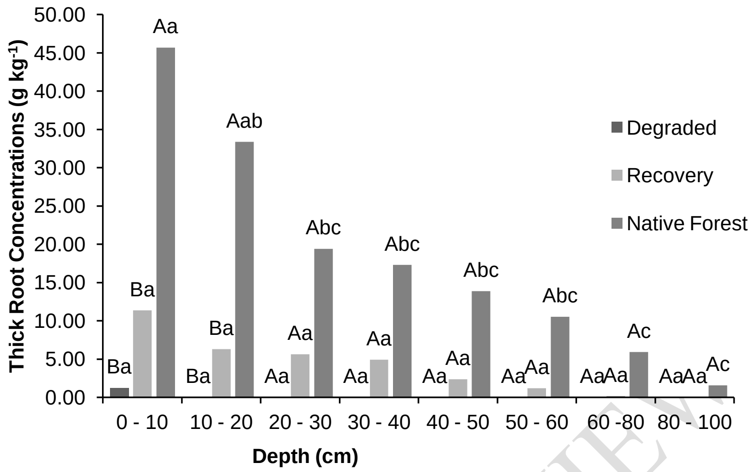

Figure 1. Thick root concentrations as a function of different post-mining areas and soil depths in Capitão Poço, Pará, Brazil. *Significant differences are indicated by different letters by the Tukey test at 5% significance (P≤0.05). Uppercase letters indicate differences between post-mining areas and lowercase letters indicate differences between soil depths.

In the three areas analyzed in this study, it was observed that from a depth of 10-20 cm there were decreases in the concentrations of thick roots, which may be due to the Amazonian soils having higher concentrations of nutrients in the more superficial layers, supporting the development of roots in these depths [11]. In similar research, it was observed that the thick roots are spaced in the topsoil, a behavior that may be related to the purpose of each type of root, such as support, nutrient absorption, mineral and water absorption [12].

There were also significant differences in the 0-10 and 10-20 cm shallow depths in relation to other areas for native forest, which may have occurred because the native forest was in balance with the environment and did not suffer anthropic disturbances. This high value of root concentration in the first layers of the soil was already expected, due to the higher nutritional levels at these depths.

The areas under recovery and the degraded area did not show statistical difference between the soil depths, however, higher average values were found in the recovery area. The area under recovery, which is in the process of natural regeneration after intervention, helps to improve quality and restore connectivity between primary forest remnants [13]. In this sense, knowing that root development depends on factors such as chemical attributes (availability of Ca and Al), soils with high Al precipitation cause a reduction in root growth, which may explain the decrease in thick roots at greater depths. [14].

From a depth of 20-30 cm to 80-100 cm, the areas did not show statistical differences between them. However, the area under recovery showed considerable mean values of increment in coarse root concentrations. The decrease in root biomass observed at a depth of 20-40 cm was found in studies on the quantification of roots that contained a teak stand, inferring that this may be related to a greater export of nutrients at this depth, due to the concentration of roots in the first 30 cm deep in the ground. Furthermore, the authors state that in the case of Teak, root biomass presents greater amounts in soils with high potential acidity and MO, associated with low amounts of Mg, Ca/Mg, Na and CEC [15].

Capacity The amount of coarse root biomass existing in the soil can be influenced by several cation exchange factors. In the first layers of the soil, the edaphic characteristics of the area, the successional stage, the density of individuals, the floristic composition, the diversity, the forms of life of the dominant plants and the history of use of the areas may result from [16;17]. About this topic, some authors explain that the vegetation starts to develop thicker roots that help to facilitate the anchoring mechanisms for plant stabilization, especially on steep slopes [18].

Increases in the amount of thick roots in the area under recovery can be explained by the high variation in biomass, depending on the regeneration period and environmental conditions [19]. The roots represented 15% of the total biomass due to the depth, from 20-100 cm. In a study carried out in Eucalyptus spp. plantations, the increase in thick roots was 9.4% of the total biomass value [20].

The concentration of fine roots found in the three areas analyzed in this study is shown in Figure 2.

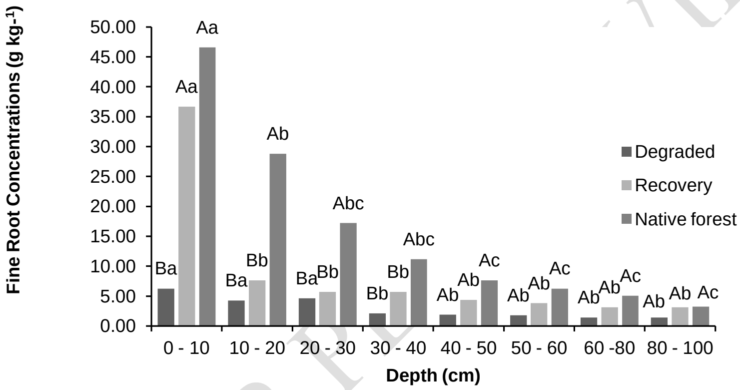

Figure 2. Fine root concentrations as a function of different post-mining areas and soil depths in Capitão Poço, Pará, Brazil. *Significant differences are indicated by different letters by the Tukey test at 5% significance (P≤0.05). Uppercase letters indicate differences between post-mining areas and lowercase letters indicate differences between soil depths.

The concentrations of fine roots, according to the analysis of variance, were higher in mean values in the superficial layers of the soil at depths of 0-10 and 10-20 cm in native forest area, as the concentration in the soil increases in depth. three areas under study decreased. This difference in the amount of fine roots in the native forest area can be partially explained by the thicker litter layer on the soil surface, corroborating components that provide greater nutrient cycling, which sustain a higher primary productivity [21].

