HARVESTING AND PROCESSING OF NATIVE WOOD FROM UPLAND TROPICAL FORESTS IN AMAPÁ, EASTERN AMAZONIA

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Resumo

Extração e processamento de madeira nativa de terra firme no Amapá, Amazônia Oriental. O conhecimento sobre o setor madeireiro e atuação de indústrias locais auxilia na gestão de uma economia florestal para a Amazônia baseada no uso sustentável. Neste estudo, foi analisada a situação do setor madeireiro do município de Porto Grande-AP, para discutir a extração e processamento de madeira nativa da Amazônia e o uso sustentável desse recurso pelo setor. Para isso, foram aplicados formulários em todas as serrarias do referido município, sobre fatores de produção e comercialização de madeira nativa no ano de 2017, além de entrevistas com comerciantes locais e coleta de dados secundários de diversas instituições ligadas ao setor madeireiro. Todas as serrarias do município exercem atividade licenciada e processaram 69.300 m^3 de madeira no período, com extração média de 21 m^3/ha. No que se refere ao rendimento produtivo das serrarias (55%), está acima do máximo, recentemente, estabelecido pelo CONAMA (35%). Não há aproveitamento de resíduos pela maioria das serrarias e a madeira serrada é comercializada, principalmente, para a região Nordeste do País, para utilização na construção civil. Desse modo, para garantir melhor desempenho econômico e ambiental do setor, recomenda-se às serrarias a busca por novas áreas florestais como fontes de matéria-prima, adesão ao mercado de certificação florestal e utilização de resíduos para geração de bioenergia. Ao governo, recomenda-se a habilitação de novas florestas para manejo, por meio de ações que solucionem indefinições fundiárias e promovam a oferta de florestas públicas, redução dos custos de licenciamento e simplificação desse processo pelos órgãos ambientais para unidades de manejo certificadas.
Palavras-chave: Setor madeireiro, produção de florestas nativas, rendimento de madeira serrada, manejo florestal.

Abstract

Knowledge about the activity of the timber sector and local industries assists in the management of a forest economy based on sustainable use in the Amazon. In this study, the situation of the timber sector of the municipality of Porto Grande-AP was examined to detail the extraction and processing of native wood from the Amazon and the sustainable use of this resource by the local sector. Forms were applied in all sawmills of the municipality, which collected information on factors of production and commercialization of native wood for the year 2017. In addition, interviews with local merchants were done and secondary data collection from several institutions related to the sector was conducted. All sawmills in the municipality exercise licensed activity and processed 69,300 m^3 of wood in the period, with an average extraction of 21 m^3/ha. The sawmills productive income was 55%, above of the 35%, maximum recently established by CONAMA. There is no destination for productive of residual waste generated by most sawmills and lumber is marketed mainly to the Northeast of Brazil for use in civil construction. Thus, in order to guarantee better economic and environmental performance of the sector, it is recommended that sawmills search for new forest areas as sources of raw material, participate in forest certification programs, and seek ways to use residual waste for bioenergy generation. The government recommends that new forests be managed through actions that solve land tenure problems and increase the supply of public forests, and for certified management units the recommendation is to reduce licensing costs, and simplify the bureaucratic processes of environmental agencies.
Keywords: Timber sector, production of native forests, lumber yield, forest management.

INTRODUCTION

The Amazon region is one of the principal producers of native tropical wood in the world and supplies local and regional lumber markets as well as those of the large urban consumer centers across Brazil, especially in the South and Southeast regions. However, the production of legal wood is a challenge for the forestry sector in the Amazon because there is intense and unfair competition from wood that is illegally harvested. In this context, forest management represents an opportunity for the logging industry in the region to reconcile economic use with conservation, thus guaranteeing sustainable use of forests (CASTANHEIRA-NETO, 2018).

The state of Amapá, part of the Amazon region, also coexists with this scenario of illegal timber harvest, principally in the forest of the várzea (river floodplains). Currently, the production of legal wood in the state comes

only from lowland forests. Despite the fact that the economy of Amapá suffers from the portion of the market that sells wood from unmanaged forests, the sheer abundance of forests in the state is a source of great potential for the development of local economies based on judicious use of forest resources. Furthermore, the location of the mouth of the Amazon River within the state favors efficient shipping to the American and European markets (AMAPÁ, 2018).

