Article

REGIONAL CONCENTRATION OF CHARCOAL PRODUCTION IN THE STATE OF PARAÍBA, BRAZIL (1994 - 2016)[1]

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ABSTRACT – Charcoal has an economic, social and environmental importance, because in addition to being a source of energy, it generates employment and income in the rural environment. Therefore, knowing your market is fundamental for the decision-making of those segments that depend on this raw material. This work analyzed the regional concentration of charcoal production in the state of Paraíba, Brazil, from 1994 to 2016. The data used to measure the regional production concentration (in tons) of native Paraíba charcoal were obtained from the Brazilian Institute of Geography and Statistics (IBGE) from 1994 to 2016. The indicators used were the Concentration Ratio [CR(k)], the Herfindahl-Hirschman Index (HHI), Theil's entropy index (E) and the Gini Index (G). The main results show that the mesorregions of Borborema and Sertão Paraibano present concentrations in charcoal production from Paraíba. The CR(k) of the municipalities had a low to moderately low concentration and a moderately high to a high concentration for the microregions; the HHI and E showed deconcentration tendencies from competitive markets; the G showed strong to very strong inequality for the municipalities and microregions on average. It is concluded that the concentration of charcoal production at regional levels is not concentrated, even though it presents a moderate concentration in the partial indices [CR(k)] for the Paraíba microregions.

Keywords: Forest economics; Biomass; Industrial Concentration.

CONCENTRAÇÃO REGIONAL DA PRODUÇÃO DE CARVÃO VEGETAL NO ESTADO DA PARAÍBA, BRASIL (1994 - 2016)

RESUMO – O carvão vegetal tem uma importância econômica, social e ambiental, pois além de fonte de energia, gera emprego e renda no meio rural. Portanto, conhecer o seu mercado é fundamental para as tomadas de decisões daqueles segmentos que dependem desta matéria prima. Este trabalho analisou a concentração regional da produção de carvão vegetal no estado da Paraíba, Brasil, no período de 1994 a 2016. Os dados empregados para mensurar a concentração regional da produção (em toneladas) do carvão vegetal nativo da Paraíba foram obtidos no Instituto Brasileiro de Geografia e Estatística (IBGE), no período de 1994 a 2016. Os indicadores utilizados foram a Razão de Concentração [CR(k)], o Índice de Herfindahl-Hirschman (HHI), o índice de entropia de Theil (E) e o Índice de Gini (G). Os principais resultados mostram que as mesorregiões da Borborema e do Sertão Paraibano se concentram a produção de carvão vegetal da Paraíba. O CR(k) dos municípios teve concentração baixa a moderadamente baixa e para as microrregiões uma concentração moderadamente alto a alto; o HHI e E mostraram tendências de desconcentração apresentando de mercados competitivos; o G mostrou em média uma desigualdade forte a muito forte para os municípios e microrregiões. Conclui-se que a concentração da produção do carvão vegetal nos níveis regionais não é concentrada, mesmo apresentando concentração moderada nos índices parciais [CR(k)] para as microrregiões da Paraíba.

Palavras-Chave: Economia florestal; Biomassa; Concentração Industrial.

1. INTRODUCTION

Charcoal has been used as an energy source since ancient times. Its use as fuel served to produce the first metal tools in the Bronze Age. Charcoal is an important source of energy consumed in tropical regions, especially in developing countries for both domestic and industrial use (Vital and Pinto, 2009; Silva et al., 2014).

Heat production for long periods of time and its low smoke emission makes this fuel attractive. Charcoal is widely used domestically for cooking and heating. As far as Brazilian industry is concerned, it is an important resource as both an energy source and as a reducing agent, mainly for the steel segment, especially for pig iron and ferroalloy and cement (Coelho Junior et al., 2006a; Uhlig et al., 2008; Rousset et al., 2011).

Charcoal production can be classified in two ways: native (from forest extraction) and planted (obtained from forestry) (Coelho Junior et al., 2006b). Brazil produced 5.5 million tons (t) of charcoal (9.9% native and 90.1% planted) in 2016. In the Northeast region, 1.08 million tons of charcoal were produced, with 32.85% being native and 67.15% planted. Bahia and Maranhão were the main producers, and adding the two represented 91.38% of the region's production (Instituto Brasileiro de Geogrefia e Estatisticas- IBGE).

The state of Paraíba produced 799 t of charcoal in 2016, which represented 0.01% of the total (native + planted) production of Northeast Brazil, and this production has been decreasing over time. The charcoal produced in Paraíba comes exclusively from vegetal extraction, mainly from the Caatinga biome. Despite the low participation in relation to the other Brazilian states, charcoal production in Paraíba presents social, economic and environmental importance as an alternative source of energy, income generation and employment (IBGE, 2018). Coelho Junior (2010) affirmed that for an economy to develop, it must implement diversification strategies in poorly exploited markets, with some potential for growth.

