EVALUATION OF PRIMARY FOREST-CAPOEIRA-PASTURE SYSTEMS IN MARABÁ (PA) BY MEANS OF SOIL NITROGEN

AVALIAÇÃO DE SISTEMAS DE FLORESTA PRIMÁRIA-CAPOEIRA-PASTAGEM EM MARABÁ (PA) POR MEIO DO NITROGÊNIO DO SOLO

EVALUACIÓN DE SISTEMAS DE BOSQUE PRIMARIO-CAPOEIRA-PASTO EN MARABÁ (PA) MEDIANTE NITRÓGENO DEL SUELO

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ABSTRACT

Soil microbial biomass (SMB) is an important bioindicator of soil health and plays a vital role in the carbon cycle and the availability of nutrients to plants, which are released as plant organisms decompose. The efficiency of this process is directly linked to microbiological activity, which is influenced by factors such as temperature, humidity, pH, composition, and the C/N ratio. Given this, this study evaluated the impact of different nitrogen fractions on three distinct land use systems (primary forest, secondary forest, and pasture). The areas studied are located on small rural properties in the Benfica Settlement, located in the municipalities of Itupiranga and Marabá, PA. The soil in the study area is dystrophic Yellow Oxisols with a clay texture, and the primary vegetation cover was characterized as dense ombrophilous forest with a climate type of Awi according to the Köppen-Geiger classification. Soil sampling was performed at three depths (0-2 cm, 2-5 cm, and 5-10 cm) in June and October 2004 and February 2005, in a completely randomized experimental design (CRD), with four replicates for each depth. Total N and microbial biomass N (MBN) were determined by chloroform fumigation. The results showed that total N concentrations were higher in forest and secondary forest soils in the surface layer, decreasing with increasing depth. In pastures, the contents were similar between different layers and also showed a reduction in their rates with increasing depth, regardless of age. Regarding microbial biomass nitrogen (MBN), forest and secondary forest soils showed similar values, with no significant changes with increasing depth. In these ecosystems, the greater diversity of species and rapidly decomposing organic matter on the surface favor microbial activity. Pastures, in turn, showed a significant reduction in MBN values compared to forests, ranging from 44% to 75%, depending on the depth and age of the pasture. This shows that the reduction in plant diversity due to the replacement of

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forest by pastures tends to decrease soil microbial biomass, while secondary forests represented transitional environments between pasture and forest and therefore had the potential for soil condition recovery.

Keywords: Microbial Biomass. Nitrogen. Soil Cover.

RESUMO
A biomassa microbiana do solo (BMS) é um importante bioindicador da saúde do solo, e desempenha um papel vital no ciclo do carbono e na disponibilidade de nutrientes às plantas, que são liberados à medida que os organismos vegetais são decompostos. A eficiência desse processo está diretamente ligada à atividade microbiológica, influenciada por fatores como temperatura, umidade, pH, composição e a proporção C/N. Diante disso, este estudo avaliou o impacto de diferentes frações de nitrogênio em três sistemas de uso do solo distintos (floresta primária, capoeira e pastagem). As áreas estudadas estão situadas em pequenas propriedades rurais no Assentamento Benfica, localizado no município de Itupiranga e Marabá, PA. O solo na área estudada é o Latossolo Amarelo distrófico de textura argilosa, a cobertura vegetal primária foi caracterizada como Floresta Ombrófila Densa de terra firme, com tipo climático Awi pela classificação de Koppen-Geiger. A amostragem de solo foi realizada em três profundidades (0-2 cm, 2-5 cm e 5-10 cm) em junho e outubro de 2004 e fevereiro de 2005, em delineamento experimental Inteiramente Casualizado (DIC), com quatros repetições para cada profundidade. Foi determinado o N-total e da biomassa microbiana (NBM) por fumigação com clorofórmio. Os resultados mostraram que as concentrações de N-total foram maiores em solos de floresta e capoeira na camada superficial, e diminuindo com o aumento da profundidade. Nas pastagens, os teores foram semelhantes entre si, em diferentes camadas e também apresentaram redução em suas taxas com aumento na profundidade, independente da idade. Em relação ao Nitrogênio da biomassa microbiana (NBM), os solos de floresta e capoeira apresentaram valores semelhantes, sem mudanças significativas com aumento das profundidades. Nesses ecossistemas, a maior diversidade de espécies e a matéria orgânica de rápida decomposição na superfície favorecem a atividade microbiana. As pastagens, por sua vez, apresentaram uma redução significativa nos valores de NBM em comparação com a floresta, variando de 44% a 75%, dependendo da profundidade e idade da pastagem. Evidenciando que a redução da diversidade vegetal pela substituição da floresta por pastagens tende a diminuir a biomassa microbiana do solo, enquanto que as capoeiras representaram ambientes de transição entre o pasto e a floresta e portanto, com potencial de recuperação das condições do solo.