However, this potential in Amapá is limited by the availability of public forests for economic use through management and by the absence of land tenure in private forests (AMAPÁ, 2018). For these reasons, most legal wood produced in Amapá comes from settlement projects under the management of the National Institute for Colonization and Agrarian Reform (INCRA), which issues and maintains records of legal possession of property, which is one of the requirements necessary to obtain environmental licenses to log forests (AMAPÁ, 2018). This is one of the motives why the logging sector in Amapá seeks out forests in agrarian reform settlement areas for management and logging activities.

The municipality of Porto Grande is the principal producer of roundwood in Amapá, with a production of 152,708 m^3 in 2017. Furthermore, it is nationally known as being among the twenty Brazilian municipalities that are the largest producers of roundwood, occupying the 15th position in this ranking in 2017 (IBGE, 2018). Despite its potential for wood production, at the time that this study was conducted there were no publications that outlined the dynamics wood harvesting sector in Porto Grande, indicating that this is a topic that has not been given much attention by Brazilian scientific research.

This context, therefore, serves as the basis of this research, since knowledge about the activities of local sawmills is a fundamental tool for the formation of an economic perspective based on sustainable use of natural resources. The sawmills are responsible for the low or high level of utilization of raw material, a factor that directly influences the area of forest that is needed to satisfy demand for timber and its sustainable harvest (CYSNEIROS *et al*., 2017). In this way, the objective of this study was to present the situation of the logging sector in the municipality of Porto Grande-AP, through discussion of the harvest and processing of wood from native forests in the Amazon, and the sustainable use of this resource by the logging sector.

MATERIAL AND METHODS

Study area

This study was conducted in all six economically active sawmills in 2018, which operate in lowland forests located in the municipality of Porto Grande (N 00° 41′ 53.91” W 051° 26′ 4.27”), in the center-west region of the state of Amapá, in the North region of Brazil, eastern Amazonia. The sawmills are located along the BR/AP-210 highway (Figure 1), which passes through the municipality of Porto Grande.

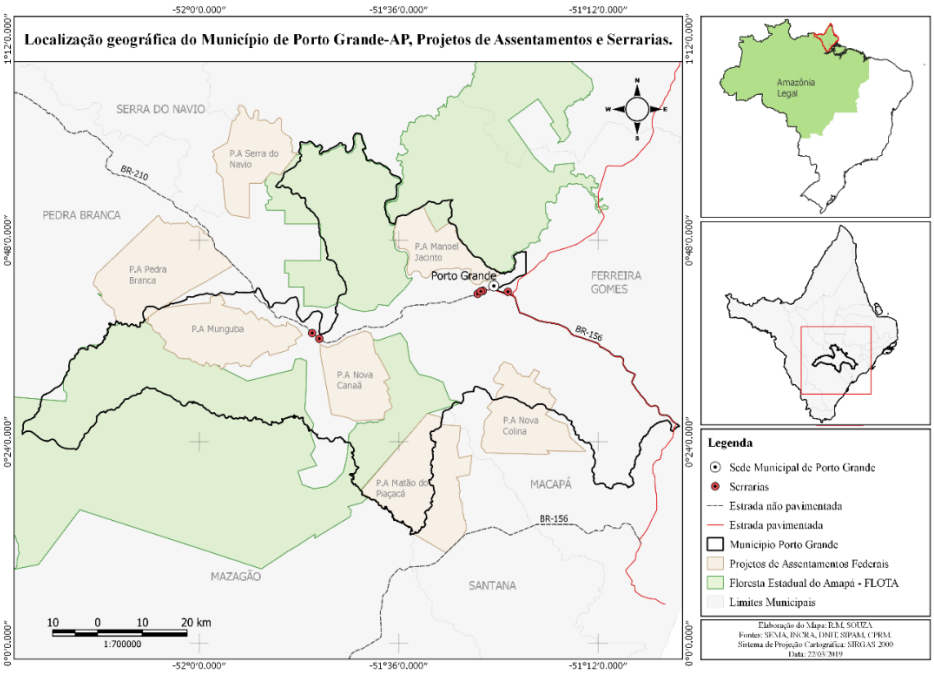

Figura 1. Localização das serrarias no município de Porto Grande. Áreas de Projetos de Assentamento e a Floresta Estadual do Amapá, principais áreas com potencial para exploração florestal no município.

