ANALYSIS OF ENERGY SUFFICIENCY IN A FAMILY FARMING PRODUCTION CHAIN

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ABSTRACT – The value chains that compose family farming constitute several economic activities relevant to the Brazilian economy. The tobacco sector stands out for its financial aspect but also its environmental appeal. For this reason, it has been giving special attention to the sustainability of the production process, including the energy efficiency of tobacco drying, where forest biomass is used as a renewable energy source. Thus, the objective of this work was to carry out a diagnosis of forest production and consumption by tobacco producers. The applied methodology was based on the inventory of the producers' forests and the Brazilian Association of Tobacco Growers' database. It was estimated that the sector's forestry base, comprised of the seven VTPR (Virginia tobacco-producing regions), had a total of 116,103.05 ha of *Eucalyptus* forest plantations. It is possible to observe that the forest structure is deregulated in both areas. The PR – Southeast, SC – North Plateau, SC – Alto Vale, and RS – Costa Doce regions showed a firewood deficit. The regions SC – Coast, and RS – Central Depression presented an oversupply of forest biomass. There is energy self-sufficiency for tobacco production for some of the VTPR. However, the scenarios showed a firewood deficit in part of the regions. Thus, results show that it is necessary to implement strategic plans to achieve energy self-sufficiency for the sector.

Keywords: Energy sustainability; Forest biomass; Rural producers.

ANÁLISE DA SUFICIÊNCIA ENERGÉTICA EM UMA CADEIA PRODUTIVA DA AGRICULTURA FAMILIAR

RESUMO – As cadeias de valor que compõem a agricultura familiar constituem várias atividades econômicas que são relevantes para a economia brasileira. O setor fumageiro é destacado pelo aspecto econômico, mas também pelo apelo ambiental. Por isso este vem dando atenção especial para sustentabilidade do processo produtivo, entre eles a eficiência energética da secagem do tabaco, onde é utilizada biomassa florestal como fonte de energia renovável. Assim, o objetivo desse trabalho foi realizar um diagnóstico da produção e consumo florestal de produtores de tabaco. A metodologia aplicada baseou-se no inventário das florestas dos produtores e no banco de dados da Associação dos fumicultores do Brasil. Foi estimado que a base florestal do setor, composta pelas sete RPTV (regiões produtoras de tabaco Virgínia) apresentaram um total de 116.103,05 ha de plantios florestais de ***Eucalyptus.*** *Ao analisar a distribuição das áreas de florestas alocadas nas classes de 2 a 7 anos foi possível observar que a estrutura florestal está desregulada em ambas as regiões. As regiões PR – Sudeste, SC – Planalto Norte, SC – Alto Vale e RS – Costa Doce apresentaram déficit de lenha. Já as regiões SC – Litoral e RS – Depressão Central apresentaram superoferta de biomassa florestal. Há autossuficiência energética para a produção de tabaco para algumas das RPTV. Contudo em parte das regiões os cenários* *mostraram déficit de lenha. Deste modo, resultados demonstram que é necessário a efetivação de planos estratégicos para alcance da autossuficiência energética para o setor.*

Palavras-Chave: Sustentabilidade energética; Biomassa florestal; Rodutores rurais.

1. INTRODUCTION

The value chains that compose family farming constitute various economic activities relevant to the economy of an agricultural powerhouse like Brazil. Among the main characteristics of family farming, the use of predominantly family labor and production in small family areas can be highlighted (Brasil, 2006).

The tobacco sector comprises activities of social and economic importance for the southern region of Brazil. According to the Interstate Tobacco Industries Union (SINDITABACO) (2020), the tobacco sector exported 549 thousand tons in 2019 and moved US$ 2.14 billion (R$ 9.5 billion) in the same year. According to the Brazilian Institute of Geography and Statistics IBGE (2017), in 2016, the three states in the southern region of Brazil produced 99% of Brazilian tobacco, involving more than 150 thousand families distributed in more than 550 municipalities. A relevant factor is that tobacco production is characterized by the effective participation of family farming inserted in integration programs with tobacco companies.

Virginia tobacco is one of the most profitable varieties of tobacco. One of its specificities is that after harvesting, it undergoes a drying process (leaf curing) in curing units that require energy to function and have the combustion of forest biomass (firewood) as their primary source. This factor makes firewood a critical input for the tobacco production chain (Simioni et al., 2017). Thus, it is common to maintain forest assets in rural Virginia tobacco-producing areas, whose primary purpose is to extract forest biomass to supply energy in the tobacco curing process.

