BALANCE BETWEEN BIOMASS SUPPLY AND DEMAND IN THE RED CERAMICS SECTOR OF RIO GRANDE DO NORTE, BRAZIL

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Resumo

Balanço entre oferta e demanda de biomassa no setor da cerâmica vermelha do Rio Grande do Norte, Brasil. O desmatamento ilegal na Caatinga, por vezes, corresponde ao suprimento da demanda energética local, ainda que opções de lenha legalizada estejam disponíveis no mercado. Estudos recentes mostram que a indústria de cerâmica vermelha é o maior consumidor de lenha no estado do Rio Grande do Norte. Considerando a lenha proveniente dos Planos de Manejo Florestal Sustentável como uma alternativa viável ao suprimento desse setor, objetivou-se, neste trabalho, analisar a atual oferta de biomassa florestal no Rio Grande do Norte, em consonância com a demanda deste insumo na indústria de cerâmica vermelha. A obtenção do número, área e volume dos atuais planos de manejo, foi concedida pelo órgão responsável pela gestão florestal estadual. Foram analisados os Planos Operacionais Anuais visando a obtenção do volume de madeira disponível em um ano. Com o levantamento, constatou-se a existência de 22 planos de manejo sustentável com autorização para exploração válida para o ano de 2019, distribuídos em 20 municípios do estado, somando uma área de 988,99 hectare. Calculou-se uma oferta atual de lenha disponível para energia de 26.223,13 $tMS.ano^{-1}$. A oferta de lenha oriunda dos planos de manejo atende apenas 5,5% da demanda energética do setor ceramista do estado. Em contrapartida, a oferta potencial de lenha disponível nos remanescentes de Caatinga do estado, supera em mais de seis vezes a demanda do setor. Conclui-se que há a necessidade de reforço na esfera governamental, para propor medidas que estimulem o uso do recurso florestal de forma legalizada em escala proporcional ao consumo atual.

Palavras-chave: desmatamento, lenha clandestina, manejo florestal da Caatinga

Abstract

Illegal deforestation in Caatinga sometimes corresponds to supplying the local energy demand, even though legalized firewood options are available on the market. Studies show that the red ceramic industry is the largest consumer of firewood in Rio Grande do Norte (RN), Brazil. Considering the firewood from the Sustainable Forest Management Plans as a viable alternative to supplying this sector, the objective was to analyze the current offer of forest biomass in RN, in line with the demand for this resource in the industry of red ceramics. The number, area and volume of the current management plans were obtained by the agency responsible for state forest management. The Annual Operational Plans were analyzed to acquire the amount of wood available in one year. The survey found 22 sustainable management plans with authorization for exploration valid for the year of 2019, distributed in 20 cities in the state, adding up to an area of 988.99 hectares. A current supply of available firewood for the energy of 26,223.13 $tMS.year^{-1}$ was calculated. It is noticed that the supply of firewood from the management plans meets only 5.5% of the energy demand in the state ceramics sector. In contrast, the potential supply of firewood available in Caatinga remnants of the state exceeds the sector's demand by more than six times. It is concluded that there is a need for reinforcement in the governmental sphere, to propose measures that stimulate the use of the forest resource in a legalized manner in proportion to the current consumption.

Keywords: deforestation, illegal firewood, forest management of Caatinga.

INTRODUCTION

The Caatinga phytogeographic domain covers an area of 912,529 km^2 of the semi-arid region in northeastern Brazil. This vast and rich "socio-ecological system" is part of a global biome called seasonally dry tropical forest (SDTF) which spans across Mesoamerica, the Caribbean and South America (SILVA *et al*., 2017). The climate in this biome is characterized as hot and semi-arid, of the BSh type, according to the Köppen classification (DUBREUIL *et al*., 2018).

The occurrence of dry forests that make up the Caatinga is threatened by the rapid advance of anthropogenic processes, such as urbanization and agricultural potential. In analyzes of the impact of human activities on the Caatinga, Silva *et al*. (2017) estimated that, since 2010, 63.3% of the biome has already been altered. Significant impacts were listed for fires (139,522 km^2), roads (346,267 km^2) and deforestation (311,225 km^2).

