Diagnosis of hollow trees in an area of effective sustainable forest management in the Amazon forest

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ABSTRACT

The sustainable practices of Forest Management activities are used with the objective of minimizing impacts to the environment, as well as exploring tree individuals with qualities that aim at the highest volumetric yield in sawmills. However, some characteristics may not be diagnosed before logging, as is the case with hollow trees, commonly found in forested areas. Thus, the objective was to diagnose the occurrence of hollow trees in two areas of forest exploitation, for the knowledge of individuals at the family and botanical species level. In order to carry out thediagnosis of the occurrence of hollow trees, data on the effective exploitation of trees in the Company's Forest Management areas were obtained through a collection of information on two Annual Production Units - UPA, named according to the company's specification as named as UPA ITP11 and UPA FLA01. In each UPA, tree individuals were identified by gender, species, family, distribution, presence of hollowness and the basic density of their wood. The results show that in the UPA ITP11 area, 7.38% of the total trees explored, had hollowness, while in the UPA FLA01 area it was 4.88% and that the majority had high basic density. Twenty botanical families were identified in the exploration areas, where the Leguminosae family obtained the greatest representation. A total of 49 botanical species explored were identified, being Manilkara huberi (Ducke) Stanley, as basic high density wood. Regarding the frequency of occurrence of hollowness, the species Dinizia excelsa Ducke, popularly known as Angelim Vermelho, stood out for the two areas under study. However, it is shown the considerable existence of hollow trees among the trees selected for forest exploitation, reinforcing the importance of better targeting of appropriate methodologies for their *identification, as well as, the better volumetric utilization of logs in sawmills, in order to certify the sustainability for the activity, regardless of the structural aspect of forestry individuals.*

Keywords: Hollow tree, tropical woods, forest management, volumetric use.

INTRODUCTION

The Amazon rainforest is the largest tropical rainforest, occupying approximately 6 million km², with complex characteristics, both environmental and socio cultural (BRAZ et al, 2014). The Brazilian legal Amazon corresponds to more than half of the national territory (LIMA; SANTOS; HIGUCHI, 2005), having a role as a climate regulator, providing environmental services and carbon storage (PEREIRA, 2010).

With the industrialization of lumber, the activity has become one of the three main economies of the States that the Amazon region covers (PEREIRA, 2010). Such potential valuation of timber species also encourages the illegal exploitation of this raw material in the region, contributing to high rates of deforestation, as pointed out by Imazon's Deforestation Alert System - SAD (2019), which only between January 2018 and January In 2019, there was a 54% increase in deforested areas in the Legal Amazon.

It was from the constant increase in deforestation in the region that solutions are constantly being created to combat and reduce illegal deforestation in the Amazon. Among the solutions, the importance of sustainable forest management was highlighted, which, according to Braz et al. (2014), has the duty to combat irrational and illegal logging, in addition to fostering development strategies.

However, the exploration of native forests becomes an imprecise activity regarding the conditions of the raw material, since the environment is in charge of constant ecological changes, giving characteristics to forestry individuals, which for industrial interests, do not become economically viable. Among these characteristics, the occurrence and, consequently, the cutting of hollow trees is common. This, since the technique, popularly known as “hollow test”, is outdated to accurately distinguish the occurrence of hollowness in the tree (Eleutério, 2011), this identification being made only on the basis of the tree's stem, erroneously excluded the possibilities of hollowness being present along the shaft.

Currently, loggers have only empirical knowledge of the possibility of the hollow in the tree for some species of commercial interest. However, studies related to the main tree species with occurrence of hollowness are still rare, this knowledge being essential to the wood processing industries, since trees with hollowness have difficulty at the time of cutting. Thus, the objective was to carry out a diagnosis of the occurrence of hollowness, of the main forest species exploited for timber consumption, in a forest management carried out in the Amazon region.

MATERIAL AND METHODS

- Characterization of the study area

The study focused on the municipalities of Itapiranga and Silves in the state of Amazonas in areas of effective Sustainable Forest Management at Empresa Mil Madeiras Preciosas Ltda, located in the municipality of Itacoatiara at the following coordinates, 3°3'14.54" to the south and 58°43 '39.85" to the West.