Resende and Boff (2002) stated that market power is demonstrated by the participation of a given region in the production or sale of a particular industrial sector. To analyze the charcoal production structure, concentration indices provide the necessary empirical elements. In order to measure competition between the charcoal-producing regions, it must be understood that when the degree of concentration between the companies increases, the competition between them decreases. This increase in control exerted by the activity is one of the primordial elements to scale the competition (Possas, 1999).

In the Brazilian forestry sector, several studies on market concentration have already been carried out, among them: Costa and Mello (2009), Noce et al. (2008) and Coelho Junior et al. (2010) for the pulp and paper sector, Coelho Junior (2013) for exports of forest products, Heimann et al. (2015) for the market of frames imported by the United States, Coelho Junior (2016) for the gross production value of the pine nut in Paraná, Schettini et al. (2016) for the world wood pellet market and Coelho Junior et al. (2018) for pulp exports.

These analyzes are relevant and it is understood that understanding the market structure is essential in the decision-making of the economic segments for both business planning and the guidance of public policies. However, there is little information on the charcoal supply in the state of Paraiba, there are no studies showing the regional concentration, and it is sought to understand this market structure. Therefore, this work analyzed the regional concentration of charcoal production in Paraíba from 1994 to 2016.

2. MATERIALAND METHODS

2.1. Study objective

The state of Paraíba occupies a territorial area of 56,584.6 km², distributed in 4 mesoregions, 23 microregions and 223 municipalities (Instituto Brasileiro de Geogrefia e Estatisticas- IBGE). The data to measure the regional concentration of the native charcoal production of Paraíba were obtained from the Automatic Recovery System (*SIDRA*) of the *IBGE* from 1994 to 2016. The regional concentration indices were calculated from the charcoal production data (in tons) of vegetal extraction (native) in the state of Paraíba, at municipal levels, microregions and mesoregions.

The evolution of the total native charcoal production in the period from 1994 to 2016 was analyzed to interpret the native charcoal scenario in Paraíba. Likewise, the participation of the producing mesoregions in 1994, 1998, 2002, 2006, 2010, 2014 and 2016 was demonstrated. Moreover, the geometric growth rate (GGR) was used according to equation 1 in order to evaluate the changes (gains and losses) of the charcoal production in Paraíba and its regional levels (Cuenca and Dompieri, 2017).

$$GGR[\%] = \left[\sqrt[\Delta t]{\frac{V_F}{V_0}} - 1\right] * 100 \quad (1)$$

where, V_F is the charcoal production for the final year, in t; V_0 refers to the values of the initial year; "t is the time variation of production (expressed in years).

2.2. Concentration and inequality measures

Concentration measures may be classified as partial and summary. The partial indexes consider only part of the regions, be it municipalities, microregion or mesoregion. The summary indices use all the regions involved in the study in question. The indices used to measure the regional concentration were: Concentration Ratio [CR(k)]; the Herfindahl-Hirschman Index (HHI); Theil's Entropy (EI) and the Gini Index (GI).

The concentration ratio [CR(k)] proposed by Bain (1959) analyzes the market share of the k (where k = 1, 2, ..., n) native charcoal producing regions of Paraíba, according to equation 2.

$$CR(k) = \sum_{i=1}^{k} Si \quad (2)$$

In which, *Si* = market share in percentage of region i (municipalities, microregion) for the quantity of charcoal produced.

It used the four [CR(4)] and eight [CR(8)] major regional producers (municipalities and microregions) of Paraíba charcoal and classified the concentration according to Bain (1959). Also, the participation of the 20 [CR(20)] and 30 [CR(30)] major native charcoal producing municipalities in Paraíba.

The Herfindahl-Hirschman Index (HHI) is a market concentration analysis tool that was independently proposed by Hirschman and Herfindahl; in 1964, Hirschman published the work "The Paternity of an Index" which claimed original possession of the index (Bikker and Haaf, 2002). The HHI (equation 3) demonstrates the sum of the participation in the square of the region (municipalities, microregion and mesoregion) in the native charcoal production of Paraíba, by means of equation 3: from each region in the state.

$$HHI = \sum_{i=1}^{n} Si^2 \quad (3)$$

In which, *Si* = market share in percentage of the region *i* (municipalities, microregion and mesoregion) for the quantity of native charcoal produced in Paraíba; n = number of participants in native charcoal production in Paraíba at regional levels (municipalities, microregion and mesoregion).