It is estimated that 93.5% of the territorial area in Rio Grande do Norte is covered by Caatinga, that is, 49,402.20 km² (BRASIL, 2011). According to the Brazilian Forest Service (BFS, 2018), the area of Rio Grande do Norte covered by natural forests is approximately 2.2 million hectares, equivalent to 42% of the state's total territory. In addition to the high annual deforestation rates in the Caatinga, the biome's protected areas in the state constitute only 2% of its all extension, comprising 108,510 hectares (ha) of protected areas in 13 Conservation Units, under the management of the Institute for Sustainable Development and Environment (IDEMA). This agency is responsible for the management of the state's natural resources.

In some cases, logging in Caatinga aims to meet local energy demand. In 2006, a firewood demand of 7.53 million m³ per year was estimated in the Northeast region of Brazil, being divided into industrial and commercial sectors, and an additional 2.82 million m³ per year for the residential sector, which totals 10.35 million m³ per year in the region (RIEGELHAUPT; PAREYN, 2010).

According to the Ministry of the Environment (2018), with the signing of the Convention on Climate Change, announced at Rio-92, there was a reorganization in the use of biomass for energy, prioritizing progress in the replacement of fossil fuels and minimizing deforestation. Discussion on the need to renew the energy matrix, nationally and globally, reinforces the relevance of renewable energy sources, such as biomass, which is a fundamental source of work and income, mainly in rural areas.

Currently, the agenda regarding the debate on the use of biomass for energy revolves around the production of biofuels, such as sugar cane ethanol and soy biodiesel; and the use of firewood and charcoal in some industrial sectors, in addition to the household and commercial sectors in Northeast Brazil. Studies in Northeastern Brazil have identified 26 industrial branches and sub-branches that consume energy biomass. In 2015, consumption was concentrated in seven branches: red ceramics, cellulose and paper, steel, processing of cassava, bakery, plaster, and vegetable oils. These accounted for 80% or more of total demand. Considering that the red ceramic industry is the largest consumer of firewood in the state, it will be prioritized in this study (BRASIL, 2018).

The consumption of biomass by the ceramic segment in the Rio Grande do Norte, estimated by the National Institute of Technology (INT) and the Association of Plants of the Northeast (APNE), is divided between about 265 counted establishments, being the third-largest consumer in the Northeast region, 474,262 tons of dry matter per year - $tDM.year^{-1}$ (BRASIL, 2018). This demand is used in this study in order to classify its relationship with the available biomass supply by the Sustainable Forest Management Plans in the state.

Rio Grande do Norte is one of the three largest producers of red ceramics in the Northeast and the largest producer of tiles in the country, as mentioned by Schwob *et al*. (2017). Its production is about 111 million per month, with 54% of tiles production, 42% of bricks/sealing blocks and 4% of other products. The red ceramic industries in the state are distributed in six poles, covering 39 cities, and totaling 186 companies. The *Seridó* Region of the state stands out, with 99 companies.

According to Riegelhaupt and Pareyn (2010), the volume and geographic distribution of firewood and charcoal supplies depend on the presence of consumers who offer interesting prices for producers. As for firewood, the cost of transportation is high considering the value of the product, and prospective buyers located more than 200 km or 300 km become unattractive for producers.

Given this, the Sustainable Forest Management Plans are one of the legalized sources to supply the demand of the ceramics sector. This exploitation system, foreseen in Law 12.651 Art. 31, of May 25, 2012, should contemplate techniques of conduction, exploration, forest replacement, and management compatible with the varied ecosystems that the tree cover forms (BRASIL, 2012). In addition, the following three principles must be taken into account when it comes to exploration: it must be ecologically correct, economically viable and socially fair (BFS, 2013).

Sustainable forest management aims to obtain, through forest resources, economic, ecological, and social benefits, based on a plan that intends to take advantage of available timber and non-timber resources (GAMA *et al*., 2005).