- Diagnosis of hollow trees in Forest Management areas

In order to carry out the diagnosis of the occurrence of hollow trees, data on the effective exploitation of trees in the Company's Forest Management areas were obtained. The study sought information that could certify the presence of hollow trees in native Amazonian forests, for this, a collection of information was obtained about two Annual Production Units - UPA, named according to the company's specification as ITP11 and FLA01. Among the information, data related to the pre-exploratory and post-exploratory forest inventory were gathered as a basis used to determine the diagnosis, according to the criteria and limits established by the company and legislation for the exercise of the activity.

Figure 1 shows the spatial location of the two UPAs, sources of information used in the study. The UPA called IPT11 is located in the municipality of Itapiranga and has an area of 7,164.56 hectares, whereas the UPA FLA01, in the municipality of Silves, has an area of 7,925.81 hectares. However, the area of effective exploitation of sustainable forest management excludes areas of permanent preservation of water bodies and restricted use, thus reducing the exploitable areas of the two Annual Production Units.

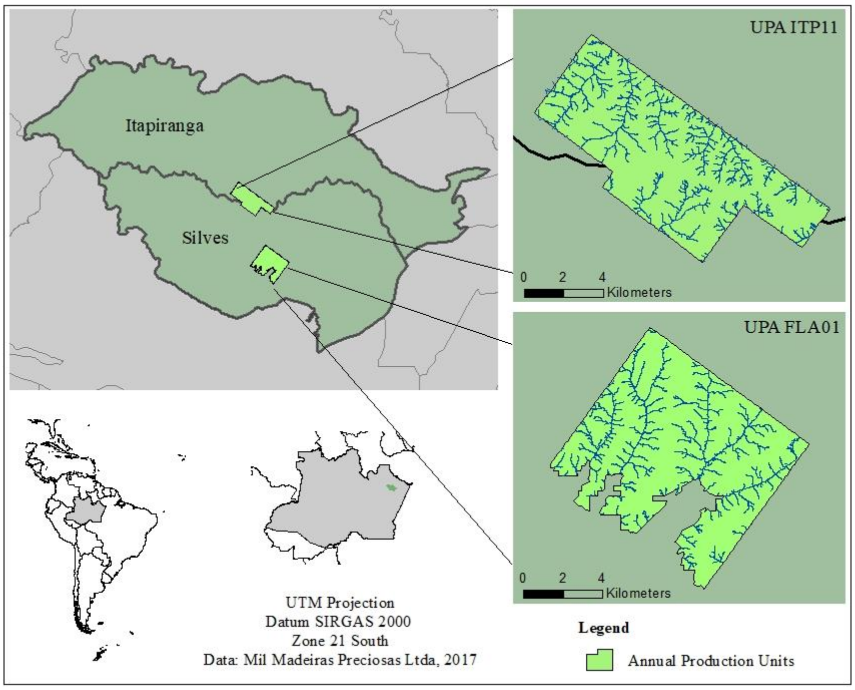


Figure 1. Location of Annual Production Unit areas, sources of study data.

The company's sustainable forest management practices begin with the work of georeferencing and macro zoning of forest areas. Subsequently, the Forest Inventory is carried out through the registration and identification of trees of potential current and future commercial value, with a diameter (DBH) from 40 cm. After mapping the environmental conditions of the management area, exploration and legal control of forest production is carried out. In the exploratory phase, directional cutting techniques are applied to the selected trees, carrying out their pre-dragging and dragging, with techniques that aim at minimum changes in the edaphic conditions of the area, favoring the regeneration of the forest after the first cutting cycle management.

After cutting each individual tree, the company performs the cubing in order to measure the volume of wood harvested. With this, it was possible to carry out the identification of the existence of hollowness in the shaft of the trees explored at the Annual Production Units under study and the density of the wood.

- Frequency of hollow trees

The total number of trees explored by species was counted, with the respective number of hollow trees found, for each UPA. In addition, an added information in this analysis was the verification of the basic density of the species, since this parameter is also identified as an identifier of possible hollow individuals.

Thus, the diagnosis allowed the recognition of individuals at the level of family and botanical species. Subsequently, the frequency count of occurrence of trees with the presence of hollowness in the shaft by species was made, according to Equation 1.

$$f_{oca} = \frac{AO}{n} x100 \qquad \text{Equation 1}$$

Where:

f_{oca}= frequency of occurrence of trees with hollow (%);

AO = number of hollow trees recorded during the cutting operation;

n = total number of trees explored.

- Data analysis

The information was obtained based on the diagnosis of the trees, frequency and distribution of the hollow trees taking into account the family, the gender of each tree and the density.