The value of the index varies between 1/n (lower limit - LL, which indicates equal participation of each individual), and 1 (maximum concentration, being a monopoly situation). Thus, as the index moves away from 1/n, the higher the concentration.

For the use of comparative analyzes when there is variation in the number of regions in a given sector, Resende (1994) suggested the Adjusted Herfindahl-Hirschman Index (HHI*), according to equation 4.

$$HHI^* = \frac{1}{n-1}(n, HHH - 1);\ \text{for } n > 1. \quad (4)$$

The use of HHI* implies a range between 0 and 1. Thus, as the index moves away from zero, the higher the concentration. This means a HHI index < 0.1 indicates a highly competitive market; in the range 0.1 ≤ HHI * < 0.15 there is a non-concentrated market; for the index 0.15 ≤ HHI* ≤ 0.25 there is moderate concentration; and finally, high concentration for HHI* > 0.25.

Proposed by Theil (1967), the Entropy Index (E) was initially formulated to verify the informational content of the message that the firms would transmit, given the degree of surprise they would have in the face of a certain event. The E (equation 5) can be applied by evaluating the regional concentration of charcoal from Paraíba.

$$E = -\sum_{i=l}^{n} \ln(Si) \quad (5)$$

In which, *Si* = market share in percentage of the region (municipalities, microregion and mesoregion) and for the quantity of native charcoal produced in Paraíba; n = number of participants in Paraíba native charcoal production at regional levels (municipalities, microregion and mesoregion); ln = napierian logarithm.

The index ranges from 0 (maximum concentration) to 1n(*n*) (minimum concentration). The Entropy Index measures the inverse of the HHI concentration. The lower the value of the index, the more regionally concentrated the charcoal production is. A greater number of regions implies higher Entropy values, depending on how unequal the size is. The Entropy value is zero in monopoly situations, which means maximum concentration. The upper limit (UL) of the index is ln(n), which means the regions have equal market shares and minimum concentration (Resende and Boff, 2002).

For HHI, Resende (1994) suggested that Entropy is adjusted according to equation 6 for intertemporal analysis. Thus, Entropy varies between 0 (monopoly - maximum concentration), and 1 (perfect competition - minimum concentration).

$$E' = -\frac{1}{\ln(n)}\sum_{i=1}^{n} S_i \ln(S_i) \quad (6)$$

The Gini Coefficient (G) is a measure of inequality developed by Gini (1912) in the work "*Variabilità e mutabilità*". This coefficient was originally formulated to measure income inequality, but can also be used to measure the degree of inequality of charcoal production in a region. The index is an accessory tool to the concentration coefficients, since a high concentration implies greater inequality. The index calculation is done using equation 7.

$$G = 1 - \frac{[\Sigma_{i=1}^{n}(Sij + Si)]}{n} \quad (7)$$

In which, n = number of participants in native Paraíba charcoal production at regional levels (municipalities, microregion and mesoregion); Sij = cumulative share (j) of region i (municipalities, microregion and mesoregion) for the quantity of native charcoal produced in Paraíba; Si = market share in percentage of region i (municipalities, microregion and mesoregion) for the quantity of native charcoal produced in Paraíba.

The G index ranges from 0 to 1, being classified as follows: 0.101-0.250 zero to weak inequality; 0.251-0.500 weak to medium inequality; 0.501-0.700 medium to strong inequality; 0.701-0.900 strong to very strong inequality; 0.900-1.000 very strong to absolute inequality (Coelho Junior et al., 2013).

3. RESULTS

Table 1 shows the evolution of charcoal production via the mesoregions in Paraíba from 1994 to 2016.

Figure 1 shows the evolution of the concentration ratio of charcoal production in the state of Paraíba via microregions and municipalities from 1994 to 2016.

Table 2 represents the evolution of the Herfindahl-Hirschman Indices (HHI) of charcoal production in Paraíba from 1994 to 2016.

Figure 2 shows the evolution of the Entropy index (E) for the charcoal production of Paraíba at regional levels from 1994 to 2016.

Figure 3 shows the evolution of the Gini index (G) for the charcoal production in Paraíba from 1994 to 2016.

4. DISCUSSION

According to Table 1, charcoal production in Paraiba decreased by 9.12% between 1994 and 2016, decreasing from 6,547 t (1994) to 798 t (2016). This decrease was justified by the decrease of the native forest stocks of the state through agricultural expansion and the growth of the cities, mainly in the Sertão Paraibano, Borborema and Agreste Paraibano mesoregions.