Amongst the forest species most used by the red ceramic sector in the state, Jurema-preta (*Mimosa tenuiflora* (Willd.) Poir.), and Cajueiro (*Anacardium occidentale* L.) stand out for meeting the demand at a lower cost (SANTOS *et al*., 2013; TAVARES, 2014; SANTOS *et al.*, 2021). Carvalho *et al.* (2020), reports in their study that the Jurema-preta (*M. tenuiflora*) is an interesting option in terms of energy production, standing out for its high values of fixed carbon, superior calorific power, and basic density, in addition to having a low content of ash, which makes it suitable for the implementation of an energy forest. Besides, Catingueira (*Cenostigma pyramidale*

(Tul.) E. Gagnon & GP Lewis) and Jurema-branca (*Piptadenia stipulacea* (Benth.) Ducke) also showed high density. The use of the exotic species Algaroba (*Prosopis juliflora* (Sw.) DC.) also stands out, as well as other forest residues (SCHWOB *et al*., 2017).

In this perspective, the present study aimed to analyze the current situation of forest biomass supply in Rio Grande do Norte, Brazil, in line with the demand for this resource by the red ceramic industry in the state.

MATERIALS AND METHODS

Data Collection

The number, area, and volume of management plans were obtained by the agency responsible for forest management in Rio Grande do Norte, the Institute for Sustainable Development and Environment (IDEMA). To this end, two databases were consulted: Cerberus, which constitutes the internal IDEMA system, and the National System for the Control of the Origin of Forest Products (SINAFLOR), developed by the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA). From these data, it was possible to measure the real volume available through the set of sustainable management plans, therefore, the offer of forest biomass.

The Annual Operational Plans (AOP) were analyzed to obtain the volume of wood available in one year. The POA consists of a document that defines the schedule of activities, the forest management procedures to be applied in a Sustainable Forest Management Plan; valid for one year, plus a three-month renewal period. If the AOP is not renewed or there are no new requests, the management plan remains without the Exploration Authorization (AUTEX), a document issued by the agency, until an operational plan is forwarded to the responsible organization. For this reason, in this research, priority was given to enterprises with the issue of AOP from August 2018, since they were authorized for the exploration and sale of firewood until the moment of the study.

Units

For data comparison, the conversion was carried out for the same units: the area expressed in hectares (ha), the volume in stereos (st), and the biomass in tons of dry matter (tDM).

To convert cubic meter (m^3) to stereo meter (st) of firewood, the stacking factor 3.4 was used, according to the technical note of the PNUD/FAO/IBAMA project in the Rio Grande do Norte (ZAKIA *et al.*, 1988). Following the equivalence of measures proposed in Brasil (2018), the 1 st of Caatinga wood corresponding to 0.214 tDM was used.

Potential Supply Available for Energy

Adapting the methodology in Brasil (2018), to calculate the potential supply of firewood available for energy in 2019, in Rio Grande do Norte, we used the total area of the state occupied by remnants of Caatinga and the average productivity considered for the 3.03 tDM ha^{-1} $year^{-1}$ biome (BRASIL, 2018), affected by three factors:

a. Access factor (AF): the fraction of the area that can be reached by the exploration. Access limitations are determined by the exclusion of 20% of Legal Reserve and 5% of the Permanent Preservation Area (PPA). Therefore, AF is equal to 0.75;
b. Sustainable harvest factor (SHF): the ratio between the biomass effectively removed and the existing one. The average SHF is 0.75 because part of the trees or areas in sustainable management plans are not cut; and
c. Energy use factor (EUF): fraction of the removed biomass that is used to obtain energy. Considering that 10% of the wood is used for stakes and posts, the energy use factor is 0.9.

The effective availability of biomass (tDM ha^{-1} $year^{-1}$) results from the formula:

Potential available energy supply (tDM $year^{-1}$) = Area (ha) x productivity (tDM ha^{-1} $year^{-1}$) x AF x SHF x EUF.

RESULTS

The current supply of firewood from sustainable management plans in Rio Grande do Norte

With this survey, it was found that there are 22 sustainable management plans with Authorization for Forest Exploration (AUTEXFL) valid for 2019, which are distributed in 20 cities in the state. Therefore, 22 plots were authorized for exploration in 2019, adding up to an area of 988.99 ha with an average yield of 126.52 st ha^{-1} (Table 1).

Table 1. Data from the Sustainable Forest Management Plans active in the years 2018 and 2019 in Rio Grande do Norte, Brazil.
Tabela 1. Dados dos Planos de Manejo Florestal Sustentável com atividade nos anos de 2018 e 2019 no Rio Grande do Norte, Brasil.