RESULTS AND DISCUSSION

- Diagnostics of hollow trees

The forest inventory carried out in the area of UPA ITP11 registered a total of 95,177 trees, while in the area of UPA FLA01, 85,657 trees were inventoried. At UPA ITP11, 20,897 trees were harvested for timber purposes, about 21% of the total number of trees inventoried. At UPA FLA01, 26,122 trees were explored, corresponding to 30% of the total trees inventoried in this area.

With the survey, 1,543 trees were identified with the presence of void in the shaft for the area of UPA ITP11 and 1,277 hollow trees for the area of UPA FLA01, representing about 7.38% and 4.88% of the total hollow trees explored respectively for both areas.

Other authors have also investigated the occurrence of hollow trees, such as Minetti et al. (2000) in a study carried out in the municipality of Itacoatiara-AM, detected about 23% of the total of trees explored were hollow. While Medeiros (2013) identified 16% of hollow trees in an INPA / ZF2 experimental area with impulse tomography. For the authors, the presence of the hollowness confers both the low volumetric yield and the low productivity of the forestry activity, making it a matter of concern to the timber companies.

In the diagnosis made by Emmert (2014), in areas of private forest (Municipality of Itacoatiara-AM) and public forest (FLONA do Jamari-RO), the equivalent of 17 of the total of trees included in the exploration planning were registered, 1% and 6.7% of hollow trees, respectively. In a more recent study by Almeida (2018), carried out at FLONA Saracá-Taquera-PA, 533 hollow trees were diagnosed in a forest exploitation area, representing the equivalent of 17% of the total of trees explored.

It is shown, therefore, that there is a large representation of hollow trees in native forest areas in the Amazon region, which can negatively interfere in the planning of exploration projects. Thus, maintaining or cutting hollow trees is an issue that involves ecological and economic implications. From an ecological point of view, the exploration or not of hollow wood would provide benefits to the forest such as the genetic improvement of species, contribution to environmental services, in addition to the shelter of small animals. From an economic point of view, it is important to consider the high costs of exploration per individual tree, the low volumetric yield of hollow logs, in addition to the uncertainty of logs usable for commercialization (Eleutério, 2011, Danielli, 2013).

The total information of the standing trees has not become a reliable parameter since the hollow test, the method to which the chainsaw saber is inserted in the shaft of the trees for such identification, is considered outdated, since the test is performed only on base of the tree, and the hollowness can occur along the entire shaft.

- Frequency and distribution of hollow trees in management areas

From the information obtained on the forest exploitation of the management areas, a total of 20 botanical families and 49 forest species were gathered for the two areas under study (Table 1).

Table 1. Trees explored in forest management area, with occurrence of hollowness.

Common name	**Scientific name**	**Botanical Family**	**Db (g.cm³)**	**ITP11**		**FLA01**	
				Arv exp	**Hollow arv**	**Arv exp**	**Hollow arv**
Maçaranduba	*Manilkara huberi* (Ducke) Standley	Sapotaceae	0.92	2,368	533	1,672	319
Black Laurel	*Ocotea neesiana* (Miq.) Kosterm.	Lauraceae	0.63	2,455	303	2,522	200
Louro-itauba	*Mezilaurus itauba* (Meissn.) Taub. ex Mez.	Lauraceae	0.8	826	157	73	9
Red Angelim	*Dinizia excelsa* Ducke	Leguminosae	0.83	85	29	327	132

Pequiá	*Caryocar villosum* (Aubl) Pers	Caryocaraceae	0.63	199	54	355	80
Cumarú	*Dipteryx odorata* (Aubl.) Willd.	Leguminosae	0.97	518	42	727	71
Amapá	*Brosimum parinarioides* Ducke	Moraceae	0.57	616	32	1,720	62
Cupiúba	*Goupia glabra* Aubl.	Celastraceae	0.69	797	38	1403	50
Louro-gamela	*Ocotea rubra* Mez	Lauraceae	0.58	1,670	61	171	2
Uxi	*Uchi endopleura* (Huber) Cuatrec.	Humiriaceae	0.78	390	17	1215	44
Red Pitch	*Protium puncticulatum* Macbr.	Burseraceae	0.63	2,176	40	88	4
Yellow Sucupira	*Enterolobium schomburgkii* (Benth.) Benth.	Leguminosae	0.84	200	8	903	30
Jatobá	*Hymenaea* courbaril L.	Leguminosae	0.76	45	3	451	33
Castanha-sapucaia	*Lecythis zabucajo*	Lecythidaceae	0.84	485	35	0	0
Brindle Angelim	*Pithecellobium incuriale*	Leguminosae	0.81	263	9	714	24
Red Arurá	*Iryanthera paraensis* Huber	Myristicaceae	0.63	999	28	244	4
Red Sucupira	*Andira parviflora* Ducke	Leguminosae	0.77	556	13	1,101	18
Red Tauari	*Cariniana micrantha* Ducke	Lecythidaceae	0.58	466	19	235	7
Tauari-cachimbo	*Cariniana rubra* Ducke	Lecythidaceae	0.65	263	6	452	17