Unlike forestry production directed to forestry-based industries (pulp and paper, charcoal, wood for industrial processes), forestry plantations of family agriculture need more studies, including forestry production capacity. This reality puts the continuity of production chains at risk, such as Virgínia tobacco in southern Brazil. Given the above, this work aims to diagnose forestry production given the demand for firewood for curing Virginia tobacco in the southern region of Brazil. As a hypothesis, it was considered that analyses that make it possible to quantify and describe the forest base of tobacco producers could favor the diagnosis of the firewood production capacity to supply the energy demand of the curing process of Virginia tobacco.

2. MATERIAL AND METHODS

2.1 Description of the study area

This research was directed to the dynamics of forestry production and firewood consumption by farmers integrated into southern Brazil's Virginia tobacco production chain. It was an exploratory study that was developed using methods and technical criteria to be closer to the dynamics of the production and consumption of firewood in tobacco properties.

The study area consisted of seven regions characterized by the expressive participation of family farms in the tobacco growing sector in Paraná, Santa Catarina, and Rio Grande do Sul (Figure 1). The existing land formation process in the southern region, the activity and proximity of industrial tobacco centers, and the profitability promoted by tobacco cultivation in small rural properties justify this choise.

The southern region of Brazil is located south of the Tropic of Capricorn, has a Cfa climate (Köppen-Geiger Classification) and some Cfb areas, with annual precipitation varying between 1200 and 2000 mm, distributed throughout the year (Alvares et al., 2014; Beck et al., 2018).

2.2 Determining the structure of the forest base

The determination of the structure of the forest base was carried out from the crossing between the single occasion forest inventory database (IFUO), carried out in 2019, and a cadastral database of the Association of Tobacco Growers of Brazil (AFUBRA). To this end, data on the total number of farmers who produce Virginia tobacco and own

Source: Authors, 2020.
Fonte: Autores, 2020.

