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Sustainability Indicators Of The Yerba Mate Agro-Industrial Complex In Brazil

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Abstract:
The growth of the tea market is based on its characteristics of being natural and healthy. Mate is widely consumed in Brazil, Argentina, Uruguay, Chile, Bolivia and is being disseminated in other countries, especially in the United States and Europe. The product has beneficial health properties such as antioxidant, anti-inflammatory, antimutagenic, antiobesity and cardioprotective functions. Considering the yerba mate agro-industrial complex in the state of Parana (Brazil), the main world producer, the general objective of the present study was to estimate economic, social and environmental indicators based on the input-output matrix of the two yerba mate production systems (extractive and cultivated) and agribusiness aiming to measure its sustainability. Assessing the economic, social and environmental impacts, the greater sustainability of the extractive production system was proven by the analysis of the indicators. For the production chain to obtain the advantages arising from the greater sustainability of the yerba mate extractive system with an increase in the price paid to the producer and generation of employment and income, there is a need to implement a product traceability system to obtain expansion of the consumer market, mainly abroad. For consumers, there will be the benefit of consuming a natural, high-quality product with beneficial properties for health.

Key Word*: input-output; carbon dioxide; organic production*.

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I. Introduction

The current growth of the tea market is based on its characteristics of being natural and healthy. Mate is widely consumed in Brazil, Argentina, Uruguay, Chile and Bolivia, being consumed in different hot and cold forms [1]. Yerba mate is being spread in other countries, especially in the United States and Europe. The wide range of by-products based on yerba mate makes it possible to expand consumption[2]. In addition to traditional yerba mate drinks, concentrated extracts are used in the pharmaceutical, cosmetic and food industries[3].

Yerba mate has beneficial health properties such as antioxidant, anti-inflammatory, antimutagenic, anti-obesity and cardioprotective functions4. These benefits are related to its chemical composition, which includes alkaloids, polyphenols, terpenes and essential oils, among other substances capable of improving people's health[5, 6].

Brazil was the world's largest producer of yerba mate in 2022, followed by Argentina and Paraguay. In Brazil, most of the production occurs in the South Region, made up of the states of Parana, Santa Catarina and Rio Grande do Sul. Parana had more than 80% of Brazilian production in 2021[7].

The production of yerba mate in its extractive form is possible in the rainforest, or Araucarias Forest, which occurs predominantly in the Southern Region of Brazil and is composed of pine trees where perennial yerba mate plants grow naturally in the shade. The traditional type of cultivation is extractivism, where producers use native yerba mate plants. The second type of cultivation is that where the number of plants in the remaining forest is increased through planting. These two forms of production, extractive and densification, are most common in Parana (around 60% of state production). The third type of cultivation is called full sun, in which yerba mate is a monoculture or can be produced in conjunction with other plants or even animals. This

type of cultivation in full sun is common in the states of Santa Catarina and Rio Grande do Sul, as well as Argentina and Paraguay. It is important to note that yerba mate grown in full sun normally has lower quality leaves than that grown in the shade of the forest and results in a different quality of drink[7, 8, 9].

It is significant to note that Brazil's official data are divided into two types of yerba mate production, extractive system (traditional or dense) and cultivated (monoculture or intercropped with other crops and animals). In this way, the extractive and dense systems are computed as a single system, extractivism. Producers call production in the forest "shade production" and the cultivation of yerba mate "full sun production". Extractive production in the dense or traditional format is considered organic (without the use of agrochemicals) and predominant in the state of Parana (Brazil), as producers cannot use chemical products such as fertilizers and pesticides within the native forest. Pest control is carried out exclusively through biological control. The industrialization process of yerba mate leaves, whether extractive or planted, does not use chemical substances and is based on the use of fire, heat and grinding. Most of the product is sold in the country itself with exports mainly to Argentina, the United States, Uruguay and Europe[7, 8, 9].

Considering the agro-industrial complex of yerba mate, the general objective of the present study was to estimate economic, social and environmental indicators based on the input-output matrix Parana – Rest of Brazil of the production systems of extractive yerba mate, cultivated yerba mate and agroindustry to assess economic, social and environmental sustainability.