Tanibuca	*Buchenavia viridiflora*	Combretaceae	0.72	95	20	62	3
Louro-aritú	*Licaria aritu*	Lauraceae	1.04	282	21	31	1
Timborana	*Piptadenia suaveolens* Miq.	Leguminosae	0.74	27	0	595	21
Pequiá-marfim	*Aspidosperma* desmanthum Benth exMuell. Arg.	Apocynaceae	0.69	359	13	210	8
Cedrinho	*Scleronema micranthum* (Ducke) Ducke	Bombacaceae	0.59	1,071	4	3,350	16
Bitter bean	*Vatairea paraensis* Ducke	Leguminosae	0.78	279	4	590	16
Guariúba	*Clarisia racemosa* Ruiz & Pav.	Moraceae	0.59	603	2	991	17
Muiracatiara	*Astronium lecointei* Ducke	Anacardiaceae	0.79	70	5	200	14
Angelim-stone	*Hymenolobium modestum* Ducke	Leguminosae	0.65	871	9	1087	9
White Pitch	*Protium paniculatum* Mar ch	Burseraceae	0.84	476	5	603	13
Muirapiranga	*Brosimum rubescens* Taub	Moraceae	0.95	179	14	80	4
White Tauari	*Couratari guianensis* Aubl.	Lecythidaceae	0.52	7	0	707	14
Manioc	*Qualea paraensis* Ducke	Vochysiaceae	0.66	754	9	141	2
Jutaí pororoca	*Dialium guianense* (Aubl.) Sandw.	Leguminosae	0.85	13	0	194	9

Angelim-do-campo	*Andira laurifolia* Ducke	Leguminosae	0.67	3	0	2052	8
Maparajuba	*Manilkara cavalcantei*	Sapotaceae	0.83	59	4	8	3
Ipê	*Tabebuia serratifolia* (G. Don) Nichols.	Bignoniaceae	0.87	3	1	23	5
Taxi-amarelo	*Sclerolobium chrysophyllum* Poepp. & Endl.	Leguminosae	0.52	0	0	95	3
Jacareúba	*Calophyllum brasiliense* Comb.	Clusiaceae	0.56	71	3	0	0
Jarana	*Lecythis poiteaui* O. Berg.	Lecythidaceae	0.8	114	2	0	0
Angelim-fava	*Hymenolobium excelsum* Ducke	Leguminosae	0.63	0	0	6	2
Acariquara	*Minquartia guianensis* Aubl.	Olacaceae	0.85	144	0	520	1
Marupá	*Simarouba amara* Aubl.	Simaroubaceae	0.39	0	0	89	1
Pequiarana	*Caryocar glabrum* (Aubl.) Pirs	Caryocaraceae	0.61	3	0	3	1
Black Sucupira	*Diplotropis racemosa* Amsh	Leguminosae	0.78	11	0	82	0
Violet	*Peltogyne catingae* Ducke	Leguminosae	0.81	24	0	26	0
Yellow Laurel	*Licaria rígida* Benth	Lauraceae	0.73	1	0	2	0
Beech laurel	*Roupala Montana* Aubl.	Proteaceae	0.77	1	0	0	0
Abiurana-guajará	*Pouteria cuspidata*	Sapotaceae	0.92	0	0	1	0

Melancieira	*Alexa grandiflora* Ducke	Leguminosae	0.53	0	0	1	0
Total				**20,897**	**1,543**	**26,122**	**1,277**

The leguminosae botanical family was the most representative among the forest species that had hollow spaces for both areas, followed by the families Lecythidaceae and Lauraceae, each containing five species. Observing that the species with the largest number of individuals explored in the two UPAS, were: *Ocotea neesiana*, *Manilkara huberi*, *Scleronema micranthum*. However, the species that obtained the greatest number of hollow individuals were: *Manilkara huberi*, *Ocotea neesiana*, *Mezilaurus itauba*, *Ocotea rubra*, *Caryocar villosum*, *Dinizia excelsa* and *Dipteryx odorata*.

