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NATURAL DURABILITY OF FIVE TROPICAL WOOD SPECIES IN FIELD DECAY TESTS

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ABSTRACT

Measuring the natural resistance of wood is fundamental for proper use. The natural durability of five tropical wood species was investigated by field decay testing during exposure for 360 days. Wood logs (length of 0,5 m; diameter of 8 cm - 12 cm) were used in this study. The mass loss and decay index were calculated and visual analysis during the exposure time was performed for all samples. The samples presented evidence of two different groups concerning natural durability. The species in the first group (*Mimosa caesalpiniifolia*, *Mimosa ophthalmocentra*, and *Mimosa tenuiflora*) showed the highest resistance to biodeterioration, better or similar performance compared to treated eucalyptus wood (as control). The other group (*Aspidosperma pyrifolium* and *Cordia oncocalyx*) had lower natural resistance in outdoor service, being more susceptible to decay. In general, the wood of the first group is indicated for outdoor uses that require medium or prolonged exposure, such as timber stakes and fence posts.

Keywords: Decay index, hardwood, natural resistance, outdoor use, wood logs.

INTRODUCTION

Wood is the most abundant biocomposite in the world and is intensely used due to its widespread distribution and potential renewability (Ramage *et al.* 2017, Karinkanta *et al.* 2018). Furthermore, technological advances are increasing the possible uses of wood, such as in composites, with improved performance.

One of the main aspects assessed for the proper use of hardwood is natural durability or resistance (Quintilhan *et al.* 2018), a factor that can limit the use of wood in different service conditions, especially in tropical countries (Medeiros Neto *et al.* 2020). Both climatic conditions and xylophagous organisms can act severely in tropical conditions, thus significantly accelerating the damage and deterioration of this biomaterial (Sundararaj *et al.* 2015, Medeiros Neto *et al.* 2020). Another reason, for example, not all uses and places are suitable for wood treated with chemical products, so hardwoods that have a considerable natural durability are interesting in order to increase their useful life.

It is not always feasible to apply preservative treatments or substances to increase the service life of certain wood products. Therefore, knowledge of naturally durable wood is essential to select the best species for finished products with superior quality to assure longer integrity of structures and public safety (Clausen 2010, Stallbaun *et al.* 2017, Oliveira *et al.* 2019). In addition, there are no environmental issues related to the process of preserving the material and its subsequent use (Sundararaj *et al.* 2015). This property of natural resistance is associated with several physical-chemical components of wood, such as the presence of key extractives (Schultz and Nicholas 2000, Kirker *et al.* 2013, Hassan *et al.* 2017, Valette *et al.* 2017), heartwood-sapwood ratio (Delucis *et al.* 2016), and juvenile-adult wood ratio.

Wood deterioration has been widely studied under varied conditions over the years. Tests of the service situations in which wood will be used can be developed in different ways

(Meyer *et al.* 2014, Araújo and Paes 2018). In the case of outdoor applications, field decay testing is essential. This method produces reliable results with respect to the natural durability and a certain species' efficiency for a given purpose (Oliveira *et al.* 2019).