In the areas analyzed in this study, the root density in the topsoil of 0-10 cm was mainly composed of fine roots. For this, factors such as soil acidity and nutrient scarcity can boost the proliferation of fine roots in more superficial parts of the soil [22]. In surveys carried out in a subtropical forest with the sequential planting method, the fine root biomass in the 0-10 cm soil layer was significantly higher than in the 10-20 cm [23].

By means of the Tukey test at the 5% probability level, the area of native forest did not differ statistically from the area under recovery at depth 0-10 cm, being statistically different in the degraded area at depths 0-10 and 10-20 cm. The fine root biomass in the upper soil layer (0-15 cm) was significantly higher than in the deeper layer (15-60 cm). Although the area under recovery has stopped being explored in less time than the degraded area, the higher proportion of fine roots may be due to the fact that in younger stands there is probably a strategy to produce roots faster after a suffered disturbance, increasing the search for resources within the largest volume of soil possible and thus return organic matter to the soil to increase vegetation growth [24].

The area under recovery, by Tukey's test at 5% probability level, also showed a significant difference in fine root concentrations when compared to the degraded area only at depth 0-10 cm, and in the others, higher mean values. A possible explanation for this result would be that the degraded area, even after 36 months of fallow, has not yet managed to recover its ecological balance in a natural way. Depth starts to affect root development due to density and penetration resistance, in addition to other factors arising from use [25]. In turn, the fine root biomass was 243.02, 261.96 and 233.39 g m² on average in the plantations of 7, 17 and 25 years, respectively [26].

At depths of 40–100 cm, the study areas did not differ statistically, despite having higher mean values for native and recovering forest compared to degraded forest. In works that verified the distributions of fine roots in different types of soils and depths, it was observed that Oxisols and Ultisols contained significantly higher proportions of roots at 50-100 cm depth, compared to other soils [27].

Figure 3 shows the biomass stocks of fine and coarse roots in the degraded, recovery and native forest areas.

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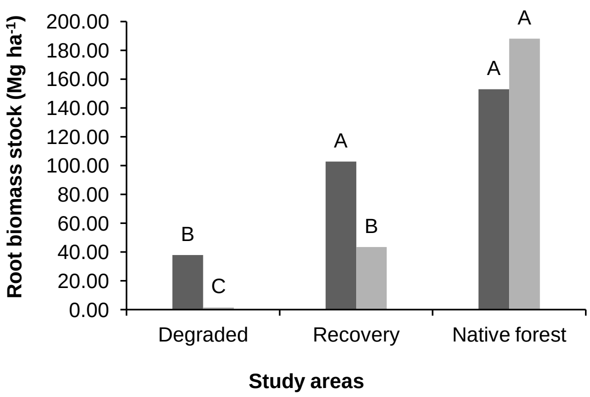

Figure 3. Stock of fine and coarse root biomass as a function of different post-mining areas, municipality of Capitão Poço, Pará, Brazil. *Significant differences are indicated by different letters by the Tukey test at 5% significance (P≤0.05). Capital letters indicate differences between post-mining areas.

According to the analysis of variance of the fine and coarse root biomass stock for the three study areas, it was verified that the fine roots present in the native forest area, by Tukey's test at 5% probability level, obtained mean values higher compared to the degraded area. However, no statistical difference was observed in the area under recovery. This behavior of the amount of fine roots in the native and recovering forest area may be due to the positive relationships between leaf areas and root biomass that demonstrate an intrinsic link, represented in the form of a linear or potential function, supported by the equilibrium theory functional between the two compartments [28].

In the area of native forest, higher mean values were observed in the concentrations of fine and coarse roots, despite not having been statistically different, by the Tukey test at the level of 5% of probability, in the concentration of fine roots in the area under recovery. This fact can be explained in terms of the physiognomy of the area, as it contains a greater number of trees and therefore suffers less impact from bad weather such as rain, wind and leaching. The fine root biomass stock in the degraded area was statistically higher than in the degraded area. This may be due to the effects of species varieties on various functional traits highly dependent on population age, soil depth and environmental stress to which the ecosystem is allocated, the effects of species mixtures on root biomass increased with species richness , in other words, higher values of fine root concentrations [29].

The coarse root biomass stock was also higher in the native forest area, differing statistically by the Tukey test at the 5% probability level, from the area under recovery and from the degraded area, as the result observed in the fine root stock. This result was also expressed with coarse roots in similar research, showing that the total coarse root biomass decreased from the forest to monoculture plantations, in which an average of 337,9300 Mg.ha-1 was found, the natural forest had a biomass of total coarse root significantly larger than rubber or oil palm plantations 159.3200 Mg.ha-1 and 842,500 Mg.ha-1, respectively [30].

The area under recovery, by the Tukey test at the 5% probability level, differed statistically with higher values of coarse roots in relation to the degraded area. This result can be explained by the use of ground cover plants carried out in the area under recovery. These plants have a high potential for production of shoot and root phytomass, being a very common soil conservation practice. [31].

In the degraded area, in turn, the amount of coarse roots observed was the smallest around 1.58, showing a significant difference in relation to the other areas by the Tukey test at 5% probability. This result is in line with studies on the same topic, where in their studies they showed that after several anthropogenic disturbances, fallow subtropical forests in which they are highly degraded can rapidly increase root biomass, production and biomass loss by mortality and reduce the turnover rate [32].

CONCLUSIONS

The area under recovery approached the native forest area in the concentration of fine roots in the first depths of the soil, demonstrating possible improvements in the quality of the soil in question and that its recovery is probably actually taking place, through the present vegetation and the advantages assigned by her to the ground. It was also noticed a decrease in the concentration of thick roots in the three studied areas, in the greatest depths of the soil.
The fine and coarse root biomass stock, in turn, did not show significant differences in the area of native forest, but it differed from the other areas in relation to coarse root biomass.

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