SFMP year	City	Stand No.	AOP year	Stand area (ha)	Stand volume (st)	Yield (st ha^{-1})
2010	Touros	7	2018	37.33	7,734.13	207.16
2012	Santa Cruz	8	2019	34.98	8,612.52	246.21
2012	Pedro Avelino	4	2018	69.81	6,589.51	94.40
2014	Assú	2	2018	20.55	2,085.93	101.51
2014	Campo Grande	5	2018	58.56	7,100.11	121.25
2014	Tangará	5	2018	41.21	3,430.02	83.24
2014	Parazinho	4	2018	46.00	4,707.18	102.33
2015	Sítio Novo	2	2019	19.00	1,817.84	95.68
2015	Caraúbas	3	2019	45.36	4,499.45	99.19
2015	Currais Novos	3	2019	45.25	7,554.00	166.94
2016	Pendências	3	2019	41.00	4,229.68	103.16
2016	Currais Novos	3	2019	45.26	166.94	3.69
2016	Acari	2	2019	28.42	8,801.18	309.68
2017	São Fernando	2	2019	46.61	3,178.11	68.18
2017	Touros	4	2019	13.96	2,688.00	192.57
2018	João Câmara	2	2019	13.96	2,688.00	192.57
2018	São Paulo do Potengi	1	2018	111.72	10,909.13	97.65
2019	Alto do Rodrigues	1	2019	25.36	2,289.00	90.27
2019	Serra Negra do Norte	1	2018	221.62	39,392.17	177.75
2019	Angicos	5	2019	44.13	2,375.52	53.83
2019	Parelhas	1	2019	65.44	1,407.49	21.51
2019	Serra Caiada	1	2019	25.20	3,897.43	154.66
			Average	50.03	6,188.79	126.52
			Total	1,100.73	136,153.34	2,783.43

Caption: SFMP: Sustainable Forest Management Plan, AOP: Annual Operational Plans.

In the 22 management plans evaluated, the total volume obtained was 136,153.33 st year^{-1}. This value corresponds to the volume of firewood authorized for commercialization in one year in Rio Grande do Norte and is equivalent to only 0.1% of the wood stock for the total forest area in the state, of 131,944,945.8 st (38,807.337 m^3), estimated by the National Forest Inventory (IFN), 2018).

Using the conversion factor 0.214 for forest biomass on the total volume obtained, we have 29,136.81 tDM year^{-1}, that is, the current total supply of firewood available in one year.

Considering an energy use factor of 0.9, we have (BRASIL, 2018):

29,136.81 tDM year^{-1} x 0.9 = 26,223.13 tDM year^{-1} or 2.6 x10^4 tDM year^{-1} available on the market for energy in Rio Grande do Norte.

The potential supply of firewood in Rio Grande do Norte

According to the National Forest Inventory (IFN, 2018), the area of natural forests in Rio Grande do Norte is equivalent to 2,212,322.05 ha. Of this total, 92.31% corresponds to Savannah-Steppe (Caatinga), varying between the types of Savannah-Steppe Forested Wooded Savannah-Steppe. Therefore, the Caatinga area in the state is 2,042,194.484 ha. Excluding the areas occupied by the Conservation Units from this total, there are 1,933,683.925 ha.

Calculation of the potential supply of firewood available for energy in RN, considering the calculation in Brasil (2018):

1,933,683.925 ha x 3.03 tDM ha^{-1} $year^{-1}$ x 0.75 x 0.75 x 0.9 = 2,966,150.285 tDM $year^{-1}$ or 296.6 $x10^4$ tDM $year^{-1}$.

A study by the Ministry of the Environment (BRASIL, 2018), estimated the potential supply of biomass available for energy in the Northeast at 29.2 $x10^6$ tDM $year^{-1}$, so the value found for the Rio Grande do Norte is equivalent to about 10% of the total potential supply in the Brazilian region.

Figure 1 presents a map of the percentage of forest cover per microregion in RN, prepared by GEIFN and published by IFN (2018), with an overlap of data on the location of each SFMP with activity between 2018 and 2019 in the state, according to the results of this study.