Sertão Paraibano remained the largest producer in the periods from 1996 to 2012 and from 2014 to 2016. In 1994, 1995 and 2013, the Borborema region became the main mesoregion for charcoal production in Paraíba.

Table 1 – Evolution of charcoal production in the mesoregions of the State of Paraíba, in tons (t), in 1994, 1998, 2002, 2006, 2010, 2014 and 2016.

Tabela 1 – *Evolução da produção do carvão vegetal nas mesorregiões do Estado da Paraíba, em toneladas (t), nos anos de 1994, 1998, 2002, 2006, 2010, 2014 e 2016.*

	1994	1998	2002	2006	2010	2014	2016
Sertão	1,588	2,146	1,343	714	516	314	370
Borborema	3,758	1,615	824	489	456	302	314
Agreste	941	904	370	262	191	120	114
Mata	260	136	10	252	-	-	-
Paraíba	6,547	4,801	2,547	1,717	1,163	736	798

Fonte: IBGE (2017).

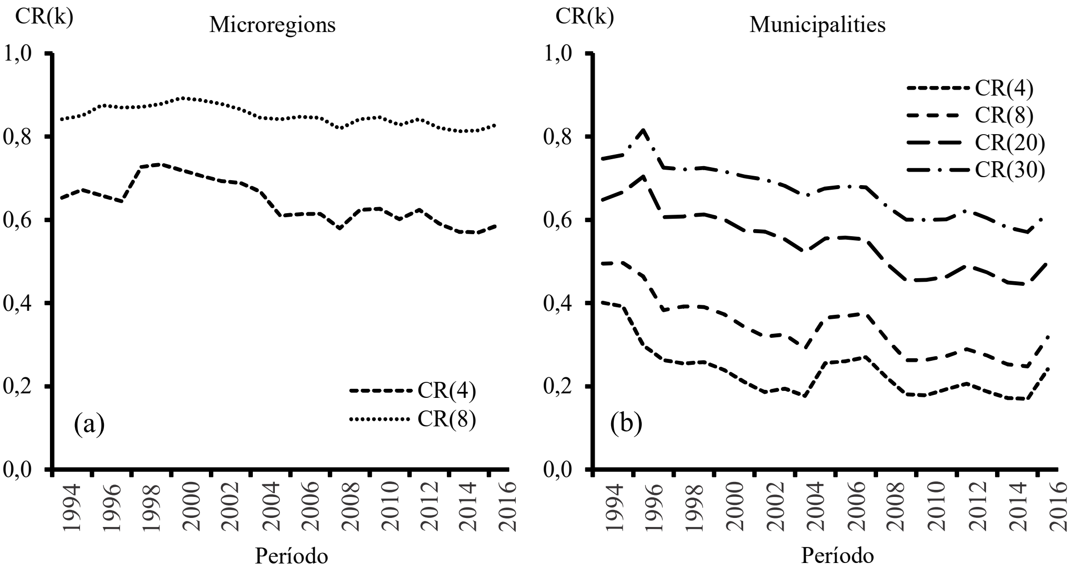

Figure 1 – Evolution of the Concentration Ratio [*CR(k)*] of the charcoal production in Paraíba, at municipal and micro-regional levels, from 1994 to 2016.

***Figura 1** – Evolução da Razão de Concentração [CR(k)] da produção do carvão vegetal na Paraíba, em nível municipal (b) e microrregional (a), de 1994 a 2016.*

Table 2 – Evolution of the Herfindahl-Hirschman index for the charcoal producing regions in the State of Paraíba, from 1994 to 2016.

***Tabela 2** – Evolução do índice Herfindahl-Hirschman para as regiões produtoras de carvão vegetal no Estado da Paraíba, de 1994 a 2016.*