II. Material And Methods

Initially, the descriptive analysis of the yerba mate agro-industrial complex and the geographic location of the largest producing state and municipalities (Parana – Brazil) are carried out to understand the characteristics of the production, processing and distribution systems. Subsequently, the calculations of economic, social and environmental indicators based on the inter-regional input-output matrix Parana – Rest of Brazil are detailed so that the results can be subsequently analysed.

Yerba mate agro-industrial complex in the state of Parana – Brazil

Figure 1 illustrates the components of the yerba mate agro-industrial complex. Agricultural inputs, whether for extractive (shaded) or cultivated (full sun) production, correspond to fertilizers, seedling production, chemical products such as agricultural pesticides, fuel, financial services (insurance, financing), machines and implements and other intermediate goods and services necessary for the production process. Green leaf production encompasses agricultural (full sun) and extractive (shaded) production, with extractive yerba mate being considered of higher quality due to its development in the shade, with a drink with a milder and less bitter flavor and providing a price higher than the value of the planted yerba mate[7, 10, 11].

Observing Figure 1, the industry covers the production of cancheed (fragmented) yerba mate to produce drinks, whether chimarrão, tereré or tea, being the main agroindustry. There are other industrial processes that use the raw material to obtain an extract that will serve as the base for various drinks, the main one being iced mate tea. There is the possibility of extracting chlorophyll, which is used in the agri-food industry as a natural coloring and preservative. The pharmaceutical industry can use by-products such as caffeine extract, theobromine, and flavonoids with various effects on the body (nervous system stimulant, compound for treating hypertension, bronchitis and pneumonia). The industrialization of yerba mate also has the possibility of obtaining by-products such as saporin and essential oil, the first compound is used as an emulsifier and the second as a bactericide and sterilant[7, 10, 11].

The existence of many by-products that can be obtained from yerba mate shows the versatility of its use. However, its main use is the production of beverages. Considering the production of yerba mate cancheed (named "cancheada"), the industrial units called yerba mates are those whose process consists of drying and grinding the yerba mate to obtain the base for preparing drinks. The industrial process for preparing the product for "chimarrão" and "tereré" basically consists of drying and crushing the green leaf from cultivation areas (full sun) or extractivism (shaded). The different desired characteristics of the product depend on procedures in relation to storage time, amount of water to be removed, crushing (fine, medium or coarse) and which can be different to meet markets that have specific demands[10, 11].

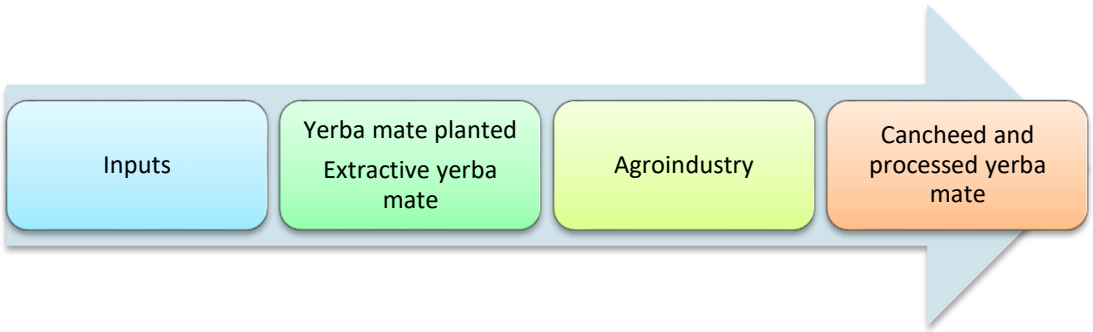

Figure 1: Yerba mate agro-industrial complex in the state of Parana – Brazil, adapted from [10, 11].