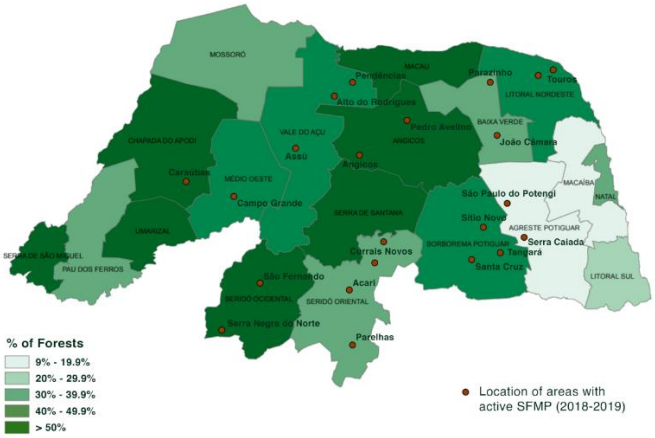

Figure 1. Map of forest cover by microregion in Rio Grande do Norte and location of SFMP with activity between 2018 and 2019. Adapted from: IFN, 2018.

Figura 1. Mapa da cobertura florestal por microrregião no Rio Grande do Norte e localização dos PMFS com atividade entre 2018 e 2019. Adaptado de: SFB, 2018.

Potential supply of other energy sources

Table 2 shows the availability of other biomass sources for supplying the ceramics sector in Rio Grande do Norte, according to estimates by the Ministry of the Environment (BRASIL, 2018), and these sources are the most used in the industrial centers of the state ceramic sector. The sum of the potential supply of firewood from *P. juliflora* and the branch pruning of *A. occidentale* and other fruit trees, available for energy in RN, is 0.363 $x10^6$ tDM $year^{-1}$.

Table 2. Availability of different sources of biomass in Rio Grande do Norte, Brazil.
Tabela 2. Disponibilidade de diferentes fontes de biomassa no Rio Grande do Norte, Brasil.

Biomass source	Area (ha)	Yield (tDM $ha\ year^{-1}$)	AF	SHF	FUE	Total availability (tDM $year^{-1}$)	Energy availability (tDM $year^{-1}$)
P. juliflora	17,465	0.00426	0.67	1.0	0.87	49.82	43.34
A. occidentale	107,020	3.7	1.0	0.9	1.0	356,376.60	356,376.60
Other plants	3,847	1.8	1.0	0.9	1.0	6,232.14	6,232.14
				Total		362,658.56	362,652.08

AF: Access Factor; SHF: Sustainable Harvest Factor; EUF: Energy Use Factor. Source: (BRASIL, 2018).

Balance of energy supply and demand

In an estimate made by the Ministry of the Environment (2018), taking into account the number of establishments in the register of the Association of Plants of the Northeast (APNE) for the Rio Grande do Norte, 265 establishments were accounted for annually consuming 474,262 tDM $year^{-1}$, corresponding to the third-largest consumption among Northeastern states, 19% of the total.

Table 3 expresses the relationship between the annual demand from the ceramics sector and the current and potential biomass supply in the state. It is noted that the current supply of firewood from the sustainable management plans meets only 5.5% of the sector's demand. Considering the potential supply of other sources of biomass (*P. juliflora*, *A. occidentale*, and other plants), the percentage of supply of demand now reaches 82.0%.

Table 3. Balance and relationship between the energy demand of the red ceramic sector in Rio Grande do Norte, Brazil, and the current supply sources, originating from the Sustainable Forest Management Plans, and the potential biomass supply, from the wood of *Prosopis juliflora*, *Anacardium occidentale*, and diverse fruit.

Tabela 3. Balanço e relação entre a demanda energética do setor de cerâmica vermelha no Rio Grande do Norte, Brasil, e as fontes de oferta atual, oriunda dos Planos de Manejo Florestal Sustentável, e de oferta potencial de biomassa, proveniente da lenha de *Prosopis juliflora*, *Anacardium occidentale* e frutíferas diversas.