Ano	Mesorregions				Microrregions				Municipalities			
	HHI	LI	HHI*	Nº	HHI	LI	HHI*	Nº	HHI	LI	HHI*	Nº
1994	0.4105	0.2500	0.2141	4	0.1959	0.0455	0.1576	22	0.0721	0.0072	0.0654	138
1995	0.4029	0.2500	0.2038	4	0.1874	0.0455	0.1488	22	0.0611	0.0073	0.0542	137
1996	0.3522	0.2500	0.1363	4	0.1323	0.0435	0.0928	23	0.0380	0.0069	0.0313	145
1997	0.3364	0.2500	0.1152	4	0.1352	0.0435	0.0959	23	0.0315	0.0053	0.0263	187
1998	0.3492	0.2500	0.1323	4	0.1549	0.0455	0.1146	22	0.0282	0.0053	0.0230	188
1999	0.3555	0.2500	0.1407	4	0.1546	0.0435	0.1162	23	0.0286	0.0056	0.0231	178
2000	0.3795	0.2500	0.1727	4	0.1667	0.0476	0.1250	21	0.0269	0.0060	0.0210	166
2001	0.3772	0.2500	0.1696	4	0.1583	0.0476	0.1162	21	0.0239	0.0063	0.0177	158
2002	0.4038	0.2500	0.2051	4	0.1496	0.0476	0.1071	21	0.0220	0.0062	0.0159	162
2003	0.3820	0.2500	0.1759	4	0.1471	0.0500	0.1022	20	0.0220	0.0062	0.0159	162
2004	0.3929	0.2500	0.1905	4	0.1305	0.0476	0.0870	21	0.0191	0.0063	0.0129	158
2005	0.3057	0.2500	0.0743	4	0.1144	0.0500	0.0678	20	0.0320	0.0066	0.0256	152
2006	0.2989	0.2500	0.0651	4	0.1163	0.0500	0.0698	20	0.0335	0.0069	0.0267	145
2007	0.2977	0.2500	0.0636	4	0.1175	0.0500	0.0711	20	0.0347	0.0070	0.0279	143
2008	0.3225	0.2500	0.0967	4	0.1126	0.0500	0.0659	20	0.0228	0.0070	0.0159	143
2009	0.3830	0.3333	0.0745	3	0.1247	0.0526	0.0761	19	0.0178	0.0071	0.0107	140
2010	0.3776	0.3333	0.0663	3	0.1289	0.0526	0.0805	19	0.0179	0.0071	0.0109	140
2011	0.3707	0.3333	0.0561	3	0.1233	0.0526	0.0746	19	0.0195	0.0074	0.0122	136
2012	0.3823	0.3333	0.0734	3	0.1382	0.0526	0.0903	19	0.0229	0.0075	0.0156	134
2013	0.3770	0.3333	0.0655	3	0.1297	0.0526	0.0814	19	0.0199	0.0075	0.0125	134
2014	0.3770	0.3333	0.0654	3	0.1190	0.0526	0.0701	19	0.0177	0.0074	0.0104	135
2015	0.3809	0.3333	0.0714	3	0.1200	0.0526	0.0712	19	0.0175	0.0073	0.0103	137
2016	0.3902	0.3333	0.0853	3	0.1196	0.0526	0.0707	19	0.0256	0.0075	0.0183	134

Obs.: Nº is equal to the number of participants for the different regional levels studied.

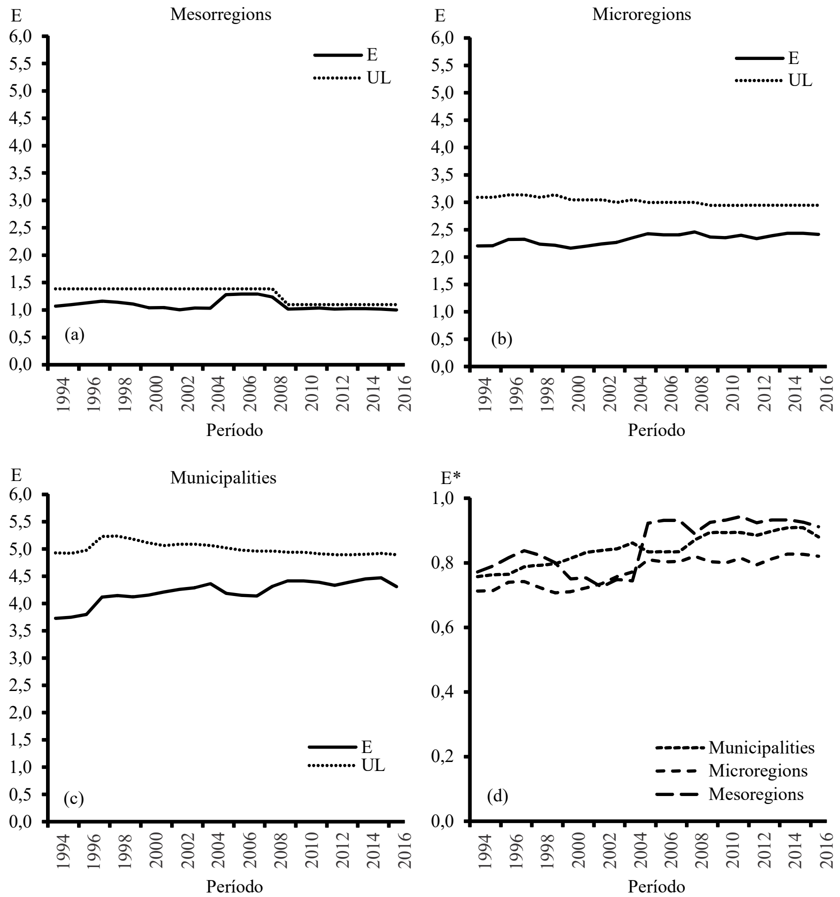

Figure 2 – Evolution of the Entropy Index (*E*) for the production of charcoal from Paraíba, at regional levels, from 1994 to 2016.