The first step in processing is the reception and weighing of the green leaf, which receives which is called "sapeco", which consists of an initial process of contact of the green leaves with the heat of the fire and loss of water. These leaves after "sapeco" are then fragmented into smaller particles. Subsequently, a new drying procedure reduces the moisture content. At this point in the process, the leaves are separated from the impurities, which are transformed into sticks[10, 11]. Yerba mate sticks can be used in furnaces, returned to the field to be incorporated into the soil or even other uses such as plywood for civil construction. The dried and crushed leaves go through storage and will be separated into two parts: coarsely ground yerba mate and finely ground yerba mate. "Soque" is the name of a new crushing process. In the case of coarsely ground yerba mate, storage, mixing and packaging take place after crushing. For finely ground yerba mate, after crushing and storage, there will be two possible products: Traditional line and Soft line. The distinction between the two depends on the type of mixing to be carried out and will apply to packaging and baling[10, 11]. The basic production process is similar for other types of products that serve different markets, which determine the type of product to be obtained. The native yerba mate with a milder and less bitter flavor has specificities, but the drying, crushing and storage processes are common to all. The products from this industry that obtains cancheada yerba mate can be used for other processes, such as the production of toasted yerba mate for tea and yerba mate-based drinks. The number of final goods shows the versatility of the use of raw materials. Different markets present definitions of quality that involve the color, bitterness and intensity of the drink's flavor. Export is a possibility with growing demand and which is important in the current upward trend in prices[10, 11].

Figure 2 was prepared with data obtained from the Parana Institute of Economic and Social Development[12], which illustrates the participation of yerba mate producing states in Brazil, the largest producing state is Parana with around 82% (Figure 2A). Figures 2B and 2C respectively illustrate the production of extractive and cultivated yerba mate in the municipalities of the state of Parana in tons. It can be noted that production is concentrated in the southern region of Parana and that there are 5 municipalities with annual production above 24, 5 tons of shaded yerba mate (extractive), they are in the southern region of the state and represented more than 50% of state production. In relation to the production of cultivated yerba mate, there were 6 locations that produced over 6 tons annually and represented more than 60% of the state total.

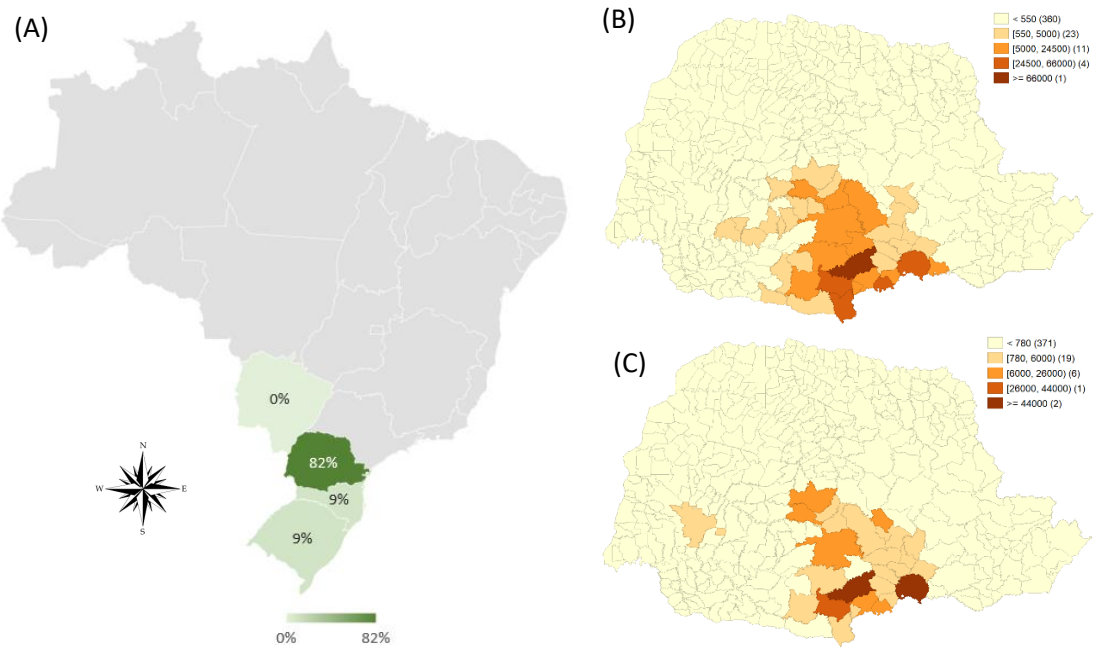

Figure 2: Geographic location and participation of Brazilian states in yerba mate production in percentage values (Figure A), extractive production of yerba mate (Figure B) and cultivated production of yerba mate in the municipalities of Parana (Figure C), year 2020. Values in tons.
Source: elaboration by the authors with data obtained from [12].