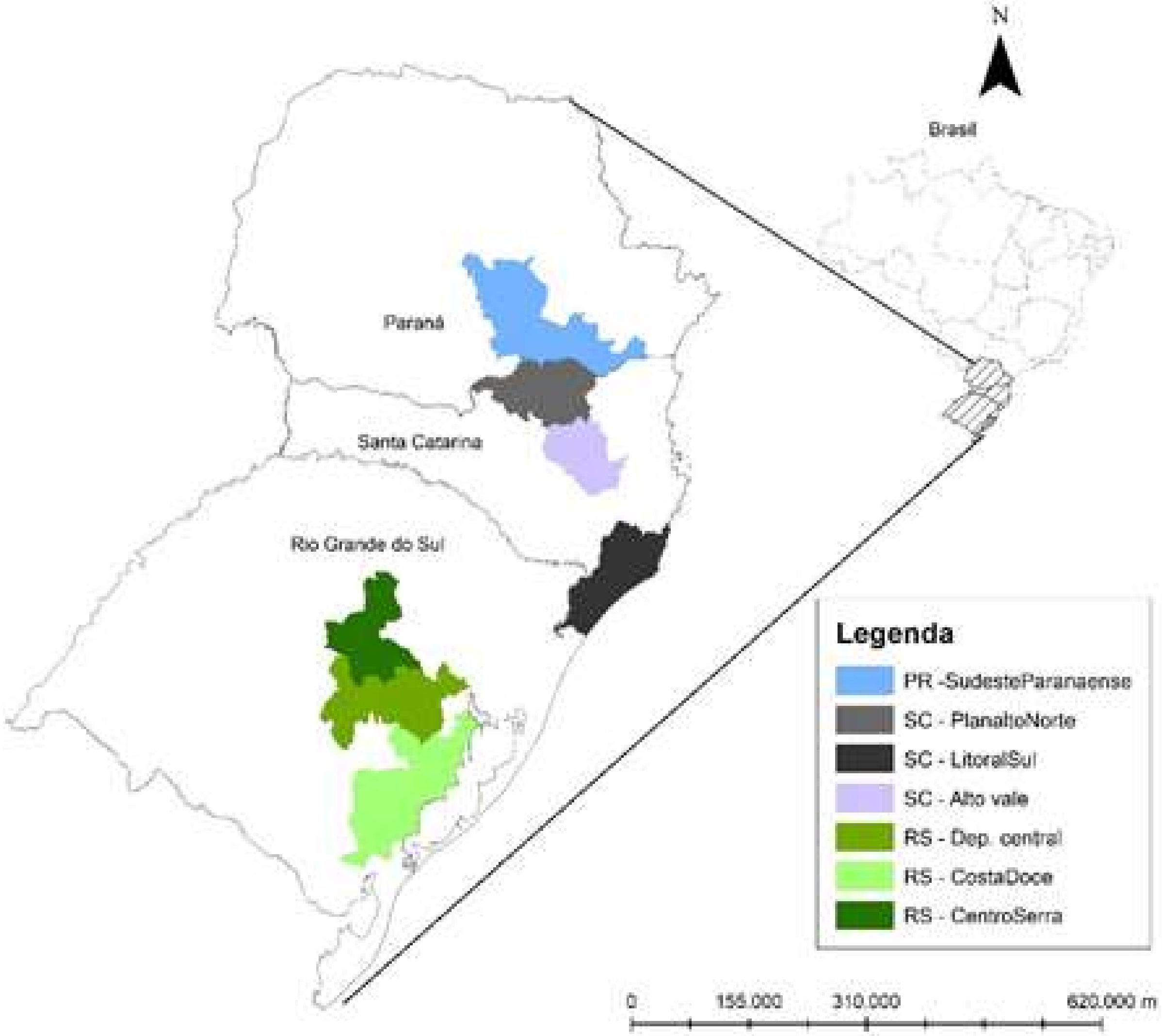

Figure 1 – Virginia tobacco-producing regions in southern Brazil.
Figura 1 *– Regiões produtoras de tabaco Virgínia no sul do Brasil.*

the land were obtained since they hold their forest plantations. Furthermore, the IFUO was performed in *Eucalyptus* forest plantations owned by landowners by measuring 538 forest plantations in 497 properties distributed proportionally in the seven RPTV regions.

The inventoried forest stands come from *Eucalyptus* sp. and are characterized by heterogeneity in silvicultural management, mainly concerning initial planting density. Therefore, according to the methodology proposed by Farias et al. (2017), these stands were measured by the Prodan method. For this purpose, three plots were allocated in each forest plantation, which served as the basis for calculating the volume (Equation 1).

$$V = \sum \frac{v_1 + v_2 + v_3 + v_4 + v_5 + (\frac{v_6}{2})}{\pi * R_6^2} \times 10000 \qquad \text{Eq.1}$$

Where: V= estimated volume in the plot, in m³ ha^{-1}, v_i= volume of tree i (1st, 2nd, 3rd, 4th, 5th or 6th), and

R_6= distance between the central point of the plot and the sixth tree.

For each VTPR, the sampled forests were grouped into seven age classes, ranging from 2 to 7 years (2 years, 3 years, 4 years, 5 years, 6 years, and 7 years) and over 7 years. Based on this procedure, it was possible to estimate the percentage of existing forests in each age class (Equation 2).

$$pf_{ij} = \frac{NFS_{ij}}{NFS_j} \quad \text{Eq.2}$$

Where: pf_{ji}= percentage of forests sampled in age class *i* and region *j*; NFS_{ij} = number of forests sampled in age class *i* of region *j* e NFS_j = Number of sampled forests in region *j*.

Based on the relationship between the total area of forest plantations and the percentage of a given age class, the size of the forest area by age class was determined (Equation 3). To summarize the forestry base of each region, an estimate was made of areas of forests aged up to 7 years and forests aged over seven years. In order to determine the structure of the forest base and estimate the forest production, it was adopted as a criterion to consider only the areas referring to forest plantations aged between 2 and 7 years.

Where: FAU_{ij}= Estimate of the forest area of the production unit of age class *i*, belonging to region *j*, TFA_j=Estimate of the total existing forest area in region *je* pf_{ji}= percentage of forests sampled in age class *i* and in region *j*.

2.3 Estimate of forest production by region

The average forest production at seven years was estimated for each VTPR. Then, a relationship was made between the total area of planted forests existing in each age class *i*, considering only forests aged between 2 and 7 years, and the average productivity of forests at the stipulated technical cutting age (CTI), that is, at seven years (Equation 4).

$$Vest_{ij} = FA_{ij} \times \bar{V}_j \quad \text{Eq.4}$$

Where: $Vest_{ij}$= Estimated production of forest stands (m³) of class *i* in region *j*, considering the volume of forest plantations at 7 years of age; $FA_{ij}i$ = class forest area of region *j* and $\bar{V}_j$= average volume at 7 years of age ($m^3\ ha^{-1}$) of forest stands in region *j*.