Figura 2 – *Evolução do Índice de Entropia (E) para a produção de carvão vegetal da Paraíba, em níveis regionais, de 1994 a 2016.*

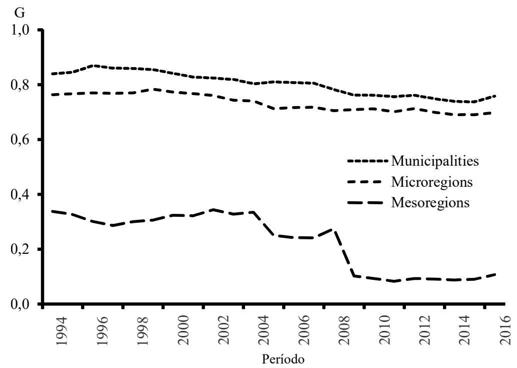

Figure 3 – Evolution of the Gini Index (*G*) for the production of charcoal from Paraíba, at regional levels, from 1994 to 2016.

Figura 3 – *Evolução do Índice de Gini (G) para a produção de carvão vegetal da Paraíba, em níveis regionais, de 1994 a 2016.*

Agreste Paraibano occupied the third place throughout the analyzed period. The Mata Paraibana mesoregion had a very small contribution in the state context because the forest fragments were practically all destined for permanent preservation areas, legal reserves and conservation units.

The results obtained by Figure 1 refer to the concentration of charcoal production as a whole, not considering the destination after production, from 1994 to 2016. Figure 1 shows the Concentration Ratio of the 4 largest microregions [$CR(4)_{micro}$] for charcoal production. An average of 20.48 microregions was observed in the studied period, with the mean $CR(4)_{micro}$ being 64.21%, characterizing high concentration according to Bain's (1959) classification. The year of greatest concentration was 1999 (73.26%) and the lowest was in 2015 (56.95%). In the studied period, the standard deviation of the $CR(4)_{micro}$ was 0.0586 and the variance was 0.0026, evidencing few changes in the concentration pattern between the microregions. For the year with the greatest concentration (1999), the microregions producing charcoal in Paraíba were: Cariri Ocidental, Serra do Teixeira, Curimataú Ocidental and Patos, respectively. In the smaller concentration year of 2015, the microregions that produced the most were Cariri Occidental, Serra do Teixeira, Patos and Cariri Oriental.

Cariri Ocidental and Serra do Teixeira were among the microregions of Paraíba that most represented the $CR(4)_{micro}$ throughout the studied period, since they maintained their productions in the first two places of the state ranking. Oriental Cariri, Litoral Norte, Sousa, Patos and Curimataú Ocidental also collaborated in some periods for the $CR(4)_{micro}$, and the last two of these were the ones that contributed the most.

The Concentration Ratio of the 8 largest microregions [$CR(8)_{micro}$] presented an average of 84.95% for the studied period, which characterized a high concentration according to Bain (1959). The standard deviation was 2.35% and variance was 0.0005 for $CR(8)_{micro}$. The highest concentration for the $CR(8)_{micro}$ was 89.20% (2000), and the lowest concentration was 81.28% (2014).

In 2000, the year of greatest concentration, the microregions with the highest charcoal production in Paraíba were: Cariri Ocidental, Serra do Teixeira, Patos, Curimataú Occidental, Cajazeiras, Cariri Oriental, Umbuzeiro and Sousa, respectively. In the year of 2014, the lowest concentration year, Cariri Ocidental, Serra do Teixeira, Patos, Cariri Oriental, Curimataú Occidental, Itaporanga, Piancó and Seridó Oriental were the microregions inserted in the $CR(8)_{micro}$.

Figure 1.b shows the Concentration Ratio of the 4 largest municipalities ($CR(4)_{mun}$] of charcoal producers from 1994 to 2016. There was an average of 150 municipalities in the studied period, and the $CR(4)_{mun}$ was 23.50%, characterizing low concentration according to Bain (1959). The year of greatest concentration was in 1994 (40.09%), while the lowest value was in 2015 (16.94%). This had a standard deviation of 0.0632 and a variance of 0.0040. For the year of greatest concentration (1994), the municipalities with the highest production were: Sumé, Monteiro, Boqueirão and Pombal, respectively. In the year 2015, which obtained lower concentration, the municipalities that produced the most were Congo, Monteiro, Itaporanga and Barra de Santa Rosa.