Figure 1. Geographic location of the municipality of Porto Grande-AP, sawmills, settlement projects and FLOTA (Amapá State Forest). These are main areas with potential for forest exploration in the municipality.

According to the Brazilian Institute of Geography and Statistics (IBGE), the municipality of Porto Grande has an area of 4,428,013 km^2 and a population of 21,484 inhabitants in 2017, with a Human Development Index (HDI) of 0.64, considered average (PNUD, 2010). The GDP *per capita* in the municipality is R$ 15.6 thousand/year, the 7th highest in the state (IBGE, 2018).

The largest contributor to the local economy is forest harvesting, which in 2017 was R$ 7.4 million (IBGE, 2018), followed by agricultural activities. Additionally, silviculture contributes to the economy, especially with respect to plantations of *Eucalyptus* spp. and *Pinus* spp. Since 2008, Porto Grande has been in first place in the IBGE ranking for wood production in Amapá.

Data collection

Data collection was done in all sawmills that process native wood from the municipality. Semi-structured interviews coupled with the use of forms that had dichotomous, chained, closed-ended, and open-ended questions. It was possible to extract multiple responses based on the following variables: production, sawmill yields, and commercialization of sawn wood.

Using this method, information was obtained on origin of raw material, harvest area, volume of annual processing of roundwood, harvest intensity, species harvested, the principal species used in production processes and most commercialized, sawn products and the principal one made, annual productive yield, utilization of residuals. Information was also obtained on, final destination of products (markets), period of sale, annual volume of sawn wood, average annual income and profit.

The interviews were done in the sawmills with owners, managers, or current employees with more than five years of experience, and this information was relative to the year 2017. Interviews were also conducted with local sellers of wood in establishments such as lumber stores, furniture factories, and home improvement/construction stores in the state capital of Macapá and in Santana, the second largest municipality in the state. These municipalities concentrate more than half (73.9%) of the population of Amapá (IBGE, 2018) and represent a large portion of the total consumption of the state of Amapá.

As a complement to these data collected in interviews, secondary data were also gathered from official institutions such as the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) by consulting the Forest Origin Document system (DOF), IBGE using the internet sites IBGE Cities, and Plant Harvest Production and Silviculture (PEVS). At the Institute of the Environment and Territorial Planning of Amapá (IMAP), the licensing agency for forest harvesting activities, research was done on forest management permits (AUTEX) that were active in 2017 using the archives of the institution.

Data analysis

Data obtained in the field were tabulated in spreadsheets using the program Microsoft Office Excel 2016. Quantitative data such as area harvested, volume of round- and sawn wood, and annual profit were calculated using basic descriptive statistics (averages) and presented in tables.

To obtain productive yield of the sawmills, the ratio between the volume of sawn wood to the volume of roundwood that was processed was calculated and multiplied by 100, similar to the method used by Biasi and Rocha (2007) using Equation 1 below:

$$Rp(\%) = \frac{V_s}{V_p} \text{ x}100 \quad (1)$$

where: *Rp (%)* represents the percent of the productive yield of a sawmill, *Vs* indicates the volume of sawn wood, and V_p the volume of processed wood.

The intensity of harvest was determined from the ratio between the volume of logs processed over the utilized area, during the same period (one year in this case), according to the equation described by Pimentel (2014):

$$It(m^3 ha^{-1}) = \frac{V_{tp}}{HA_a} \quad (2)$$

where: *It* (m^3 ha^{-1}) represents the harvest intensity in cubic meters per hectare used by the sawmills for wood harvest, *Vtp* is the volume of logs processed, and *HAa* is the quantity of hectares on an annual basis. Averages were calculated for these results.

For the analysis of closed-ended questions with respect to the origin of raw material, residual utilization, profit, and period of sale, the variables were categorized to obtain a percentage for each response.

For questions where the response could be multiple (species used and the most commercialized, sawn products made, and residual utilization) the relative frequency was calculated, which consists of the ratio between

the sum of the responses given for a specific question over the sum for all the items responded, similar to the method in Del Menezzi and Bonduelle (2002), as shown by Equation 3 below:

$$FR(\%) = \frac{\sum rd}{\sum ir} \text{ x100} \quad (3)$$

where: *FR (%)* is the relative frequency, *rd* indicates the responses of the interviewees to the question, and *ir* represents the items responded for the question.