Demand (tDM year^{-1})	Current SFMP supply (tDM year^{-1})	Ratio: Supply/ Demand (%)	Potential supply of other sources (tDM year^{-1})	Ratio: Supply/ Demand (%)	Balance (tDM year^{-1})	Total demand met (%)
474,262.000	26,223.130	5.53	362,652.082	76.467	-85,386.79	82.00

Illegal deforestation in Rio Grande do Norte has filled a portion of the biomass supply in the red ceramic sector in the state. On the other hand, owners of a Sustainable Forest Management Plan in the state have had difficulties in selling their firewood stock. A reflection of this is seen in the AOP emission data over the past year. Table 4 shows the request for two remnants of native vegetation, in two different management plans, requested in 2019. In summary, a remainder can be requested from the agency, in the year in which the AOP is issued, given that the entrepreneur was unable to sell 100% of its authorized volume in the field; the latter, in turn, has the possibility to request the organ, in the following year, the remaining area for exploration. In 2018, two forest management areas sold, respectively, 18.27% and 64.27% of their authorized volume for the year.

Table 4. Data from the remaining Sustainable Forest Management Plan requested in 2019, in Rio Grande do Norte, Brazil.

Tabela 4. Dados dos remanescentes de Plano de Manejo Florestal Sustentável solicitados em 2019, no Rio Grande do Norte, Brasil.

AOP year	Stand area (ha)	Initial volume (st)	Remaining forest area (ha)	Remaining forest volume (st)	Volume sold in the AOP (st)	Volume sold in the AOP (%)
2018	69.81	6,589.5100	69.81	5,385.4885	1,204.0215	18.27
2018	221.62	39,392.1729	79.17	14,072.9474	25,319.2255	64.27

AOP: Annual Operational Plans.

Considering the potential supply of firewood in the remaining forest areas of the state (Table 5), it can be seen that the balance between supply and demand is quite positive and that Rio Grande do Norte has an area with sufficient Caatinga vegetation to supply the entire forest. energy demand from the ceramics sector only with firewood from sustainable forest management.

Table 5. Balance and relationship between the energy demand of the red ceramic sector in Rio Grande do Norte, Brazil, and the potential supply of firewood available in the Caatinga remnants of the state.

Tabela 5. Balanço e relação entre a demanda energética do setor de cerâmica vermelha no Rio Grande do Norte, Brasil, e a oferta potencial de lenha disponível nos remanescentes de Caatinga do estado.

Demand (tDM year^{-1})	Potential supply in RN (tDM year^{-1}	Balance (tDM year^{-1})	Ratio: Supply/ Demand (%)
474,262.000	2,966,150.285	2,491,888.285	625.42

DISCUSSION

According to Riegelhaupt and Pareyn (2010), in addition to firewood from forest management, fruit pruning and the exploitation of Algaroba (*P. juliflora*) supply part of the industrial demand in Ceará, Rio Grande do Norte, Pernambuco, and Paraíba.

Prosopis juliflora is a species of easy adaptation to semi-arid regions, with extensive use for forage and timber production. Its dispersion can be done by animals, which create homogeneous, dense, and rapidly growing populations. Currently classified as invasive exotic, with dispersion restricted to lowland and shallow areas (BRASIL, 2018).

Cajueiro (*A. Occidentale*) plantations are widespread in the state, aiming at the production of pseudofruit and cashew nut. Due to the advanced age of most plantations in the region, pruning is necessary in order to promote fruiting. Such pruning is a sustainable alternative to biomass since pruned trees continue to grow. It is considered an accessible input, with a low acquisition price and that does not have a Forest Origin Document (FOD) requirement (TAVARES, 2014). However, the biomass available for branch pruning of Cajueiro is limited to the current stock. Estimates by extension workers from the Institute of Technical Assistance and Rural Extension (EMATER) and firewood traders predict that all of this biomass will be used in the next 10 years (BRASIL, 2018).

In addition to these two sources, the biomass of several fruit trees, derived from pruning, was considered in this study because it has gained interest in biomass consumers in recent years due to the lack of legal restrictions for its use (BRASIL, 2018).