The concentration ratio of the 8 largest charcoal producing municipalities [$CR(8)_{mun}$] presented an average of 34.22% in the studied period, which characterizes a concentration considered moderately low according to Bain's (1959) classification. The year of greatest concentration was in 1995 with a concentration of 49.58%, while the lowest value was in 2015 (24.80%). This presented a standard deviation of 0.0732 and a variance of 0.0054; values similar to those observed in the [$CR(4)_{mun}$].

In 1995, the year with the highest concentration, the municipalities with the highest production were Sumé, Monteiro, Boqueirão, Pocinhos, Pombal, Barra de Santa Rosa, Congo and Aroeiras, respectively. In the year 2015, the 5th to 8th municipalities that produced the most were Camalaú, Sumé, Cacimba de Areia and Juru.

The concentration ratio of the 20 largest charcoal producing municipalities [$CR(20)_{mun}$] presented an average of 54.58% in the studied period. The year with the highest concentration was in 1996 with a concentration of 70.37%, and the lowest was 44.44% in 2015. This had a standard deviation of 0.0748 and a variance of 0.0056; values similar to those observed in the [$CR(4)_{mun}$] and [$CR(8)_{mun}$].

In 1996 when there was a greater concentration, the municipalities with the highest charcoal production were Monteiro, Barra de Santa Rosa, Cacimba de Areia, Teixeira, Aroeiras, Immaculada, Umbuzeiro, São Sebastião do Umbuzeiro, Desterro, Camalaú, Juru, Patos, São João do Rio do Peixe, Cajazeiras, Mãe d'Água, Boqueirão, Pombal, Quixaba, Água Branca and Manaíra, respectively.

While in 2015, the municipalities of Congo, Monteiro, Itaporanga, Barra de Santa Rosa, Camalaú, Sumé, Cacimba de Areia, Juru, São João do Cariri, Quixaba, Piancó, Serra Branca, Patos, Picuí, Caraúbas, Teixeira, Santa Teresinha, Boqueirão, Água Branca and Immaculada composed the [$CR(20)_{mun}$].

The Concentration Ratio of the 30 largest charcoal producing municipalities [$CR(30)_{mun}$] of Paraíba presented an average of 66.97% in the studied period, while the year of greatest concentration was in 1996 with a concentration of 81.54%, and the lowest was 57.05% in the year 2015. This had a standard deviation of 0.0642 and a variance of 0.0041.

In 1996, the 21st to the 30th municipalities that obtained the largest charcoal production were Cuité, Passagem, Salgadinho, Cabaceiras, Serra Branca, São João do Cariri, Piancó, Sumé, Tavares and São José do Bonfim, respectively. In the year 2015, the 21st to the 30th municipalities that obtained the highest production were São José de Espinharas, Santo André, São João do Tigre, Desterro, Taperoá, Damião, Cuité, Tavares, Cajazeiras, and São José do Bonfim.

The Herfindahl-Hirschman (HHI) indices of charcoal production in Paraíba from 1994 to 2016 (Table 2) showed that the municipal (HHI_{mun}) and micro-regional (HHI_{micro}) levels were classified as lowly concentrated. This classification is somewhat different from the $CR(4)_{mun}$ and $CR(4)_{micro}$ by the squared participation of all charcoal producers. On the other hand, the index of the mesoregions (HHI_{meso}) showed a higher concentration, and with this less competition among the regions.

For the municipalities, HHI_{mun} and HHI^*_{mun} showed similar behavior, which demonstrated the competitiveness of the market. The mean HHI_{mun} in the studied period was 0.0285, while the lower limit (LL) was 0.0067. The standard deviation of HHI_{mun} presented in the period was 0.0135, and the LL was 0.0007. In observing the difference between HHI and LL, the year of greatest concentration was 1994, with a difference of 0.0649. In 2015, the difference between HHI and LL was 0.0102, which was the lowest concentration in the period.

The periods from 1994 to 2000 and 2004 to 2008 were those with the highest concentration trend, although the index was still showing well distributed production in the sector. HHI^*_{mun} averaged 0.0217 during the analyzed period. This was classified by Resende (1994) as highly competitive. The standard deviation of HHI^*_{mun} in this period was 0.0135 with a variance of 0.0002. The year of least competitiveness in production was 1994, the first year of the period, with HHI^*_{mun} of 0.0649. Next, the year of greater competitiveness had a HHI^*_{mun} of 0.0102 in the year of 2015.