Palavras-chave: Biomassa Microbiana. Nitrogênio. Cobertura do Solo.

RESUMEN
La biomasa microbiana del suelo (BMS) es un bioindicador importante de la salud del suelo y desempeña un papel vital en el ciclo del carbono y la disponibilidad de nutrientes para las plantas, que se liberan a medida que los organismos vegetales se descomponen. La eficiencia de este proceso está directamente relacionada con la actividad microbiológica, influenciada por factores como la temperatura, la humedad, el pH, la composición y la relación C/N. Por lo tanto, este estudio evaluó el impacto de diferentes fracciones de nitrógeno en tres sistemas distintos de uso de la tierra (bosque primario, bosque secundario y pastizales). Las áreas de estudio están ubicadas en pequeñas propiedades rurales en el Asentamiento Benfica, ubicado en los municipios de Itupiranga y Marabá, Pará. El suelo en el área de estudio es un Latosol Amarillo distrófico con una textura arcillosa; la cobertura vegetal primaria se caracterizó como Bosque Ombrófilo Denso de suelo de tierra alta, con un tipo de clima Awi según la clasificación de Koppen-Geiger. El muestreo de suelo se realizó

a tres profundidades (0-2 cm, 2-5 cm y 5-10 cm) en junio y octubre de 2004 y febrero de 2005, en un diseño experimental completamente aleatorizado (DCA), con cuatro réplicas para cada profundidad. El N total y la biomasa microbiana (MBN) se determinaron mediante fumigación con cloroformo. Los resultados mostraron que las concentraciones de N total fueron mayores en suelos de bosque y bosque secundario en la capa superficial, disminuyendo con el aumento de la profundidad. En pasturas, los niveles fueron similares en diferentes capas y también mostraron una reducción en sus tasas con el aumento de la profundidad, independientemente de la edad. Con respecto al nitrógeno de la biomasa microbiana (MBN), los suelos de bosque y bosque secundario presentaron valores similares, sin cambios significativos con el aumento de la profundidad. En estos ecosistemas, la mayor diversidad de especies y la materia orgánica de rápida descomposición en la superficie favorecen la actividad microbiana. Las pasturas, a su vez, mostraron una reducción significativa en los valores de NBM en comparación con los bosques, que oscilaron entre el 44% y el 75%, dependiendo de la profundidad y la edad de la pastura. Esto resalta que la reducción en la diversidad vegetal causada por el reemplazo de bosques por pasturas tiende a disminuir la biomasa microbiana del suelo, mientras que los bosques secundarios representaban ambientes de transición entre pasturas y bosques y por lo tanto tenían potencial para la recuperación del suelo.

Palabras clave: Biomasa Microbiana. Nitrógeno. Cobertura del Suelo.