Firewood from SFMP

The negative ratio between the supply of firewood from SFMP and the demand for biomass from the red ceramic sector was observed in other states in the Northeast region (Table 6). Pareyn (2010) narrates that, in 2007, the supply of SFMP forest products in Pernambuco met only 5.8% of the state's total energy demand. In the state of Sergipe, 53% of the energy input consumed by ceramics comes from native forests, the remainder being Pinus (24%), bamboo (12%), and Eucalyptus (11%) (MACHADO *et al*., 2010). The energy balance of Paraíba reveals that the demand for firewood by industry and commerce was met by 13.9% of firewood from forest management (SUDEMA, 2004).

Table 6. Balance and ratio between the demand for biomass in the red ceramic sector and the supply of firewood from SFMP in some Northeastern states, Brazil.

Tabela 6. Balanço e relação entre a demanda de biomassa do setor de cerâmica vermelha e a oferta de lenha proveniente dos PMFS em alguns estados do Nordeste, Brasil.

State	Demand (tDM year^{-1}) [a*]	SFMP supply (tDM year^{-1})	Balance (tDM year^{-1})	Ratio: Supply/ Demand (%)
Paraíba	105,897	30,851.5158 [b]	-75,045.4842	29.13%
Pernambuco	297,842	48,720 [c]	-249,122	16.36%
Rio Grande do Norte	474,262	26,223.13	-448,038.87	5.53%
Sergipe	148,421	6,559.56 [d]	-141,861.44	4.42%
Total	1,026,422	112,354.2058	-914,067.794	10.95%

Caption: [a] Brasil (2018); [b] Góis *et al*. (2019); [c] Pareyn (2010); [d] Machado *et al.* (2010). *Considering that a Caatinga wood stereo is equivalent to approximately 0.21 tDM.

Regarding the number of management plans of the operation in Rio Grande do Norte, Carvalho *et al.* (2020) found 21 plans with a valid license until the beginning of 2018. Therefore, in 2019, there was an addition of a management plan, with 22 plans with authorization for exploration 2019.

The area managed from August 2018 to November 2019, corresponds to only 0.0002% of the area that the Caatinga biome occupies in Rio Grande do Norte. In other states of the Northeast, such as Pernambuco, the area authorized for deforestation reached 11,104 ha in the period from 2001 to 2005 (PAREYN, 2010). In Ceará, there is the highest concentration of sustainable management plans in the Northeast, the state has 44% of the total number of plans, 35% of its managed area, and 32% of the authorized annual volume (APNE, 2014).

While in Rio Grande do Norte the production of the areas managed between 2018 and 2019 was 136,153.33 st year^{-1}, in 2007, in the state of Pernambuco, a production of 232,000 st year^{-1} was estimated (PAREYN, 2010). However, due to its high demand, the Brasil (2018) states that Pernambuco is the state with the worst performance in the legal supply of the sectors' total energy demand, being almost seven times greater than the legal supply.

Similarly, this study reveals a deficit in the supply of demand from the ceramics sector by the legal offers, leaving a significant amount that may be being served by firewood from illegal deforestation (Figure 1).

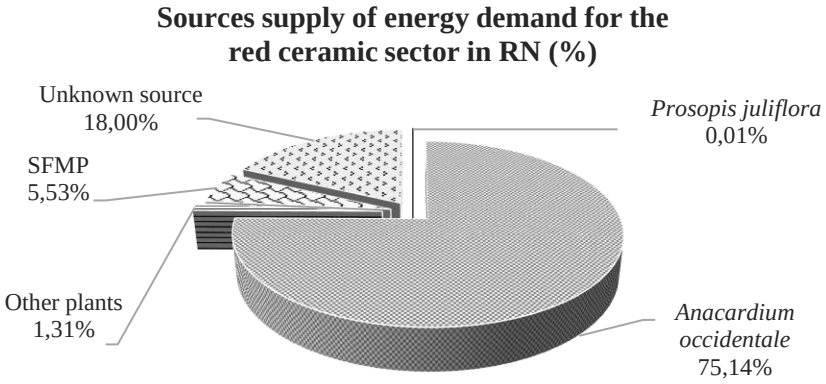

Figure 2. Graph of supply sources of energy demand for the red ceramic sector in Rio Grande do Norte (RN), Brazil. Adapted from: Brasil, 2018.