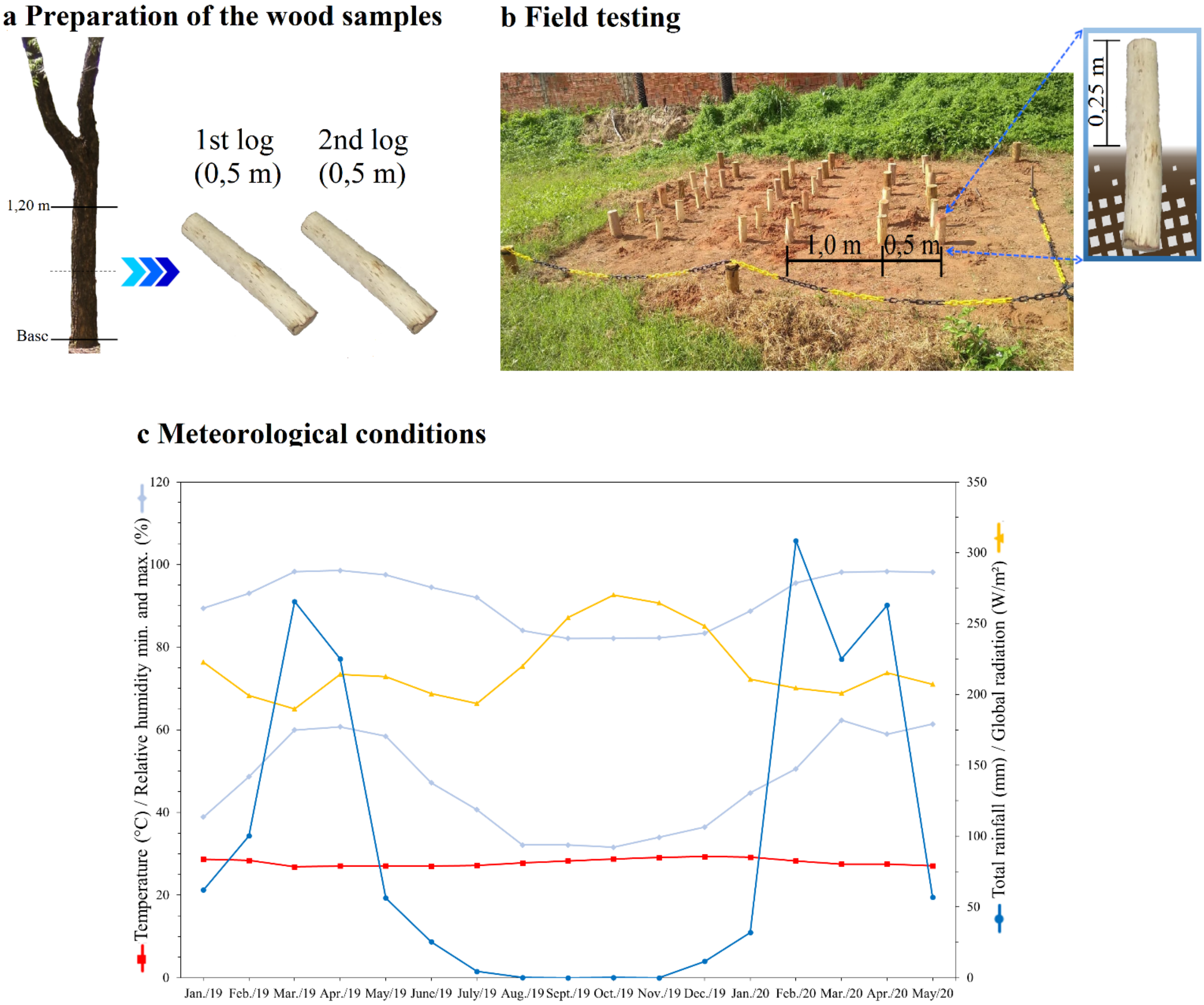
The use of forest resources is important to the population in the Caatinga biome. However, wood products need to be used rationally, based on their potential and limitations. Thus, it is relevant to obtain data and develop proposals to evaluate, understand and enhance the properties of each wood species, aiming to maximize its service time and minimize expenses. In this study, the natural durability of five tropical wood species – *Aspidosperma pyrifolium*, *Cordia oncocalyx, Mimosa caesalpiniifolia, Mimosa ophthalmocentra* and *Mimosa tenuiflora* – was evaluated by field testing. Eucalyptus wood treated with chromated copper arsenate type C (CCA-C) was employed as control.

MATERIALS AND METHODS

Species location and wood samples

The tropical species (*Aspidosperma pyrifolium* Mart. & Zucc. (Ap); *Cordia oncocalyx* Allemão (Co); *Mimosa caesalpiniifolia* Benth. (Mc); *Mimosa ophthalmocentra* Mart. ex Benth. (Mo); and *Mimosa tenuiflora* (Willd.) Poir (Mt)) came from Fazenda Ipê (Latitude 05° 30' 02" South and Longitude 37° 25' 34" West), in the municipality of Governador Dix-Sept Rosado, Rio Grande do Norte state (RN), Brazil. For each species (Ap, Co, Mc, Mo, and Mt), random sampling was performed in a native forest stand to obtain three uniform trees (Ø: 8 cm - 12 cm; without apparent wood defects) by felling.