1 INTRODUCTION

Microbial biomass is an important bioindicator of soil quality, it plays an important role in the carbon cycle, acting as a reservoir in the soil storing nutrients such as N, P and S, which are gradually released during their death and decomposition, making them available to plants. It is vital for nutrient recycling (Souza et al., 2010). Because the microfauna present in the soil is extremely active and efficient, performing functions such as the release of nutrients from organic matter, the fixation of nitrogen from the air, and the production of substances that protect plants (Andrade, 2020).

The increase in soil organic matter content increases microbial activity, favoring nutrient cycling and helping to control soil diseases (Nannipieri et al., 2017). Almost all organic matter present in the soil originates from plant organisms, whose composition varies between different species of plants and animals and, within the same species, changes according to the age of the plant and the soil fauna (Cunha et al., 2015). Organic residues in the soil release essential nutrients that are gradually made available through decomposition carried out by microorganisms (Manna et al., 2015).

Thus, BMS and the balance of the carbon-nitrogen ratio is an important parameter for understanding N cycling in the soil, as it is fundamental for the decomposition of organic matter, as the main objective of this process is to promote conditions that favor the fixation of nutrients, which will be used as fertilizers later (Maragno et al., 2007). (Bidone, 2001) emphasizes that the effectiveness of organic matter degradation is directly related to microbiological activity, which is affected by several factors, including temperature, humidity, ventilation, pH, types of organic matter and the ratio of C/N in the soil.

2 OBJECTIVE

The present study aimed to evaluate the different nitrogen fractions of an Oxisol under different land use and land cover systems in Eastern Amazonia.

3 MATERIALS AND METHODS

3.1 AREA OF STUDY

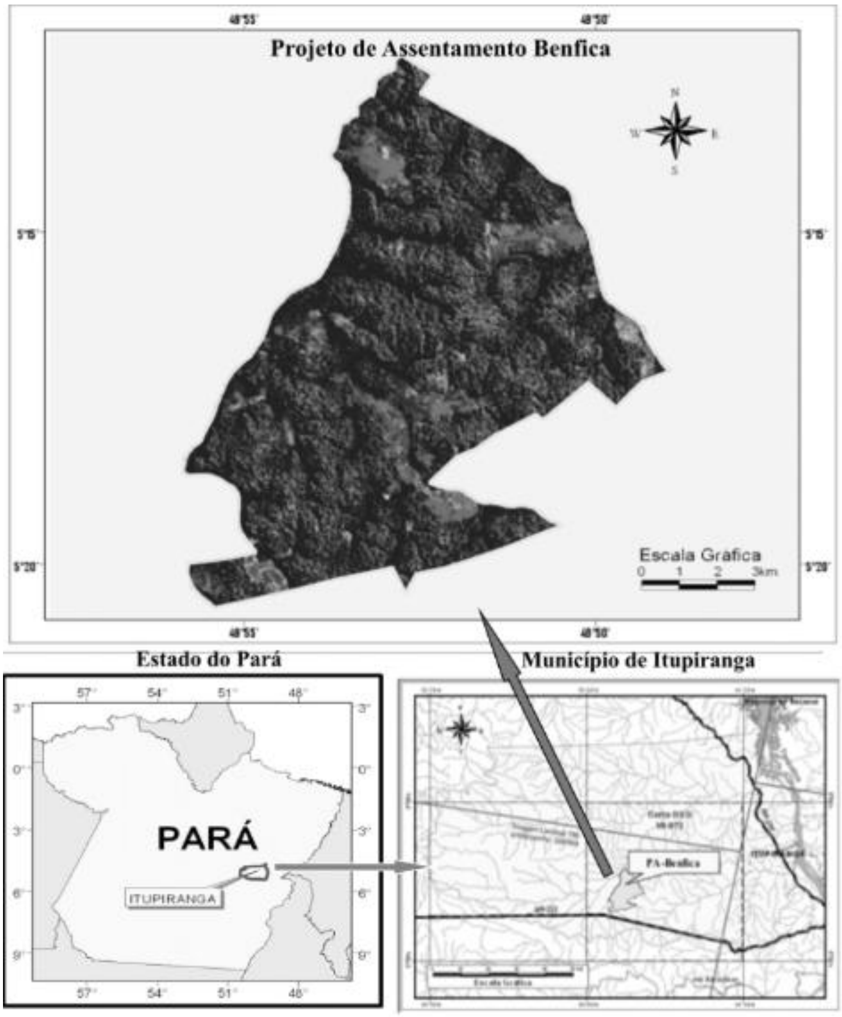
The areas of this work are located in properties of small rural producers, located in the rural area of the municipality of Itupiranga and in the municipality of Marabá, PA. The soils vary according to the relief. On the plateaus, there are mainly oxisols; in the middle parts of the slopes, podzolic and cambisols and, in the lower slopes, hydromorphic soils occur in a generalized way (Sampaio, et al., 2010).