Finally, the primary data were compared to the secondary data by calculating the percent variation in order to identify the difference between quantities of the relative percentage, by obtaining responses from the relationship between a previous quantity (data obtained through interviews) and a posterior quantity (data obtained from official agencies). Equation 4 below was used for this calculation:

$$V(\%) = \frac{V_1 - V_2}{V_2} \text{ x100} \quad (4)$$

where: *V (%)* is the percent variation, V_1 represents the response obtained in the field, and V_2 that from the secondary data.

RESULTS

Presentation of activities of sawmills

All six sawmills in the municipality of Porto Grande are registered in the National Registry of Legal Entities (CNPJ) under the official denominations of Small Business (EPP) and Microcompany (ME). These companies also engage in activities licensed by the state environmental protection agency, IMAP. The machinery used by these sawmills has a low level of automation, and in general have vertical and horizontal bandsaws and a circular saw (trimming machine and crosscut saw). The average annual energy bill resulting from energy consumption during production processes was R$175,000.00

All the interviewees responded that the principal area where wood was harvested is located in Settlement Projects (SP) under management of INCRA. The owners of the sawmills negotiate the use of the areas of forest legal reserve of these SPs with their occupants (settlers) through means of legal contracts to harvest wood. The analyses of the AUTEX showed that the settlers are considered the party that are owners of the forest management plan on an individual basis. In this negotiation, the loggers are responsible for navigating the bureaucratic process, planning, and execution of the forest management plan. In exchange, they pay the settlers, on average, R$ 45 / m^3 of wood authorized in the forest management plan, independent of species. The SPs that have been the most harvested by the sawmills of Porto Grande were, in 2017, Munguba and Nova Colina.

Production of roundwood and harvest intensity

The sum of annual production of roundwood in 2017, as reported by the sawmills, was 69,300 m^3, and the average harvest intensity was 21 m^3 ha^{-1} (Table 1). Table 1 shows the data for volume of roundwood harvested by each sawmill, with the area utilized and the cutting intensity.

Tabela 1. Volume de madeira em tora de floresta nativa de terra firme da Amazônia Oriental, área e intensidade de extração de cada serraria em Porto Grande, Amapá, no ano de 2017.

Table 1. Timber log volume of upland Eastern Amazon native forest, area used and harvest intensity of each sawmill of Porto Grande, Amapá, in the year 2017.

Sawmill	*Size	Volume (m^3)	Area (ha $year^{-1}$)	Harvest intensity (m^3 ha^{-1})
A	Small	15,600	600	26
B		12,900	575	22
C		12,600	600	21
D		12,000	500	24
E		10,200	560	18
F		6,000	450	13
		Total = 69,300	**Total = 3,285**	-
		Average = 11,550	**Average = 547**	**Average = 21**

Legend: *Size, as classified by Rocha (2002).

Two commercial species were most prominent in the sawmills: maçaranduba (*Manilkara huberi* (Ducke) Chevalier) and angelim vermelho (*Dinizia excelsa* Ducke). The importance of these two species to production was confirmed by the data from the management plans authorized by IMAP for harvesting activities in 2017 (Figure 2).