From each tree, the bark was removed and a log was cut from the base up to 1,2 m. Subsequently, wood samples (all presenting heartwood and sapwood) were obtained from two defect-free logs with length of 0,5 m (Figure 1a) and were kept at equilibrium moisture content (10% - 12%). The samples initial mass (air dried) was recorded. Physical and chemical analyses of these samples were performed in a previous study of our group (Batista *et al.* 2020a), and the results are shown in Figure 2a-b. The CCA-C treated eucalyptus wood (*Eucalyptus* sp.) was obtained from a local lumber yard located in the municipality of Mossoró, RN, and analyzed in



the same conditions as a positive control.

Figure 1: Schematic layout of the experimental study at different steps. Cut of the tree to logs and sample dimensions (a), installation of the field test and wood sampling (b), and characterization of the weather by monthly averages in the Mossoró region/Brazil (c). Panel c is adapted of the dataset from the automatic weather station A318 (Latitude 04° 09' South and Longitude 37° 37' West) of the Instituto Nacional de Meteorologia (INMET 2020).

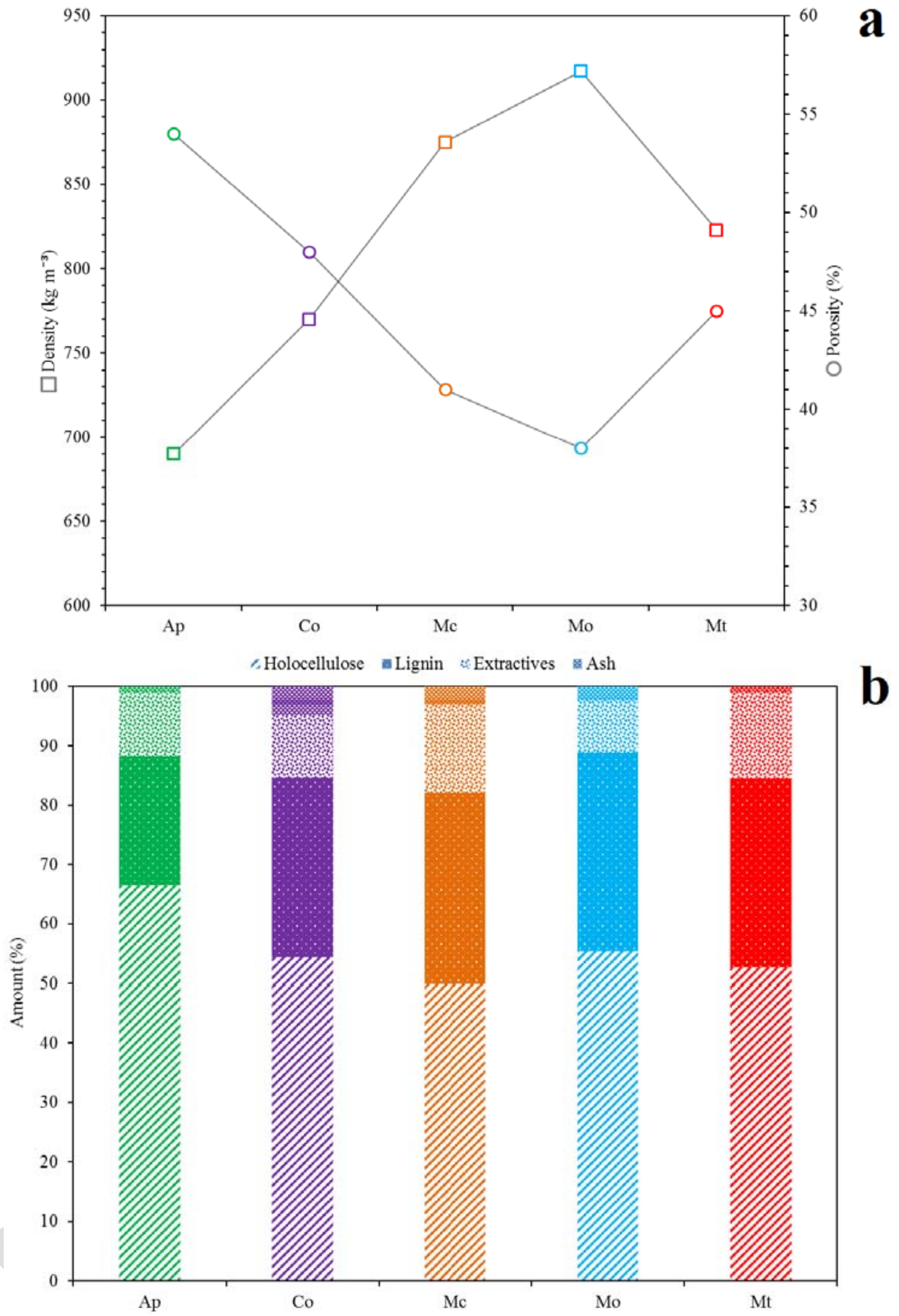


Figure 2: Physical (a) and chemical (b) characterization of the five tropical wood species used in this study. Adapted from Batista *et al.* (2020a).

Experimental area and conduction of the field tests

The area of the experiment (Latitude 05° 12' 20,57” South and Longitude 37° 19' 11,40” West; 25 m altitude) was located in Mossoró. Based on the Köppen-Geiger-Pohl climate classification, this region is characterized as having type Aw climate, tropical wet-dry (Arnfield 2020). According to the Instituto de Desenvolvimento Sustentável e Meio Ambiente do Rio Grande do Norte (IDEMA 2008), the soil of the region has flat relief with good to imperfect drainage (medium to fine texture).

The field test was conducted at an outdoor site without vegetation, with area of approximately 14 m². The logs (samples) were distributed in three randomized blocks (1,0 m apart), each composed of duplicates for each species, placed vertically in the ground buried to half of their length (0,25 m). The distance between logs was 0,5 m (Figure 1b). The samples were exposed during 360 days. The meteorological data are shown in Figure 1c. Every 60 days until end of the experiment, all samples were cleaned with a soft bristle brush and subsequently evaluated.