Figura 2. Gráfico da oferta de fontes de demanda de energia para o setor de cerâmica vermelha no Rio Grande do Norte (RN), Brasil. Adaptado de: Brasil, 2018.

Although the red ceramic industry is the largest consumer of this input and with the greatest growth prospects, the existence of other sectors that consume biomass in Rio Grande do Norte, such as domestic, bakery, plaster, lime, etc., should be considered among others (BRASIL, 2018). Therefore, the supply potential used in this study serves an even smaller portion of the ceramic sector, as it shares the commercialization of the input with the other sectors. In addition, the data on the potential supply of other biomass sources is an estimate by the Ministry of the Environment (2018), which may not correspond to the actual supply of these inputs in the state.

The current biomass offers that make up table 2, constitute a sustainable alternative to supply the energy demand in the state's ceramics sector. However, with the data from Brasil (2018) of potentially available supply, it is noted that these inputs are not enough, with scope for the consumption of clandestine firewood.

In addition, despite the widespread use of Cajueiro (*A. Occidentale*) branch pruning as energy input and its low acquisition price, recent studies show that its wood has a low density and calorific value, which intensify the consumption of this fuel in m³, consequently increasing, the total cost of acquisition for production (SANTOS *et al.*, 2020). In contrast to the wood of Jurema-preta (*M. tenuiflora*), which proved to be a potential species for generating energy in the burning of bricks, presenting values of fixed carbon, higher calorific value and basic density that promoted the reduction of consumption in m³ and, consequently, savings in the total cost of acquisition for burning (SANTOS *et al.*, 2020; CARVALHO *et al.*, 2020).

The potential supply of available firewood exceeds the demand of the ceramics sector by more than six times. Therefore, the problem in this balance is not related to the scarcity of legal biomass in the state, but to the ease of producers in accessing illegal firewood in relation to the production of firewood in sustainable management.

In general, the manageable area in the state can be mostly private property. Therefore, the proper management of forests in Rio Grande do Norte depends on the initiative of individual owners and government incentives. According to Molnar *et al.* (2011), the expansion of the market for products originating from sustainable management will be possible from the increase in inspections on illegal activities.

Forest Supply Plan

In accordance with Article 34 of Federal Law No. 12,651 / 12 (BRASIL, 2012), industrial companies that use a large amount of forest raw material are required to prepare and implement a Sustainable Supply Plan (SSP) that will be submitted for approval competent environmental agency in the act of environmental licensing of the activity. In other words, in the case of the red ceramic industries, the producer should prove that his production is linked to Sustainable Forest Management Plans. This linking stage is an integral part of the project's environmental licensing process, in order to ensure its supply of forest raw material, according to its production capacity.

The access, by the environmental agencies, to the technical reports prepared by the enterprise, containing the data referring to its annual production, total consumption of raw material, and proof of the origin of the inputs used, would increase the monitoring power and reduce the need for visits by tax agents to the industry.

However, industries that use forest raw material in the state do not have a Sustainable Supply Plan linked to their production activities. Therefore, this would be a recrimination alternative to the use of clandestine firewood, enabling the expansion of the sale of legalized firewood.

The management system of environmental agencies and the policy for the forestry sector in the state are deficient in this respect. As a result, the use of wood by industries occurs in an uncontrolled manner, without meeting the minimum sustainability requirements. With the aggravating factor of performing industrial activities in disagreement with legal precepts in force in the current Forestry Code of the country.

There is also a need to reinforce the management policy of the environmental agency, to propose measures that encourage the use of forest resources in a legalized manner on a scale proportional to current consumption. Measures such as increased enforcement combined with the severe prohibition of illegal practice reduced SFMP licensing fees, and educational measures to inform rural property owners about the benefits of sustainable forest management.

CONCLUSIONS

- The current supply of firewood from the Sustainable Forest Management Plans in Rio Grande do Norte supplies a small portion of the energy demand in the ceramics sector in the state (5.5%).
- The potential supply that Rio Grande do Norte presents, concerning its remaining areas, could supply the sector's demand more than six times.
- The implementation of the Supply Plan as a mandatory requirement for the red ceramic industries in the state is an alternative to reduce illegal deforestation caused by the sector.

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