2.4 Total consumption of firewood in the curing process of Virginia tobacco

Estimates of the total firewood consumption in the tobacco curing process for each VTPR were based on queries to the AFUBRA database, referring to the 2018/2019 harvest. In this procedure, information on the total production of Virginia tobacco was extracted by VTPR. These were related to the average firewood consumption in the curing process and for each VTPR.

For each VTPR, estimates of the total consumption of firewood were obtained through the relationship between tobacco production and the average consumption of firewood per ton of cured tobacco, considering the use of conventional curing units (greenhouses) (7,52 $m^3\ t^{-1}$) or forced air (5.22 $m^3\ t^{-1}$) (Welter et al., 2019) (Equation 5). Thus, the average consumption of firewood per ton of cured tobacco was obtained from the weighted average between the percentage of tobacco growers that use each type of curing unit (Equation 6).

$$TCF_j = TPv_j \times \overline{AFC_\iota} \quad \text{Eq.5}$$

Where: CTL_j= Total consumption of firewood (m³) in region *j*; TPv_j= tobacco production in region *i*; recorded in the 2019 harvest and $\overline{CML}$ = Average firewood consumption per ton of cured tobacco.

$$\overline{AFC_\iota} = \frac{\%\,conventional_j \times C_{conventional_j} + \%\,forced\_air_j \times C_{forced\_air}}{\%\,conventional + \%\,forced\_air} \quad \text{Eq.6}$$

Where: % $convencional_i$= % of tobacco growers using conventional-type curing units; % $forced\_air_i$= % of tobacco growers using forced-air curing units; $Cconventional_i$= average firewood consumption in conventional type curing units and C_{forced_air}= average firewood consumption in forced-air curing units.

2.5. Construction of firewood production and consumption scenarios.

Using the structure of forest production referring to each VTPR, a firewood supply and demand scenario was simulated. For this, the average productivity at seven years diagnosed in the forest inventory and the total consumption of firewood in each region were considered. Thus, the classic volume regulation method was adapted, still meeting the condition of harvesting only 7-year-old units. In order to apply a criterion for the construction of the scenarios, only the forest area corresponding to the forest plantations of age classes 2, 3, 4, 5, 6, and 7 years was considered

Table 1 – Estimated forest area, tobacco production, and firewood consumption for Virginia tobacco-producing regions.
Tabela 1 *– Área florestal estimada, produção de tabaco e consumo de lenha por região produtora de tabaco Virgínia.*

Regions	Total producers with forest plantations	Average forest area (ha)	Total forest area (ha)	Tobacco production (ton)	Firewood consumption (m³/year)
PR - Southeast Paraná	12,330	1.5	18,495.00	114.161.60	819,231.70
SC - North Plateau	10,292	1.5	15,026.32	43,493.90	522,041.50
SC - Alto Vale	7,101	2.1	15,125.13	22,697.40	414,142.30
SC - South Coast	3,087	2.7	8,273.16	74,343.30	173,065.10
RS - Centro Serra	19,004	1.6	29,646.24	149,805.30	777,107.60
RS - Central Depression	5,561	1.8	9,731.75	82,312.30	158,663.30
RS - Costa Doce	12,455	1.6	19,803.45	47,268.70	462,104.30
Total	69,830	--	116,103.05	534,082.50	3,326,355.90

Source: Authors, 2020.
Fonte: Autores,220.

since 7 years, and the technical cutting age is commonly used in energetic *Eucalyptus forests*.

The periodic volume target (V_P) was obtained from the weighted average of the total area based on productivity at seven years old, considered the technical cutting age. The method consisted of adaptations of the procedure used by Davis and Johnson (1987) (Equations 7 and 8).

$$CA_j = \frac{TFA_j}{CTA} \quad \text{Eq.7}$$

Source: Authors, 2020.
Fonte: Autores, 2020.

$$V_p = \frac{\left(\sum_{i=1}^{7} A_n * V_7\right)_j}{TFA_j} * CA_j \quad \text{Eq.8}$$

Where: CA_j= area, in ha, of the compartment used in the control by area in region *j*; TFA_j= total forest area belonging to region *j*; CTA= cutting technical age; V_P= volume weighted per ha; A_n= forested area belonging to classes from 2 to 7 years old, in region *j*; V_7= average volume per ha at 7 years of age in region *j*.