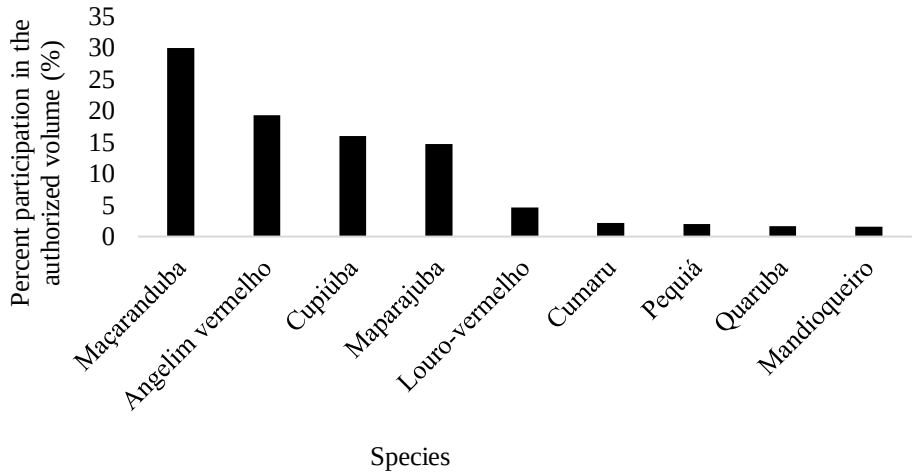

Figura 2. Espécies mais exploradas no município de Porto Grande-AP, de acordo com os inventários florestais que subsidiaram a elaboração dos planos de manejo aprovados.
Figure 2. Principal timber species used by sawmills in the municipality of Porto Grande-AP, according to the forest inventories conducted in the preparation of approved management plans.

The two most processed and commercialized species by the sawmills were mentioned in the responses with a frequency of 50%. In general, timber harvest is selectively done, with about 10 to 15 species being used. Besides the two principal species, angelim vermelho and maçaranduba, the other species that were cited with high frequencies were angelim pedra (*Hymenolobium nitidum*), mandioqueiro (*Qualea paraensis* Ducke), cumaru (*Dipteryx odorata* (Aubl.) Willd.), quaruba (*Vochysia paraensis* Ducke), cupiúba (*Goupia glabra* Aubl.), sucupira (*Bowdichia nitida* Spruce) and louro vermelho (*Ocotea rubra* Mez.).

The sawmills produce eight types of sawn wood products, which are beams, slats or laths, boards, rafters, planks, roof beams, pillars, and blocks. Beams represent 50% of total production, and laths 21%, and the average price of these product varies on the type of products and the species.

Sawmill productivity

The average annual productive yield of sawmills in 2017, as estimated using the information collected in all the sawmills in Porto Grande was 55% (Table 2).

Tabela 2. Rendimento produtivo das serrarias do município de Porto Grande-AP, Amazônia oriental.
Table 2. Productive yield of the sawmills of Porto Grande-AP, eastern Amazon.

Sawmill	Roundwood production (m^3 $year^{-1}$)	Volume of sawn wood (m^3 $year^{-1}$)	Yield (%)
A	15,600	4,800	31
B	12,900	6,600	51
C	12,600	6,600	52
D	12,000	6,000	50
E	10,200	5,500	54
F	6,000	5,400	90
Total	**69,300**	**34,900**	**-**
Average	**11,550**	**5,817**	**55**

The sawmill with the lowest production (F), had a very high value for productive yield (90%), which greatly differed from the observed pattern for the other sawmills and also for sawmills across the Amazon. This could be related to underestimation of the volume of wood processed, since in general, for this type of small business there is greater control over the volume of sawn wood that is commercialized. The low harvest intensity for this same sawmill (Table 1) also supports this assumption.

Byproducts and residuals from production (wood scraps and sawdust) are not utilized by more than half (57%) of the respondents. They stated that these byproducts and residuals are a problem that results from the industrial process, and emphasized that they still have the expectation that the state and/or municipal governments will implement public policies that will support studies that will research on how to improve utilization of these materials and reduce residual generation.

Commercialization

The annual volume of sawn wood that was commercialized in 2017, as estimated by the information obtained from the sawmills of Porto Grande was 34,900 m^3. The period of greatest sale of wood products was during the rainy season from December to July, considered to be the Amazon winter. However, in 2017 there was, and still is, demand for wood during the entire year.

With respect to the destination of these products, 100% of the respondents related that export to national markets is the predominant destination, with the Northeast region being the most important importer. In this region, the states of Bahia (BA) and Rio Grande do Norte (RN) are the largest buyers. Just one respondent stated that his sawmill also provides wood to the Southeast region, with exports to the states of São Paulo (SP), Rio de Janeiro (RJ) and Minas Gerais (MG). The shipping of production occurs through third-party freight transport.

The internal market (local and state) consumes the residuals from industrial production, principally slabs, scraps, pieces from trimming, etc., and a small portion of sawn wood, as verified in the DOF system. The sawn wood produced in Porto Grande and sold in Amapá was 990.47 m^3, or just 2% of production. Average annual income was not informed by any of the interviewees, but 71% of them consider this activity to be lucrative and related an mean percent gain of 22% per year.