Mass loss

The physical decay of the wood material was determined by mass loss (Equation 1). The samples, before and after the exposure, were dried to moisture of 10 % - 12 % in a forced air oven (70 °C ± 5 °C), and mass was recorded.

$$\mathrm{ML} = \left[\frac{(\mathrm{Mi} - \mathrm{Ma})}{\mathrm{Mi}}\right] \times 100 \quad (1)$$

Where: ML is the mass loss (%), Mi is the initial mass of the sample (g), and Ma is the mass of the sample after exposure for a certain time (g).

Decay index

The wood samples were evaluated according to the decay susceptibility index (DSI), calculated by Equation 2, according to Curling and Murphy (2002). Additionally, we applied a new decay susceptibility index (NSDI) as described by these same authors, according to Equation 3. These analyses relate the condition of the species under study with a control.

$$\mathrm{DSI} = \left(\frac{\mathrm{MLs}}{\mathrm{MLc}}\right) \times 100 \qquad (2)$$

$$\mathrm{NDSI} = \frac{\mathrm{MLs}'}{\mathrm{MLc}'} \qquad (3)$$

Where: DSI is the decay susceptibility index (%), MLs is the mass loss of the studied wood (%), MLc is the mass loss of the control wood (%), NDSI is the new decay susceptibility index (dimensionless), MLs' is the mass loss of the studied wood (g), and MLc' is the mass loss of the control wood (g).

RESULTS AND DISCUSSION

The mass loss results of the wood samples over time are shown in Figure 3. Wood is a lignocellulosic biomaterial and its deterioration increases with exposure time. The Co wood underwent the greatest mass loss. The other wood species (Mc, Mo, Mt, and Ap) showed greater resistance to deterioration (final mass loss < 14 %), either by biotic or abiotic factors, that is, they demonstrated greater natural durability (residual mass > 86 %) when applied in outdoor service. These results are similar to or better than those obtained for the control (eucalyptus).