The planning horizon considered in the simulation was 21 periods (years). It was also assumed that the production units had the same production capacity over time.

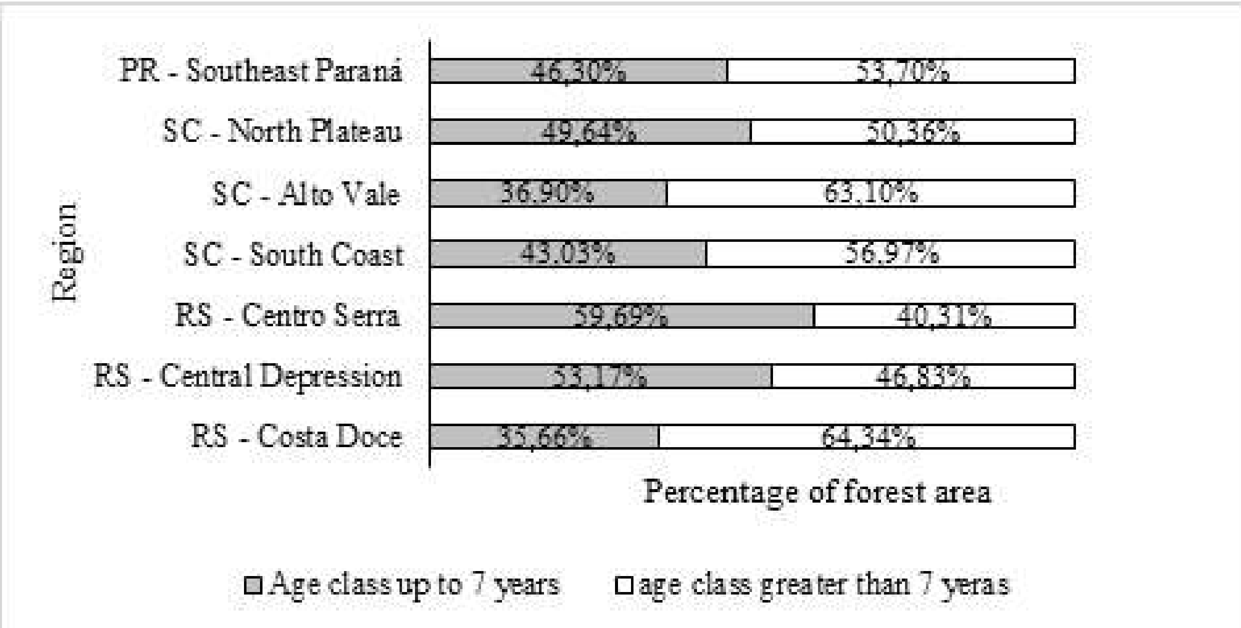

Figure 2 – Percentage of forest plantations up to seven years old and over 7 years old.
Figura 2 *– Percentual de plantios florestais com idade até 7 anos e superior a 7 anos.*

Table 2 – Estimate of forest production at age 7 for forest production units in tobacco-producing regions, considering age classes from 2 to 7 years.
Tabela 2 *– Estimativa da produção florestal aos 7 anos para unidades de produção florestal das regiões produtoras de tabaco, considerando classes de idade de 2 a 7 anos.*

Region	Age class (years)	Area (ha)	Estimated production at 7 years (m³)
PR - Southeast Paraná	2	1,194	343,348.40
	3	806	231,760.17
	4	1,373	394,850.66
	5	716	206,009.04
	6	1910	549,357.45
	7	2,566	738,199.07
SC - North Plateau	2	693	185,360.72
	3	1223	327,107.16
	4	1168	312,569.06
	5	1413	377,990.49
	6	1508	403,432.16
	7	1454	388,894.07
SC - Alto Vale	2	592	152,768.53
	3	473	122,215.86
	4	710	183,323.79
	5	1,301	336,092.32
	6	1,440	371,740.12
	7	1,065	274,984.39
SC - Coast	2	593	175,710.53
	3	297	87,856.75
	4	494	146,425.94
	5	989	292,851.88
	6	791	234,282.68
	7	396	117,141.34
RS - Centro Serra	2	2,590	677,676.31
	3	2,999	784,677.29
	4	2,840	743,064.34
	5	3,067	802,509.91
	6	3,067	802,509.91
	7	3,135	820,345.15
RS - Central Depression	2	772	227,070.42
	3	541	158,948.70
	4	927	272,483.91
	5	1,081	317,900.35
	6	1,159	340,605.63
	7	695	204,365.14
RS - Costa Doce	2	1,137	284,518.18
	3	1,351	337,863.62
	4	853	213,389.26
	5	1,386	346,756.61
	6	853	213,389.26
	7	1,481	370,466.25

Source: Authors, 2020.
Fonte: Autores, 2020.