DISCUSSION

Presentation of activities of sawmills

Since all the legalized sawmills in Porto Grande operate with the necessary environmental licenses, this suggests that logging activity in the region is conducted in a sustainable manner, in the assumption that techniques of forest management are being applied. However, the fact that these sawmills do not possess their own forests for wood harvest makes them depend on forests owned by other entities or people, such as the SPs managed by INCRA. This government agency established as a rule that only the settler (an individual beneficiary of agrarian reform) or an association (collective representation) can act as the rightful owner of the Sustainable Forest Management Plan (PMFS) for use of forest resources such as timber (BRASIL, 2010).

In this way, the settlers are the only owners of forest management plans, as was verified in the AUTEX documents emitted by IMAP, and they receive payments for the extracted timber without actively participating in the process of management. Since the local logging companies function as the timber harvesters and are responsible for the entire bureaucratic process of obtaining licenses without the participation of the settlers in this process, this generates a dynamic that is in agreement with the legal norms established by INCRA.

With respect to the result that revealed that the SPs Munguba and Nova Colina are the SPs that are the most harvested, this indicates that this model of timber harvest in lots within SPs could be nearing its useful life. Since the legal reserve of each lot is a small area and timber harvest occurs in a single Annual Production Unit, as verified in the AUTEX emitted by IMAP, tree harvest occurs just once in each area, thus forcing the harvest front to migrate to other areas that are further away. This was also shown in the analysis of the DOF, which revealed that more than half (64%) of the wood processed in the sawmills of Porto Grande does not come from the municipality.

Production of roundwood and harvest intensity

The volume of 69.300 m^3 of annual production of roundwood found in this study was compared to the volume authorized for extraction by IMAP (98,268,69 m^3), and showed a percent variation of 29.4% less in relation to the volume authorized by the environmental agency. This difference in the volume harvested by the sawmills could be attributed to the two-year validity of the AUTEX. Since the licenses were emitted in 2017, it's possible that the sawmills were not able to execute the entire management plan during that one year.

The volume obtained from the sawmills was also compared to the quantity of harvested roundwood (152,708 m^3) published by IBGE for Porto Grande, which was 56% less than that reported by this agency. This difference could be attributed to the diversity of sources from which the IBGE extracts data and bases its estimates on, since some of these data were taken from PEVS research, in which the collection of data is done at the state level, with little contribution from informants from institutions linked to the logging sector (ÁLVARO, 2008). This situation makes it possible to affirm that the statistics of the IBGE for roundwood production in Porto Grande diverge from the principal sources such as IMAP and the sawmills themselves, with values above those registered in this study.

When comparing the estimated volume produced by the sawmills with that reported in the DOF system for domestic transport of logs going to Porto Grande, with origin from this municipality as well as the entire state of Amapá, a volume of 159,618,11 m^3 of logs was reported in 2017, showing that just 36% of the wood processed in Porto Grande was harvested in forests of this municipality. This indicates a limitation of available areas near the sawmills, meaning the SPs of the municipality itself, moving the logging front to other more distant areas. This limitation is enabled by the harvest model in a single APU by the fact that the management plans do not consider

the next harvest cycle, silvicultural treatments, or monitoring of harvested areas, as required by the law called Native Vegetation Protection (Law nº 12.651/2012).

In this scenario, to guarantee better economic and environmental performance of this sector, it is recommended that sawmills search for new areas of forest as sources of raw material. However, for this to occur, the government must approve the news areas through a public offering of forests by issuing forest harvesting concessions and should also resolve land tenure issues in order to provide access to private forests.

With respect to harvest intensity, all sawmills, in spite of harvesting in a single APU, presented levels of intensity within the limits established by the CONAMA resolution nº 406/2009. This resolution determines a maximum harvest limit of 30 m^3 ha^{-1} for management plans that involve the use of machines to skid logs.

The species maçaranduba and angelim vermelho are two of the most used in sawmill production, and the frequency of these species in the responses of the interviewees was corroborated with the species authorized for harvest in the management plans emitted by IMAP. This analysis confirmed that these species are the most sought after in logging operations in Porto Grande. The demand for these species can be attributed to the fact that they have high quality wood and possess technological properties that make them attractive for a diversity of uses (ROSA *et al.*, 2014). Furthermore, these are also some of the most abundant species in the region and are characterized as hyperdominant species in lowland Amazonian forests (APARICIO *et al*., 2014). However, the concentration of management and logging activity using just a few species could lead to exhaustion of species of these families in the medium or long term. Management techniques that guarantee the continuity of wood production over time represents an alternative to indiscriminate deforestation (ÂNGELO *et al*., 2014).