As noted, the species *Ocotea neesiana* and *Manilkara huberi* appear as the species that have both the largest number of explored individuals, as well as the largest number of hollow individuals, for the two study areas. However, when viewed spatially, according to Figure 2, it is noticed that the distribution of these occurs in a different way. *Ocotea neesiana* is found to have dispersed occurrence over the entire management area, while the species Manilkara *huberi has* the occurrence in a more grouped form. Both species are common throughout the Brazilian Amazon, occurring on dry land, with high added commercial value.

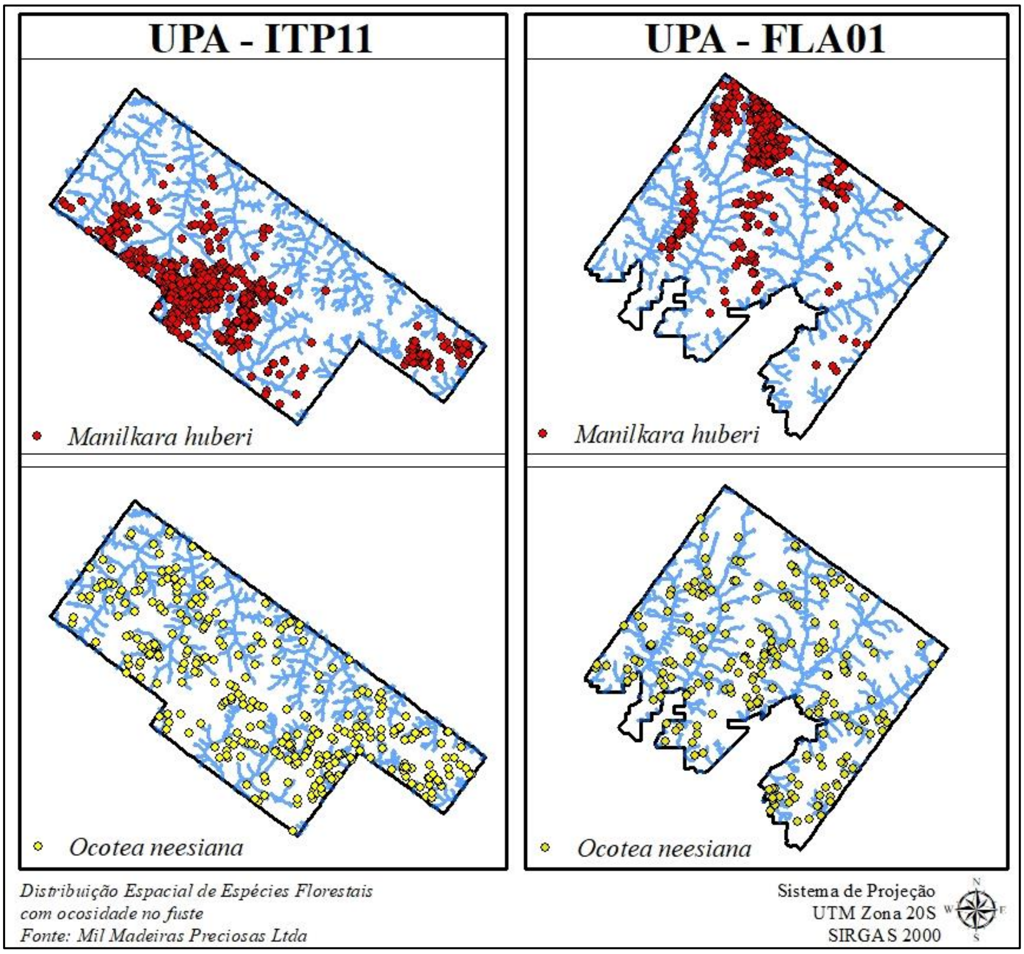


Figure 2. Spatialization of the species *Ocotea* neesiana *and Manilkara huberi,* identified with a greater number of arboreal individuals with hollowness for the two study areas.