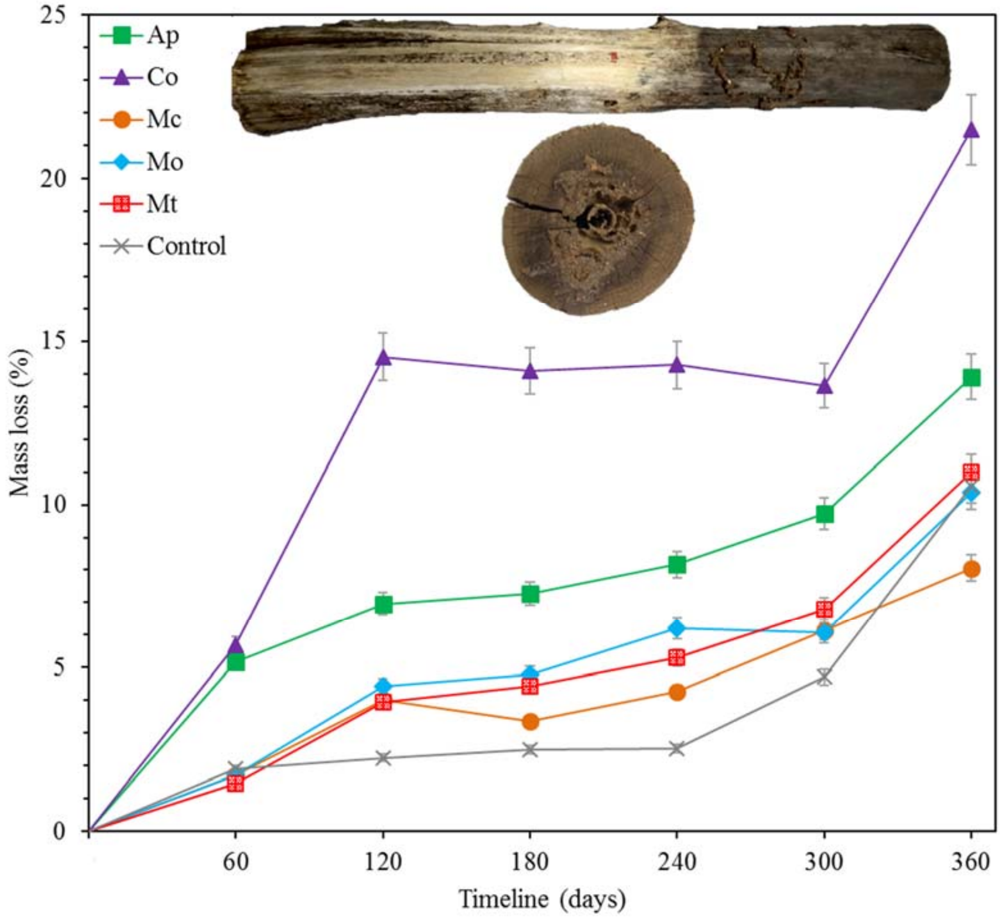


Figure 3: Mass loss behavior of the different wood exposed over time in the field test (Averages, n = 6 for each specie in each time). Digital images (side and top view) shown samples attacked by termites.

The mass loss was affected by certain meteorological conditions, such as periods with total precipitation above 50 mm (in March and April 2019 and February to April 2020), and consequently high relative humidity along with reduction in the global incident radiation. These conditions promoted an increase in the moisture balance of the wood and the storage of water in the soil. These conditions facilitate attack by deterioration organisms (Tomazeli *et al.* 2016), such as underground termites. These termites were the main agents that caused the mass decay of the samples, as shown in the digital images in Figure 3. They attacked the critical zone (wood-soil contact region) of some logs and the pith region in the inner wood layer. The pith has a cavity surrounded by a more flexible layer composed of nutritional substances.

Underground termites need a source of moisture (soil or wood) for their activities, such as feeding, and can thus cause major harm to lignocellulosic materials (Clausen 2010). They are responsible for the highest percentage of damage caused to wood products around the world, mainly in wooden structures.

To a lesser extent with respect to mass loss from wood deterioration, water-soluble compounds are leached due to rainfall and relative humidity (Dalla Costa *et al*. 2018). Abiotic factors such as high solar radiation promote scission of surface fibers of the wood, providing entry for fungi and insects, which cause deeper injuries (to cellulose-hemicellulose chains present in the cell wall). Previously deteriorated material is more susceptible.