Ribeiro (2012) recommended the insertion of new species into forest production as an alternative that serves to reduce pressure on traditional commercial species, especially those of greatest economic value. However, producers, lumber sales companies, and consumers present resistance when a new species is offered on the market, due to the well-established and appreciated physical and mechanical characteristics of traditional commercial species. For this reason, it is necessary to search for species that have the same technological characteristics as the traditional ones in order to new species to gain traction in the market.

Sawmill productivity

The percent value for average production yield (55%) of the sawmills is above that (41%) reported for 2009 by Hummel *et al*. (2010) for the logging sector in the Legal Amazon. With the change made by CONAMA in 2016 in the percentage volumetric yield from 45% to 35%, the values shown above, which were within the established legal limits, are now considered irregular.

Since 2009, the coefficient of volumetric yield (CRV) was used according to the specific characteristics of each sawmill, with the only limit imposed being a maximum of 45% yield of sawn wood from a log or small, irregularly short logs. If the sawmill attains a CRV value that is greater than 45% a technical study needs to be presented to the environmental agency in charge of compliance (BRASIL, 2009).

In 2016, the CRV was reduced from 45% to 35% with the objective of eliminating the generation of excess (false) credits for wood in the DOF system. During the period when the CRV was 45% the system conceded, for each m^3 of processed logs, 0.45 m^3 of sawn wood in the form of credit. However, the reduction of the CRV was proposed to CONAMA by IBAMA and the Brazilian Forest Service (SFB), with the objective of avoiding excess credit in the system and improving rules for industrialization and transport of managed timber (BRASIL, 2016).

On the other hand, the reduction in the CRV could stimulate the processes that cause losses in production and increase the generation of residuals, a common environmental problem in the Amazon. This problems arises due to the fact that the logging sector in the Amazon region presents low productive performance due to the use of machines that have a low level of technology and workers that have little knowledge of the raw material with which they work (MELO *et al*., 2016). Furthermore, the level of utilization of raw material directly influences the forest area necessary for harvest to meet the demand for wood (DANIELLI *et al*., 2016). Therefore, the yield from the sawing of the logs in the sawmills is directly related to the sustainable use of forest resources since inefficient use of timber goes directly against the current worldwide preoccupation with sustainability and availability of natural resources. In this context, it is evident that the agencies responsible for command and control over the logging industry, in a concerted effort to eliminate fraud in the DOF system, could end up increasing losses of raw material.

In all the interviews done in the sawmills it was verified that there is no destination for word byproducts and residuals. Sawdust is stored on the log landing area in open air conditions with no specific reuse method and is generally burned. This demonstrates that wood residuals are considered an industrial liability and not as a possible income opportunity and method of cost reduction. According to Santos *et al*. (2017), sawmills need to include byproducts of log cutting as wood pieces that have aggregated value and therefore contribute to waste

reduction and increase profitability of the company, as demonstrated by Silva *et al*. (2018) who studied the properties of these industrial residuals from the production of plant-based charcoal Amapá.

Figueiró *et al*. (2019) indicated as an alternative use for sawdust its use in the generation of bioenergy. The application of residuals generated in the sawmills of Porto Grande as a source of energy in these same mills could reduce annual energy costs incurred during the wood production process, which are on average approximately R$175 thousand/year, and this use would also represent an environmentally responsible action. However, the discussion of the use of these residuals as a bioenergy source is recent and still remains little investigated in the Amazon region.

In relation to the expectation of the interviewees that the government will implement public policies that support improved utilization of wood and a reduction in residuals, there seems to be a lack of knowledge among the respondents with respect to the CONAMA resolution nº 474/2016. This resolution establishes that it is the responsibility of the entrepreneur to financially support and conduct technical studies to promote improved utilization of wood and a reduction in residuals. The Native Vegetation Protection law determines that the party responsible for generation of residuals is also responsible for their final destination (BRASIL, 2012). In this context, it is important to emphasize that the entrepreneurs of the logging and wood production sector have a responsibility to be familiar with environmental legislation and to internalize the negative externalities inherent to this activity.