Of all forest species explored in the two areas of the production unit, there were six that did not show hollow individuals, namely: *Licaria rigida, Roupala montana, Pouteria cuspidata, Alexa grandiflora, Peltogyne catingae* and *Diplotropis racemosa,* with emphasis on the two last species, popularly known as Violeta and Sucupira-Preta, respectively. Both species showed a significant number of individuals explored in both areas. For the species *Peltogyne catingae,* 24 and 26 tree individuals were found in the areas of the ITP11 and FLA01 production units, respectively, while for the species *Diplotropis racemosa*, 11 tree individuals were explored in the UPA ITP11 and 82 in the UPA FLA01.

The basic density of wood was one of the parameters observed in this research, since, according to research carried out by INPA / CPPF (1991) and by Corassa (2014), low density wood is more easily deteriorated by xylophagous organisms, as they have certain mechanical ease of entering them.

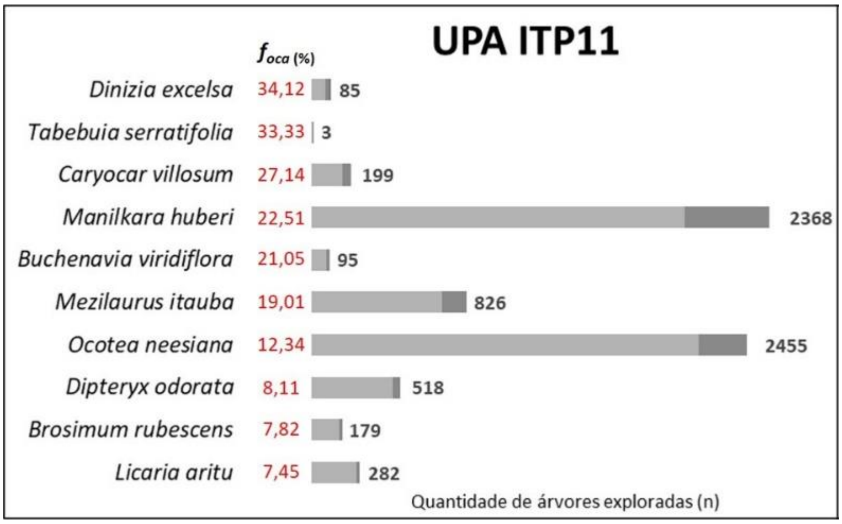
Therefore, of the 49 species explored for the two study areas, about 55% are classified as high density wood, and the other 45%, correspond to medium density wood. These species, in general, should provide greater mechanical resistance to avoid wood degradation by xylophagous organisms. However, a significant number of hollow individuals was observed, showing that species of high and medium basic density are also susceptible to attack by xylophages.

Corroborating with these results, the Eleutério (2011) research carried out in the eastern Brazilian Amazon with the objective of identifying the distribution of hollow trees in a wood management area, also obtained similar results, since most hollow trees belonged to species with high wood density (such as *Dinizia excelsa Ducke, Manilkara huberi, Manilkara bidentata, Astronium lecointei,* among other species).

In addition, Eleutério (2011) also observed that, one of the inherent factors for the identification of hollow trees in the field, was the diameter of the stem, because the larger the diameter and the older aspect of the trees, the greater the probability of the occurrence of hollowness in the arboreal individual. Different results were found by Medeiros et al (2017) and Barros et al (2019), when researching the quality of the wood of 19 Amazonian trees with small diameters, detected the presence of hollowness along the stem in most trees at the time mechanical processing, verifying that some trees presented these characteristics from the middle to the apex of the commercial shaft.

However, the relationship between the density of the wood and the occurrence of hollowness may be conditioned by the mechanical support of the wood, where trees with a higher basic density can provide greater resistance to biotic and abiotic forces that cause the stem to break, thus being able to guarantee their survival for long periods.

For the general diagnosis of the occurrence of hollow trees, the 10 most frequent species of hollow individuals are shown for the two areas of forest management, UPA ITP11 and FLA01, according to Figure 3.