The dominant soil of the studied area is the dystrophic Yellow Latosol with clayey texture. The primary vegetation cover of the region is of the Terra Firme Forest type, classified as Dense Ombrophilous Forest (Bigarella, et al., 1996), under an original vegetation of humid tropical forest, classified by Koppen-Geiger as Awi category, hot and humid tropical, with average annual rainfall of 2000 mm and average temperature of 26 °C, with one dry and the other rainy period, well defined (Silva; Laurel; Sousa, 2021).

The Benfica Settlement project, implemented by INCRA in 1998, is located in the Southeast mesoregion, Paraense, Municipality of Itupiranga, with an area of 10,026.00 hectares (Latitude 05º 16' S and Longitude 49º 50' W and 95.0 m height) (Coelho; Miranda; Mitja, 2013).

Figure 1

Location of the Benfica Settlement in the Region of Marabá, Pará



Source: Sampaio et al. (2010).

The settlement comprises a total of 183 lots occupied since 1994, with an estimated population of 1,000 inhabitants (Biri Kassoum; Maœtre D'hotel, 2002).

3.2 SOIL SAMPLING

Soil sampling was carried out in the three different areas, in the periods of June and October 2004, and February 2005, using as a collection standard a 150 m long transect, at sampling points that were spaced every 10 m (totaling 15 points per transect), at depths 0-2 cm, 2-5 cm, 5-10 cm (3 for each area studied). The experimental design was Completely Randomized (DIC), with four replications for each depth. The objective of the transect design was to capture the spatial heterogeneity of the soil along the gradient of ecological succession.

At each point, soil samples were collected at the three depths (five simple samples to form a compost). After collection, the soil samples were packed in polyethylene bags, hermetically sealed to maintain humidity, identified and immediately placed in Styrofoam boxes with ice, to minimize microbial activity. They were then sent to the soil microbiology laboratory of the Federal Rural University of the Amazon and kept in refrigeration until the analyses.

The sample collection and management procedure was conducted in accordance with the recommendations of Embrapa (Teixeira et al., 2017), ensuring that the samples were adequately representative of the areas studied, enabling the analysis of the chemical, physical and biological attributes of the soil.