Commercialization

The seasonality of commercialization of wood products can be associated with the conditions under which management occurs in the Amazon, which are dictated by environmental legislation. The Normative Instruction IN nº 05/2006-MMA establishes that the environmental agency responsible for ensuring compliance with laws must indicate the intervals during the rainy season when restrictions are imposed on logging activities, according to local seasonality conditions. Considering this, the sawmills of Porto Grande do not have an entire year to conduct logging operations, since during the period of intense rains the entry of heavy machinery into forests is not permitted. For this reason, local sawmill operators stock roundwood harvested during the dry season for processing and sale during the period of heavy rains.

Sawn wood produced in Porto Grande is sold principally to the Northeast region of Brazil, and to a lesser degree to the Southeast region, as shown in the results, and this sale is primarily to the civil construction sector. This is corroborated by the study of Braga and Sarrouf (2011), who analyzed the applications for which wood was produced in the Amazon. These authors identified that the largest part of wood purchased by consumers was in products of lower aggregated value in relation to other uses for this wood, such as for furniture.

The municipality of Porto Grande, although it is the largest producer of wood in the state of Amapá, is unable to supply the internal civil construction market due to the lack of demand from the local market. This might be justified by the increase in costs associated with forest management that are reflected in the price of final sawn wood products, because wood from managed lowland forests faces unfair competition from wood illegally harvested in várzea forests on islands in the Amazon estuary in the state of Pará (PA) which supply establishments that sell wood in Amapá, as verified in the interviews with local wood sellers.

The prices of wood from várzea forests are lower due to the illegal nature of this logging activity (ÂNGELO *et al*., 2014). Additionally, wood from várzea forests, is in general considered to be of inferior quality than that from lowland forests, which is considered to be "noble" for most uses (ROSA *et al*., 2014).

The annual profit of 22%, as informed by the respondents, is similar to that reported by Hummel *et al*. (2010) for the logging sector in 2009. In light of these data, it is evident that there was stagnation in financial yields in the logging sector in this region between 2009 and 2017, a situation that did not occur with other raw materials associated with production chains based on biodiversity. For example, the value of açaí (*Euterpe oleracea* Mart.) production, a common fruit in the Amazon region that is much appreciated and sought after both nationally and internationally, increased approximately 333% during this same period (IBGE, 2018).

This gap in profits between açaí and the logging sector could be associated with the proportion of illegal activities that exists in the wood products production chain. Illegal wood is sold for lower prices in the market compared to wood harvested from managed forests, so much so that the prices for illegal wood do not reflect prices that would exist in a market environment characterized by a competitive equilibrium, or even the opportunity costs associated with logging activities (ÂNGELO *et al*., 2014). According to Paiva *et al*. (2015), the recommended measures needed to reverse the tendency of stagnation in wood prices and make wood production become a profitable business that contributes to the economy of the country are related to the adhesion of the wood industry to the forest certification market.

Adhesion to certification systems allows for monitoring of the entire production chain. Wood products that have a seal of certification guarantee that the production process respected environmental, fiscal, and labor legislation, and that the raw material originated in a managed environment (PAIVA *et al*., 2015). It is also

recommended that the government provide incentive to logging companies to adhere to forest certification programs, such as reductions in licensing costs and, for certified management units, simplification of bureaucratic processes conducted by environmental agencies.

CONCLUSIONS

- The sawmills of the municipality of Porto Grande all have the proper licenses to engage in logging activities, with wood being produced using authorized management plans. However, factors such as limitation of new areas for management, harvesting in a single APU in settlement projects, and the fact that management plans do not consider the next harvest cycle, silvicultural treatments, or monitoring of harvested areas, are barriers that could impede sustainable wood production.
- The average production yield of the sawmills is above the CRV established by the CONAMA resolution, demonstrating that the reduction of the CRV does not correspond with the reality of the studied sawmills, which could serve as a disincentive in the search for improved efficiency of production of the sawmills and thus contribute to an increase in the generation of residuals in this sector.
- The commercialization of wood products in primarily to the national market, and specifically to the civil construction sector. The local internal market purchases only subproducts of the wood production process due to unfair competition from wood that is illegally harvested. Therefore, it is recommended that the local logging industry adhere to the forest certification market, which will make monitoring of the entire production chain possible and thus enable expansion into new markets.

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