3. RESULTS

A production of 534,082.5 tons of tobacco was determined for the 7 VTPR, which requires an annual volume of firewood of 3,326,355.85 m³. Of this amount, the regions PR – Southeast Paraná and RS – Centro Serra were the ones that stood out with the most expressive consumption (Table 1).

The forest areas per rural property varied between 1.46 and 2.68 hectares, and the estimated total forest base area is 116,103.05 ha of *Eucalyptus plantations*.

Source: Authors, 2020.
Fonte: Autores, 2020.

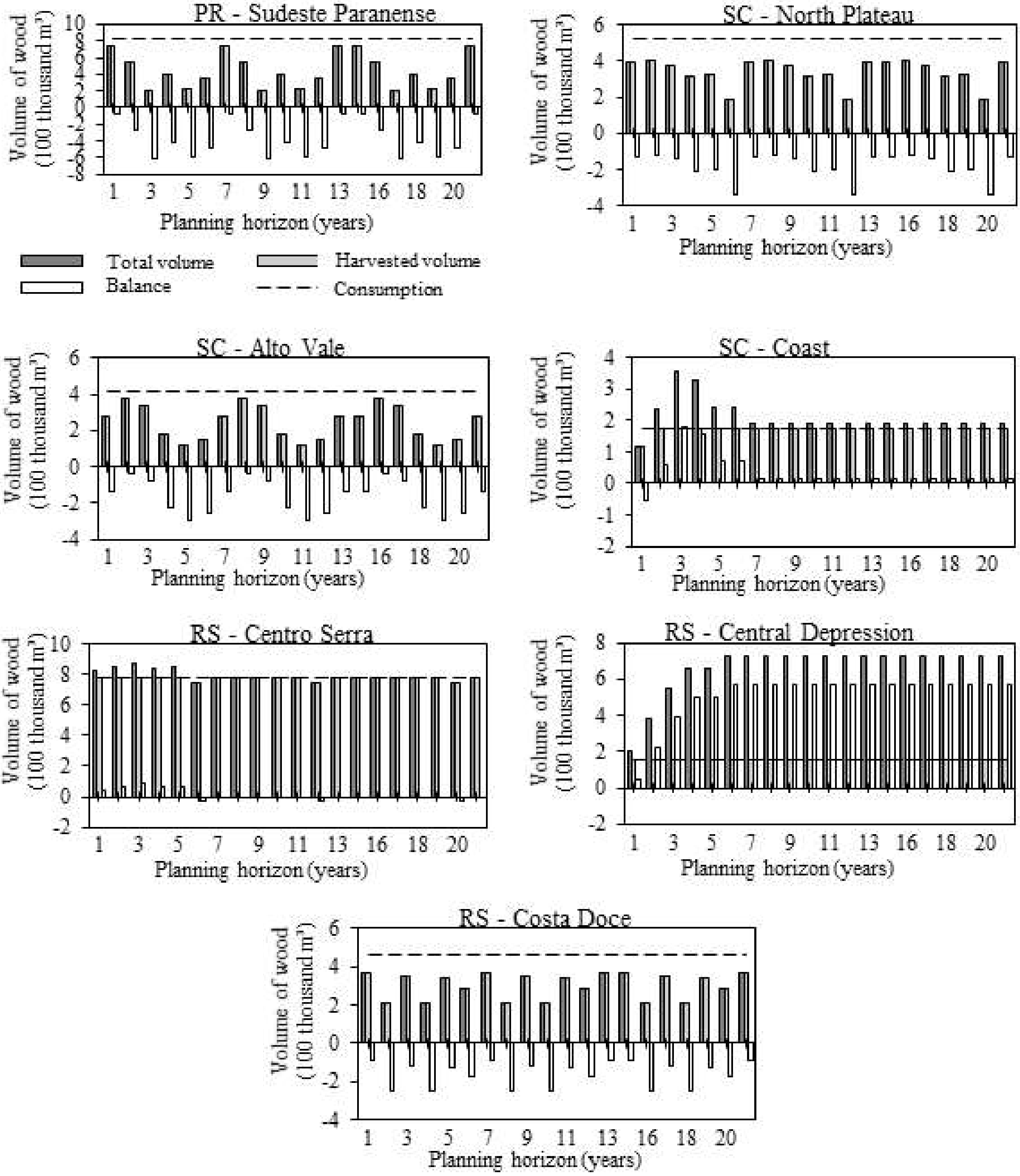

Figure 3 – Standing wood production and firewood consumption scenarios, considering the forest base of family farmers inserted in the Virginia tobacco production process, considering forest age groups from 2 to 7 years old.
Figura 3 *– Cenários de produção de madeira em pé e de consumo de lenha, considerando a base florestal de agricultores familiares inseridos no processo produtivo do tabaco Virgínia, considerando florestas com idade entre 2 e 7 anos.*

The SC – South Coast and RS – Central Depression regions resulted in the smallest forest areas (Table 1). It was also observed that approximately 50% of the structure of the forest base is composed of old stands, which were allocated to the age group over 7 years old (Figure 2). When analyzing the distribution of forest areas allocated in the 2 to 7 year age groups, it was possible to observe that the forest structure is deregulated in both regions (Table 2).

As for the scenarios, some regions (PR – Southeast, SC – North Plateau, SC – Alto Vale, and RS – Costa Doce) tended to present a deficit of firewood for consumption in the tobacco curing process. On the other hand, a surplus of forest biomass was obtained in the regions of SC – Litoral, RS – Centro Serra, and mainly in RS – Central Depression (Figure 3).

4. DISCUSSION

Studies on productive chains involving forestry production in Brazil have made essential contributions in different sectors. Of these, some are aimed at assisting in the analysis of bottlenecks and the preparation of planning for future scenarios. Some examples are the analysis of the biodiesel agro-industrial complex in Brazil (Castro et al., 2010), the charcoal production chain (Silva et al., 2021), of eucalyptus wood (Soares et al., 2010) and biomass of forest origin (Simioni et al., 2010; Simioni et al., 2018).