Based on the results of the DSI and NDSI of the five tropical wood species (Figure 4a-b), Co and Ap were most susceptible to deterioration in relation to the control, ranging from 200 % to 650 %. The three *Mimosa* species (Mc, Mo, and Mt) demonstrated deterioration similar to or less than the control (NDSI < 1,7). Curling and Murphy (2002) applied these indices to correlate mass losses of the studied wood species with reference values. However, they studied species with lower rates, and hence less susceptibility to natural deterioration in service.

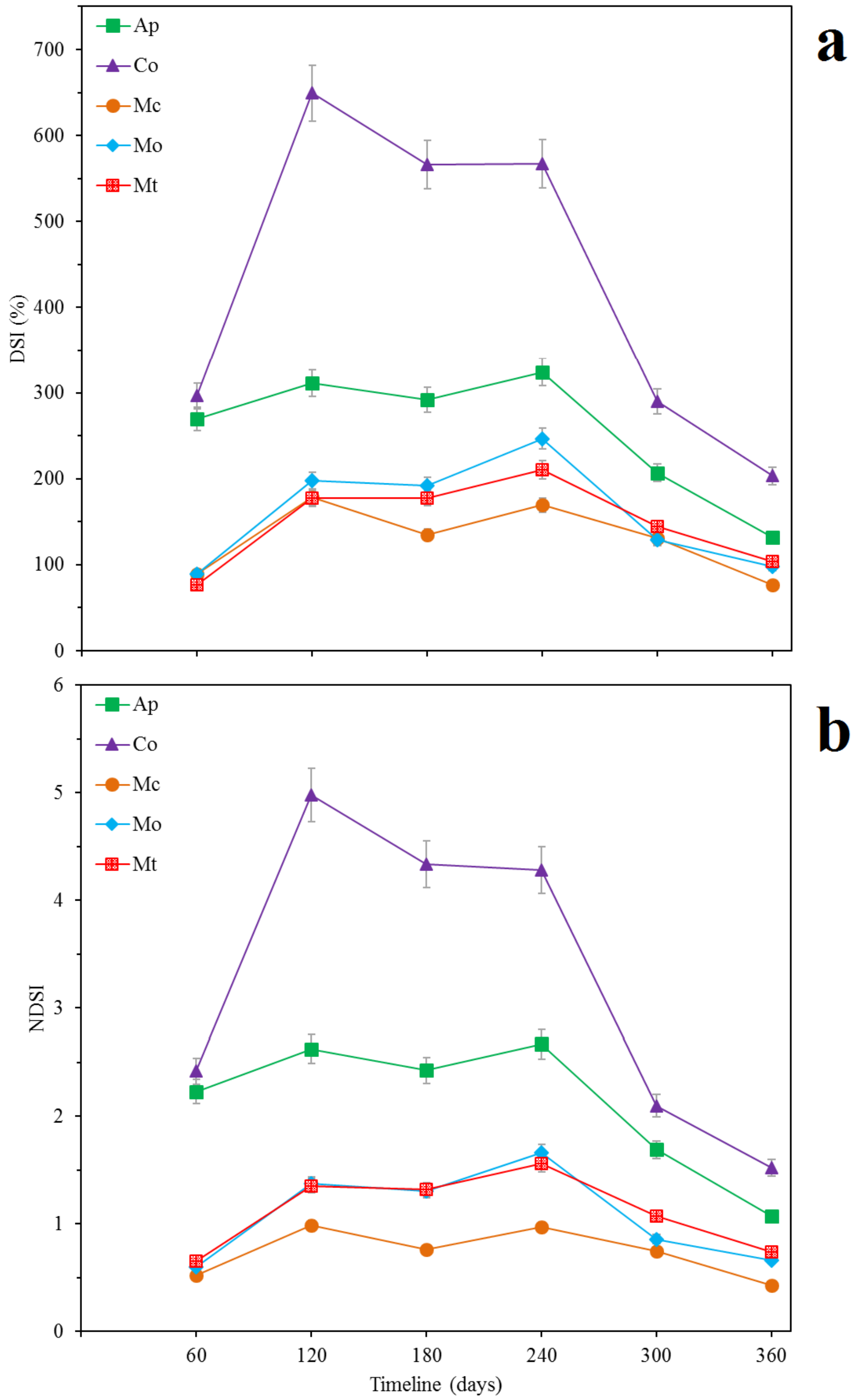


Figure 4: Decay susceptibility index - DSI (a) and new decay susceptibility index - NDSI (b) behavior of the different wood exposed over time in the field test (Averages, n = 6 for each specie in each time).