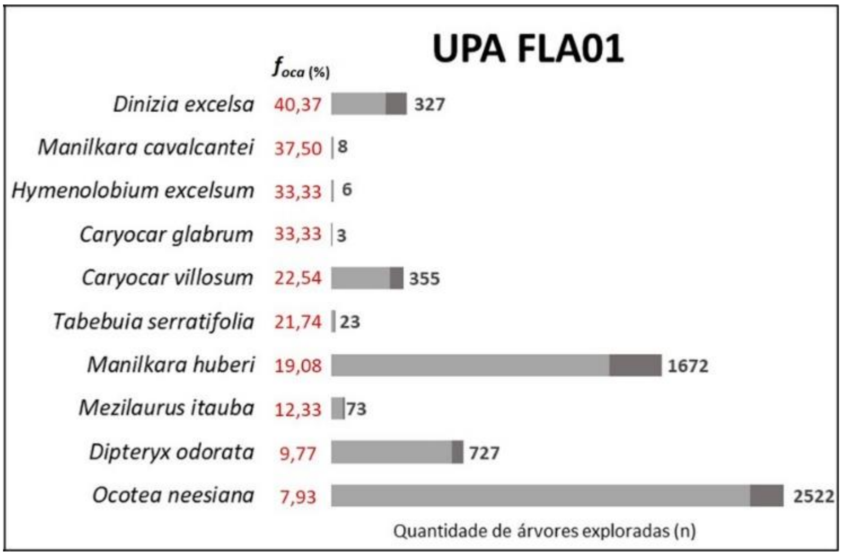


Figure3. Diagnosis of the frequency of occurrence of hollow trees in the two study areas.

It is noted that the species that obtained the greatest number of explored individuals, concomitantly with the largest number of hollow individuals, seen previously, did not necessarily present higher frequencies of occurrence of hollowness. The species *Dinizia excelsa* Ducke, popularly known as angelim vermelho, presented a great occurrence of hollowness for the two areas under study. In the work of Eleutério (2011), this same species with an intermediate abundance in a universe of 38 species studied, was the most hollow, with a frequency of hollowness greater than 20%.

According to engineers responsible for the company[1], who monitor the entire process of forest management activities, they reported that *Dinizia excelsa*, *Manilkara huberi* and *Mezilaurus itauba* species are the most frequently observed for these and other areas of forest management activities, practiced over the years by the timber company.

Thus, the diagnosis showed the significant presence of hollow trees in forest management areas in the Amazon region, which compromises the wood yield for the activity. Some logging companies avoid cutting down hollow trees as they cause a significant decrease in the volume of wood, which is also calculated when planning forest management activities. As a way of minimizing volume losses due to the

[1] Conversa informal: Engenheiros Florestais Bruno e Marcos

occurrence of hollow individuals, Emmert (2014) proposes that these hollow trees could be identified and marked in the forest inventory, avoiding the loss of time and excluding them from the volumetric wood planning and the list of possible cut trees.

However, the identification of these hollow trees in the field is a very complex issue, since the occurrence of the hollow in the shaft can vary from the base to the top, as well as in the degree of deterioration. Thus, it is noted the importance of timber companies to opt for the adoption of new technologies with the use of non-destructive techniques to assess the quality of the wood in the standing tree, before the process of selection of trees for exploration, as proposed by Medeiros (2013) and by Santos (2019), when they used impulse tomography, proving that it is possible to use this technique to classify hollow trees of some tree species.

CONCLUSION

Arboreal species in the Amazon have a hollow presence, which occur mainly in high density basic species of wood. Despite the general diagnosis of the occurrence of hollow trees pointing out that these are not the majority in forest areas, it was observed that for every 23.5 thousand tree species inventoried in management areas, about 6.2% (approximately 1.5 thousand trees) have a hole in its stem. The result of the diagnosis reinforces the importance of citing hollow trees in legislation, both in terms of the appropriate methodologies for identifying these in the field, and also in terms of volumetric use in sawmills, in order to certify sustainability for the activity, regardless of the structural aspect of forest individuals.

BIBLIOGRAPHY

Almeida, Vivian Barroso. Impacto da ocorrência de oco no rendimento volumétrico e financeiro da colheita de madeira na Floresta Nacional de Saracá-Taquera, Pará. 2018. 53 p. Dissertação (Mestrado em Ciências Florestais) - Universidade Federal Rural da Amazônia, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior.

Barros, Sámia Valéria dos Santos ; Higuchi, Niro ; Nascimento, Claudete Catanhede do ; Araújo, Roberto Daniel de ; Filho, Prof. Dr. Flávio de São Pedro . Wave Propagation Technology in Non-destructive assays for Wood Qualifying in Tropical Amazon. International Journal for Innovation Education and Research, v. 7, p. 259-274, 2019.