3.3 DETERMINATION OF TOTAL NITROGEN (N-TOTAL)

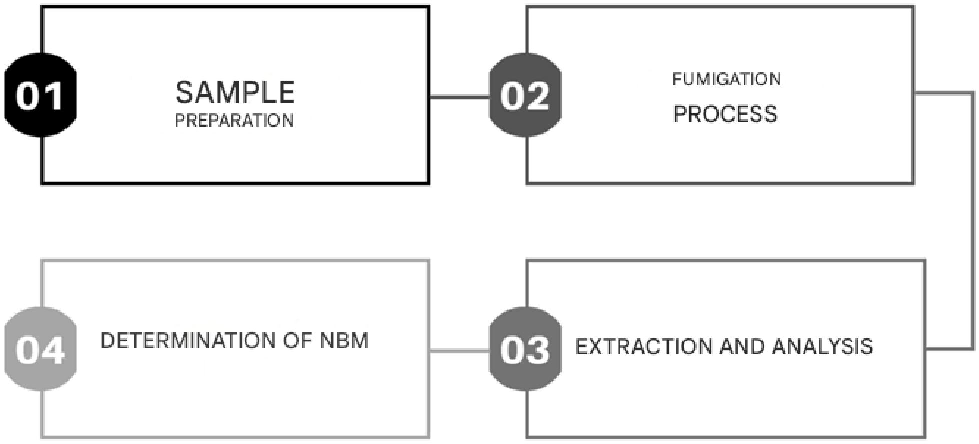
The soil samples were submitted to chemical analysis at the Soil Chemistry Laboratory of the Institute of Agrarian Sciences of the Federal Rural University of Amazonia, where the total nitrogen of the soil was determined, according to Teixeira et al., (2017).

3.4 MICROBIAL BIOMASS NITROGEN (NBM)

Figure 2 presents a simplified flowchart of the steps involved in the determination of Microbial Biomass Nitrogen (NBM) according to the description of Brookes et al., (1985), and recommended adaptations for tropical soils (Vance et al., 1987).

Figure 2

Flowchart of the NBM Determination Methodology



Samples of approximately 12.5 g (fresh weight) were placed in a desiccator and subjected to fumigation with alcohol-free chloroform for 24 hours. After fumigation, the soils were extracted with 0.5 mol L-1 K2SO4 solution, agitated for 30 minutes and filtered. Non-fumigated samples were treated simultaneously. The extracts were stored in plastic jars, under freezing until the beginning of the chemical analyses.

The factor used to determine NBM was Kn=0.54, recommended by Brookes et al., (1985), as adapted by Joergensen and Mueller, (1996), which was applied, expressing the fraction of nitrogen recovered after fumigation. The NBM results were expressed as micrograms (µg) of N per gram of soil (dried at 105 °C for 24 hours).

4 RESULTS AND DISCUSSION

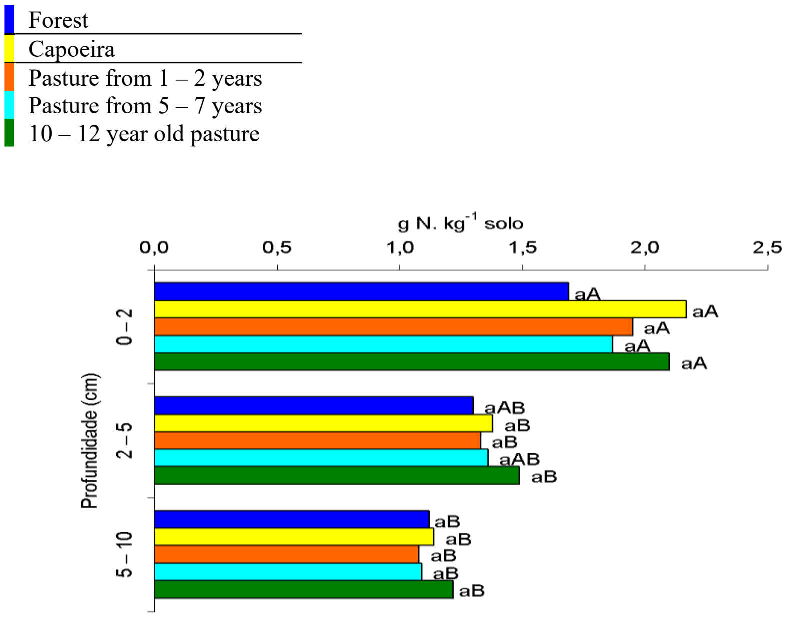
4.1 TOTAL NITROGEN (N)

In the soils under forest and capoeira, the concentrations of total nitrogen (N) are 1.69 g kg-1 and 2.17 g kg-1, respectively, in the upper layer, and show a significant decrease with depth (p-value < 0.05). In the pasture areas, the contents are similar, varying between 1.87 and 2.10 g kg-1 in the surface layer, and do not show relevant variations with the age of the pastures. A significant reduction was also observed with increasing depth (Figure 3).