The Virginia tobacco production chain demands significant volumes of firewood for the tobacco curing process in the seven analyzed regions. For the VTPR, where the place showed a surplus of standing wood, it is evident that when considering only forests aged between 2 and 7 years, the diagnosed forest base was able to promote energy sufficiency. This positive balance between supply and demand for biomass for this production chain can strategically constitute a competitive advantage for expanding tobacco production in these regions. Creating logistics strategies to supply forest biomass to other areas or production chains in processes such as grain drying may also be interesting.

Evidently, one of the significant factors is the greater number of farmers who own the land, which reflects in more areas with forest plantations, consequently, a greater supply of forest biomass to supply the demand. This is consistent with the PR – Southeast Paranaense and RS – Centro Serra regions had the largest forest areas. However, it should be noted that the profile of forest production capacity is particular in each tobacco-producing VTPR in terms of size and average forest production.

Notably, the existing forest structure in the tobacco sector has an irregular distribution in the age classes of the forest stands. This factor directly interferes with the availability of wood in adequate quantity and quality to supply the healing units over time. Therefore, it corroborates the need for action plans that promote the achievement of forest regulation, especially in regions that do not have energy sufficiency. Notably, in all areas studied, a considerable part of the forest base is made up of forest stands older than 7 years, which in general are highly heterogeneous stands in terms of age and rotation. Such factors made them not be considered in this study.

In addition, it is common for producers, when planting forests, to plant an area greater than necessary to supply the annual demand for firewood. This factor can undoubtedly result from failures in the technical guidance process to help family forestry production for the Virginia tobacco production chain.

The level of technology used for silvicultural management of forest assets directly reflects on the quality and quantity of forest output in a given area. The context of family forest production of farmers who produce tobacco, for the most part, is inefficient in carrying out silvicultural practices such as adopting adequate initial planting densities, cover fertilization, weed control, and pest monitoring. Such factors reflect the high heterogeneity of forest plantations (Simioni et al., 2018).

Also, it must be considered that the forest production of the reality of each family farmer is closely aligned with the existing variations in productive capacity. Thus, along with silvicultural practices, these factors influence forest productivity (Rode et al., 2015).