From 2004 to 2008, HHI_{mun} increased due to the decrease in the number of producing municipalities. However, from 2009, despite the decrease in the number of municipalities that produced charcoal, this gradually approached its lower limit (market homogeneity), changing the initial condition from a low concentration to an even more competitive production.

This gradual deconcentration in the studied period is mainly explained by the growth of the market share among the municipalities in the state. From 2009 onwards we can see slight variations in HHI_{mun}, where there was only a small increase in concentration in 2012 until 2013.

The analysis of the HHI_{micro} presented higher mean values than the municipal HHI, with a mean of 0.1381 with an average Ll of 0.0491. The mean difference between the indicators was 0.0891. The average value in relation to HHI^*_{micro} was 0.0936, being classified as a highly competitive market. HHI_{meso} obtained an average value of 0.36655, and the average difference between HHI and Ll was 0.0865 and for the HHI^*_{meso} it was 0.11180, thus indicating a non-concentrated market.

The evolution of the Entropy index (E) for the charcoal production of Paraíba at regional levels from 1994 to 2016 is presented in Figure 2. The municipal, microregional and mesoregional E of Paraíba presented an approximation between E and Upper Limit (UL), indicating deconcentrated trends. However, different E scales were observed for each regional level due to the quantitative observations in the analyzed period, which is not to say that they have different concentrations.

The meso-regional entropy index (E_{meso}) averaged 1.0921, being considered a scale closer to zero (Figure 2a) when compared to the other regional levels, but it is not appropriate to say that this indicator was the most concentrated in the production of charcoal in Paraíba. EI_{meso} and its limit remained very stable, demonstrating competition between charcoal producing mesoregions in the state.

Figure 2.b shows the microregional entropy index (E_{micro}) for charcoal producing in Paraíba, which has a less concentrated market as compared to other regional levels (municipalities and mesoregions) and with little variation in the entropy index (E_{micro}), with a mean of 2.3283 and a moderate concentration. Figure 2.c shows that charcoal production in Paraiba municipalities showed a larger numerical scale from 1994 to 2016, but indicates a lower concentration, meaning that the distance between the E_{mun} index and its UL had an average of 4.2153.

Figure 2.d further facilitates the understanding of concentrations between the regional levels by means of the adjusted Entropy Index (E*). The Paraiba regions

have demonstrated a non-concentrated market structure because their entropy values are close to 1, which results in a minimal concentration in the market over the years. The regional E* were very close to each other.

The evolution of the Gini (G) index for charcoal production in Paraíba (Figure 3) from 1994 to 2016 showed that there was inequality at all regional levels over the years studied. There was a change in the concentration classification for G_{meso} and G_{micro}, where G_{meso} presented a Weak/Average classification from 1994 to 2004, and in 2008 became Zero/Weak inequality from 2005 to 2007 and from 2009 to 2016; G_{micro} was classified as Strong/Very Strong for the period 1994 to 2012, and as Medium/Strong inequality from 2013 to 2016. The G_{mun} was classified as Strong/Very Strong throughout the studied period.

G_{micro} presented an average of 0.7331, which classifies it as strong to very strong inequality. Its variance in the studied period was 0.0010. The year with the greatest inequality was 1999, with an index of 0.7830. The year of 2014 had the lowest inequality index, with 0.6904. On the other hand, G_{meso} presented a mean of 0.2289 (classified as zero to weak inequality) with a variance of 0.0110. The year with the greatest inequality was 2002 with an index of 0.3435, while the year with the lowest inequality was in 2011 with an index of 0.0828. The G_{mun} indicator presented an average of 0.8028, which classifies it as strong to very strong inequality. Its variance in the studied period was 0.0019. The year with the greatest inequality was that of 1996, with an index of 0.8694, while 2015 had the lowest inequality index with 0.7369.

5. CONCLUSION

From the presented results, it is concluded that:

Paraíba's charcoal production is concentrated in the interior of the state, located in the mesorregions of Borborema and Sertão. In the period from 1994 to 2016, there was an annual decrease of 9.12% p.a. in the production of charcoal from Paraiba.

The CR(k) shows that there is competition between the municipalities, presenting a low to moderately low concentration, and a oligopolistic market structure for the microregions, with moderate to high concentration in the studied period.

HHI showed deconcentrating trends of competitive markets for the regional levels studied. The EI corroborated with the HHI analysis, indicating similarity in concentration between the regional levels of charcoal production in Paraíba. The average G showed a strong to very strong inequality for the municipalities and microregions, and a weak concentration for the mesoregions.

Thus, the indicators used generally showed a reduction in concentration over the years and gave good evidence of the market structure of charcoal production in Paraíba.

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ERRATA

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