The levels found in both the forest and pasture areas were similar to the results found by Piccolo (1994). However, Brady, (1989); Long; Espíndola, (2000) and Moraes, (1991), comparing natural vegetation with pasture, found a drop in the total N content of the soil, which, in general, was very vulnerable to cultivation, as it was concentrated in the superficial layer of the soil. On the other hand, Maia et al., (2015), studying soil fertility indicators in Capoeira and SAF managements, in Marabá, concluded that in terms of N quantification in these areas, there were no significant differences, being statistically similar up to the 40 cm soil layer.

Figure 3

Nitrogen content (N) in a Yellow Latosol of Itupiranga/PA, under different types of vegetation cover. Averages followed by the same letter, lowercase, at the same depth; between depths, do not differ by Tukey's test at 5 % significance



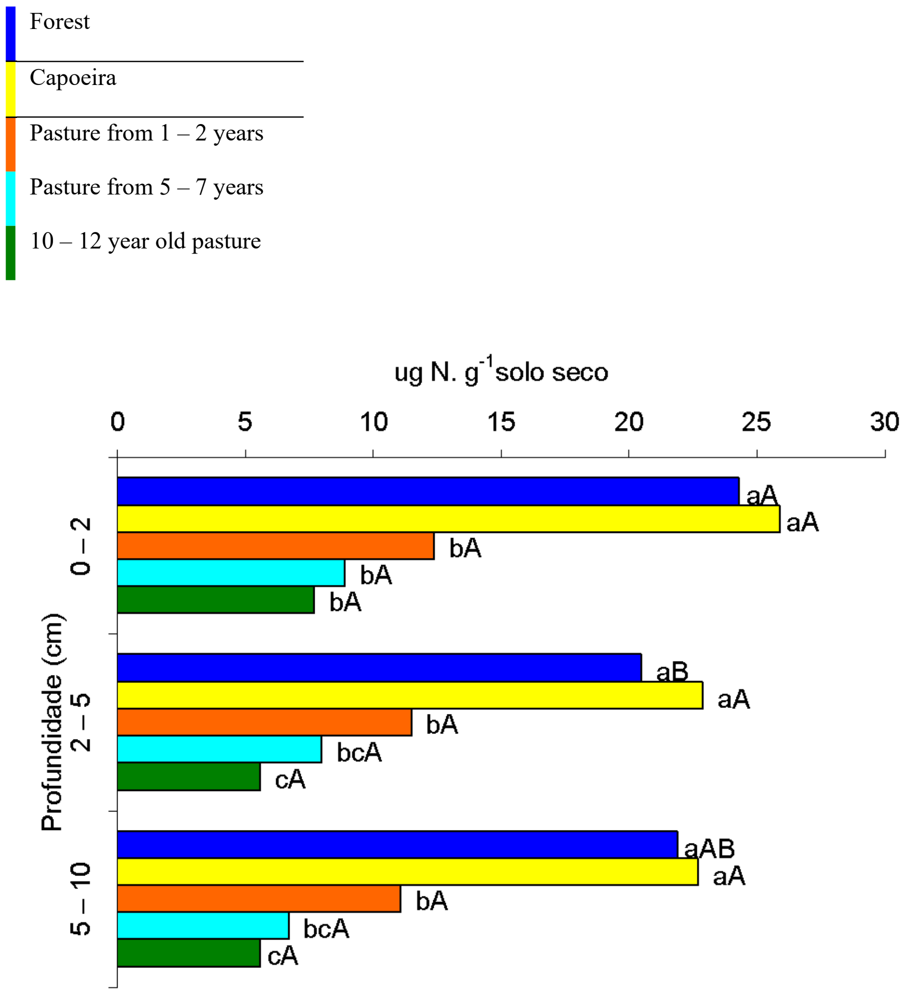
The higher concentration of N at the depth of 0-2 cm is due to the greater accumulation of organic matter in the surface layer. Several studies, such as those by Pezarico et al., (2013), D'Andréa et al., (2004), Hernandez-Hernandez; Lópes-Hernández, (2002), mention this relationship, explaining that the nitrogen content in the soil decreases with increasing depth, in different management systems and soil types.