Barros, Ana Cristina; Verissimo, Adalberto. **A expansão madeireira na Amazônia**: Impactos e perspectivas para o desenvolvimento sustentável no Pará. 2°. ed. Belém, Pará: Imazon, 2002. 166 p.

Braz, Rafael Leite et al. Caracterização anatômica, física e química da madeira de clones de *Eucalyptus* cultivados em áreas sujeitas à ação de ventos. **Ciência da Madeira**, [S.l.], v. 5, n. 2, p. 127-137, set. 2014.

Braz, Rafael Leite et al. Resíduos da colheita florestal e do processamento da madeira na Amazônia – uma análise da cadeia produtiva. **Journal of Biotechnology and Biodiversity**, [S.l.], v. 5, n. 2, p. 168-181, maio. 2014.

Corassa, Janaína de Nadai et al. Témitas Associados à Degradação de Cinco Espécies Florestais em Campo de Apodrecimento. [S.l.]: **Floresta e Ambiente**, 2014. 7 p.

Danielli, Filipe Eduardo et al. Modelagem do rendimento no desdobro de toras de Manilkara spp.

(Sapotaceae) em serraria do estado de Roraima, Brasil**. ScientiaForestalis**, Piracicaba, v. 44, n. 111, p. 641-651, set. 2016.

Danielli, Filipe Eduardo. Modelagem do rendimento no desdobro de toras de *manilkara* spp. (Sapotaceae) em serraria na nova fronteira madeireira do estado de Roraima, Brasil. 2013. 82 p. Dissertação (Mestrado em Ciências de Florestas Tropicais) – Ciências de Florestas Tropicais, Instituto Nacional De Pesquisas Da Amazônia, Manaus, Amazonas, 2013.

Eleutério, Ana Alice. **Wood decay in living trees in eastern Amazonia, Brazil**. 2011. 102 p. Thesis (doctorate in philosophy) – Faculty of Environmental Sciences, University of Florida, Florida, 2011.

Emmert, F. 2014. Combinação de dados de campo e métodos computacionais para o planejamento da exploração florestal na Amazônia. Tese De Doutorado. Universidade de Brasília.

INPA/CPPF. 1991. Catálogo de madeiras da Amazônia: Caracteristicas tecnológicas; Área da Hidrelétrica de Balbina. CPPF/INPA, Manaus, 163p.

Lima, José Ricardo Araújo; Santos, Joaquim dos; Higuchi, Niro. Situação das indústrias madeireiras do estado do Amazonas em 2000. **Acta Amazônica**. V. 35, n. 2, p. 125-132, 2005.

Medeiros et al. **Tomografia de impulso na avaliação da sanidade e rendimento *Micrandopsis scleroxylon* W. Rodr.** 2017. Nativa, Sinop, v.5, esp., p. 649-655, dez. 2017.

Medeiros, Romulo Geisel Santos. Avaliação do rendimento da madeira de árvores de floresta em pe por meio de metodologia nao destrutivas. 2013. Dissertação (Mestrado em Ciências Florestais e Ambientais) - Universidade Federal do Amazonas, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior.

Medeiros, R. ; Nascimento, C. C**.** ; Barros, S. V. ; Paula, E. V.m. ; Higuchi, N. . Tomografia de impulso na avaliação da sanidade e rendimento de Micrandopsis scleroxylon W. Rodr. NATIVA, v. 5, p. 649, 2017.

Minetti, L. J.; Filho, R. F. de O.; Pinto, L. A. de A.; Souza, A. P. de; Fiedler, N. C. Análise técnica e econômica o corte florestal planejado de floresta tropical úmida de terra firme, na Amazônia Ocidental. Revista Árvore, v. 24, n. 4, p. 429-435, 2000.

Pereira, Denys et al. **Fatos Florestais da Amazônia**. Belém, Pará: Imazon, 2010. 126 p.

Pereira, Denys; Lentini, Marco. **Guia SAMFLOR**: Sistema de Apoio ao Manejo Florestal. Belém, Pará: Imazon, 2010. 68 p.

Santos, Filipe Bruno Batista dos. Potencial Tecnológico de espécies Arbóreas por tomografia de impulso para auxiliar no manejo Florestal na Amazonia. 2019. Dissertação (Mestrado em Ciências florestais e ambientais -PPGCIFA) - Universidade Federal do Amazonas, Conselho Nacional de Desenvolvimento Científico e Tecnológico.