Studies indicate that wood with higher basic density and contents of lignin, extractives and inorganic components is more resistant to deterioration by organisms such as termites, fungi and bacteria (Kirker *et al.* 2013; Mounguengui *et al.* 2016; Hassan *et al.* 2017; Valette *et al.* 2017; Batista *et al.* 2020b). However, a simple and direct association cannot be drawn based on the physical-chemical composition of the studied species (Fig. 2a-b) and other the variables previously discussed. Other factors can also influence this response. Because our samples came from native populations, the age of the species may have had a large influence on deterioration, due to differences between juvenile-adult wood and heartwood-sapwood ratios (Medeiros Neto *et al.* 2020), as well as the competition and antagonism of deterioration organisms, distance between sources of infection and edaphoclimatic conditions (Brischke and Meyer-Veltrup 2016).

With regard to extractive compounds, these are substances present in plants associated with metabolic functions and defense and protection mechanisms (Hassan *et al.* 2017; Valette *et al.* 2017). According to Quintilhan *et al.* (2018), extractives are present in greater concentration in the outermost layers of the heartwood, and in adult wood, the extractives in the inner part of heartwood decrease its toxicity against invasive organisms. However, its quantity in the wood is not the predominant factor in the resistance response. Certain classes of these compounds have relevant antimicrobial and insecticidal activities (Kirker *et al.* 2013), such as phenolic compounds, present in significant quantities in Mimosa species' heartwood (Gonçalves *et al.* 2010; Maia *et al.* 2020).

As expected, all the wood samples in this study showed visual deterioration due to weathering throughout the year, mainly caused by two factors, total precipitation and global radiation. Nevertheless, the integrity as materials in service was not significantly affected. The first abiotic factor, water exposure, leads to absorption in the wood structure and later desorption. This promotes dimensional instability in the material and affects its natural resistance. The formation of cavities and cracks in the wood structure occurs in the medulla-heartwood-sapwood direction (Figure 5a), thus generating new attack zones for xylophagous organisms. The second factor, solar radiation, promotes the oxidation of the lignin present in the surface layers of the wood (portion above the surface), causing chemical reactions in the wood with the biotic and abiotic components of the soil (portion below the surface). This causes the color to darken (Figure 5b). Mt and Mo woods exhibited the greatest visual deterioration.

Figure 5: Final appearance from the samples of the different wood (left to right: Ap, Co, Mc, Mo, and Mt) of the top (a) and side view (b), after exposure to the field test.

These findings contribute to knowledge about the technological properties of these tropical wood species of the Caatinga biome, in particular Mimosa species' for outdoor applications such as timber stakes and fence posts. Due to small size classes (height and diameter) in harvestable age, and well as commons deformations (tortuosity) in tree trunks. However, the rational and appropriate use through sustainable forest management of these Mimosa species' is necessary, in order to avoid exacerbated exploitation by deforestation in rural areas.

CONCLUSIONS

The five tropical wood species discussed here have various uses in Brazil. Under the experimental conditions, the woods demonstrated variable natural durability in field test. The species *Mimosa caesalpiniifolia*, *Mimosa ophthalmocentra* and *Mimosa tenuiflora* are highly resistant to deterioration, with good performance, and comparable to that of treated eucalyptus wood. The other two species (*Aspidosperma pyrifolium* and *Cordia oncocalyx*) were more susceptible to natural deterioration. The first three species can be applied for external use, such as stakes and fence posts, without the need to apply preservative products to increase durability in service. Further investigations are strongly recommended, with longer exposure times of tropical wood species (3-5 years) and mechanical analysis after field testing.

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