4.2 MICROBIAL BIOMASS NITROGEN (NBM)

The NBM contents showed considerable variations in relation to the type of vegetation at the depths analyzed (Figure 4). In forest soils and under capoeira, the NBM values are similar, ranging from 20.5 to 24.3 μg g-1 of soil, without significant changes according to depth. In ecosystems with greater species diversity, such as forest and poultry farms, there is a significant accumulation of rapidly decomposing organic matter on the surface, which increases the availability of substrates and fosters a higher concentration of nutrients in the microbial biomass, which due to the low C/N ratio, does not generate increases in total N stocks (Cardoso et al., 2010).

Figure 4

Nitrogen of microbial biomass (NBM), in an Oxisol of Itupiranga/PA, under different types of vegetation cover. Averages followed by the same letter, lowercase, at the same depth; between depths, do not differ by Tukey's test at 5% significance



The NBM values found under forest and capoeira are comparable to those of Luizão et al., (1999) in studies carried out in forest and capoeira areas of 5 years, (35 and 26 µg g-1 soil, respectively). However, lower than those reported by other studies such as Feigl et al., (1995) who found values between 35 and 74 µg N g-1 soil in primary forest in the Brazilian Amazon and Vasconcelos, (2002) in a study carried out in capoeira of different ages in Castanhal (PA) that found values between 33 and 63 µg N g-1 soil.

By relating the results obtained to those presented by Rodrigues et al., (2013), with studies on the subject in soils of AFS, poultry and pasture, we can observe characteristics similar to these values, allowing us to infer that the greater amount of organic matter available for easy decomposition in forest and poultry systems can cause an increase in the NBM values in these areas, on the other hand, pastures tend to present less diversity of organic matter and consequently lower quality, also affecting their NBM values.

The results also indicate that the pastures showed a reduction in the NBM values in relation to those found in the forest soils, ranging from 44 to 75 %, as a function of the depth and increasing with the age of the pasture, although not significantly in the surface layer. These low values under pastures are related to those of Xavier et al., (2006) and Gama-Rodrigues et al., (1997), who found values in pastures around 8 µg N g-1 soil, confirming a trend towards a decrease in microbial mass in these areas. On the other hand, Luizão et al., 1999), in Manaus (AM), found values around 24 µg N g-1 soil , in an abandoned pasture area.

It is important to highlight that the replacement of the forest for the establishment of pastures followed the same trend of decrease for both the levels of MBC and NBM, and the capoeira shows signs of recovery for these attributes. The determination of NBM is of great importance, as it allows the monitoring of N during a given period and, consequently, estimates the amount of N that can be reabsorbed by plants, ensuring a better understanding of the cycle of the element in these land use systems.

In view of the results obtained, it was found that the areas corresponding to the forest were the ones that presented the highest values in total N and NBM, the lowest indices of these parameters were observed in the pasture areas, whose biological diversity is much lower. Capoeira, despite presenting a reduction in NBM values compared to forest, appears as intermediate between the areas studied, with potential for recovery of soil conditions.

5 CONCLUSION

The conversion of forest areas into pasture exerts strong pressure on soil quality, among these characteristics affected in these conditions are the nitrogen levels of microbial biomass (NBM), which can affect the soil nitrogen cycle, impairing the quality and limiting the performance of microbial biomass.

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