The occurrence of deficits and surpluses in the simulations show the actual need to promote forest management practices, such as forest extension, which make it possible to maintain a sustained production of forest biomass to promote energy self-sufficiency. These actions should mainly value the relationship between family farmers, the land, and the Virgínia tobacco production chain since they are protagonists in the forestry production process for firewood extraction. However, it should be noted that the management practices adopted by rural producers can limit the reach of their maximum production potential. Therefore, another factor that should be considered for the Virginia tobacco production chain is the technology level employed in the tobacco curing process, as more specialized curing units promote more efficient consumption of forest biomass (Pasa et al., 2021).

In this way, the assistance of public and private entities in forest extension work to transmit and contribute to the improvement of forest management in small rural properties would be interesting for the execution of actions to improve silvicultural practices and process technology tobacco cure. In addition, the search for strategies for sizing the area of planted forests required per rural property to achieve energy sustainability in the sector. According to Greff et al. (2015), companies and unions have a strong incentive to achieve energy self-sufficiency sustainably in the tobacco-growing industry. However, it is emphasized that these actions must be performed at the regional level to benefit forest management.

It is worth mentioning that the partnership between tobacco companies and family farmers has sought the sustainability of forestry production, which makes the sector stand out in economic, social, and environmental terms. In recent years, the industry has attracted attention due to its efforts concerning the environment. In addition, one can highlight the interest in environmental certification with ISO 14001 (Frey and Wittmann, 2007; Dutra and Hilsinger, 2013).

In this context, on the part of the integrating companies, there is a demand for the use of forest biomass of legal and sustainable origin in the tobacco curing process. According to Chinangwa et al. (2017), in recent years, companies in the tobacco sector have been increasingly investing in initiatives that favor farmers' implementation of planted forests.

Although firewood is not the main product of rural tobacco-producing establishments, tobacco companies' support for the production and development of private forest promotion programs is extremely important. In this program, generally adopted by logging companies, the supply of the main inputs is established, with clonal seedlings, financial resources, and technical assistance, which competes with rural development (Rode et al., 2015). According to Simioni et al. (2018b), this is a way for small producers to start forestry activity without the need for their investments.

As much as forests are expected to be managed by maximizing production and profit, this is only sometimes possible or desirable in family farming. As forest activity is not the focus of tobacco production but an input present in the production chain, the search for solutions in forest planning for tobacco farming is undoubtedly beneficial so that they can be applied in the reality of the conjuncture to which it belongs the sector's forestry production. However, in the 2017 Agricultural Census, it was found that only 20% of agricultural establishments were produced with the help of technical assistance in Brazil (IBGE, 2019).

The reality of the conjuncture that involves the forestry production capacity (supply) and the consumption of firewood (demand) differs between regions. However, the areas that showed an energy deficit in the firewood consumption and production scenario did not achieve energy self-sufficiency throughout the planning horizon. Therefore, to achieve energy sufficiency management, actions are needed to provide integration with firewood suppliers, which appear as an alternative to obtaining forest biomass for use in the tobacco curing process.

For the Virginia tobacco production chain, the need to use biomass from renewable sources is evident, and to know in more depth the dynamics of firewood production to enhance its use for energy purposes. It is also noteworthy that identifying limiting factors becomes a competitive gain that can favor the development of action plans to implement improvements (Simoni et al., 2018).

Given the peculiarities that permeate family forestry production, this study methodology can be applied to analyze the energy sustainability of other production chains that use energy from forest biomass and that are inserted in the value chains of family farming.

5. CONCLUSION

The panorama of the forest base of the tobacco sector, for some producing regions in southern Brazil, is consistent with energy sufficiency in the medium and long term, when only forest production from forests aged between 2 and 7 years is taken into account. On the other hand, some regions present a deficit of biomass for consumption in the curing process of Virginia tobacco.

The scenarios resulting from the analysis show that it is necessary to promote the implementation of strategic plans to achieve energy self-sufficiency for the sector.

It is valid for tobacco companies to articulate directly with tobacco producers, who are involved in the integrated Virginia tobacco production system, both in forestry production and the technology used in the curing process. Thus, based on the scenario presented, the regions with a biomass deficit would be the first to be worked on.

AUTHOR CONTRIBUTIONS

Conceptualization: Souza PD, Farias JA. Performed the analyses: Souza PD, Pasa DL. Analysis of results: Souza PD, Ximendes MC, Badin TL. Writing-original draft: Souza PD, Pasa DL, Farias JA. Writing-review and editing: Souza PD, Farias JA, Badin TL, Ximendes MC. Supervision and coordination of research: Farias JA.

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