Considering the total production of yerba mate in 2020, around 60% came from extractivism (shaded production) and another 40% from production in cultivation (called full sun). Extractive production depends on the existence of the rainforest, present predominantly in the southern region of the state of Parana, as can be seen in Figure 3. Full sun production (cultivated) is located nearby, considering the climate and knowledge acquired by producers with extractive production. It can be seen in Figure 3 that in the yerba mate producing region there are 6 municipalities that had between 24.8 thousand hectares and 78.9 thousand hectares of preservation areas of the Atlantic Forest, in which the Araucarias Forest subsystem is inserted.

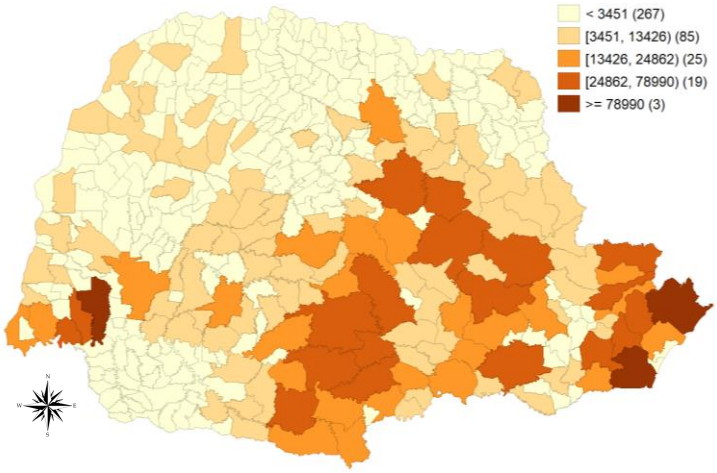

Figure 3: Conservation area of the Atlantic Forest of the Municipalities of the state of Parana, 2018. Values in hectares.
Source: elaboration by the authors based on data from [12].

The extractive production of yerba mate sustainably uses the remaining forest and helps in its preservation, as there is an economic interest in maintaining the proper environment for the development of yerba mate as a drink of greater value and quality.

Input-output matrix

The input-output matrix method was originally developed to analyse and evaluate the relationships between the various production and consumption sectors of a national economy. It can be applied to the study of smaller economic systems, such as states, municipalities, or a set of municipalities[13]. In the case of the present study, we work with the inter-regional model Parana – rest of Brazil, which is illustrated in Figure 4, which summarizes the relationships within the inter-regional input-output system for two regions: (E) State of Parana and (RBr) Rest of Brazil.

	Buyer sectors State (E)	***Buyer sectors Rest of Brazil (RBr)***	***Final Demand (E)***	***Final Demand (RBr)***	***Total Production***
Selling sectors State (E)	Intermediate Inputs (Z^{EE})	Intermediate Inputs (Z^{EBRr})	(Y^{EE})	(Y^{RBrE})	(X^{E})
Selling sectors Rest of Brazil (RBr)	Intermediate Inputs (Z^{BRrE})	Intermediate Inputs (Z^{RBrBRr})	(Y^{RBrE})	($Y^{RBrRB}r$)	(X^{RBr})
	Rest of the World Import (I^{ME})	Rest of the World Import (IM^{RBr})			
	Net Indirect Tax (IIL^{E})	Net Indirect Tax (IIL^{RBr})			
	Added Value (E)	Added Value (RBr)			
	Total Production Region (E)	Total Region Production (RBr)			
	Employment (E)	Employment (RBr)			

Figure 4: Interregional input-output system with two regions.
Source: Adapted from [14].

The interregional input-output model, also called the Isard Model[15], requires a large mass of real or estimated data, especially regarding information on intersectoral and interregional flows. Complementing the regional system, the inter-regional system shows the exchange relationships between regions, exports and imports, which are expressed through the flow of goods and services that are intended for both intermediate consumption and final demand. In a synthetic way we have the relations between two regions, the model can be presented based on the intersectoral and interregional flows of goods and services between the State (E) and the Rest of Brazil (RBr), with n sectors, where Z^{EE} is the monetary flow from sector i to sector j of the State itself (E), Z^{RBrRBr} is the monetary flow from sector i to sector j of the Rest of Brazil (RBr) to itself, Z^{RBrE} is the monetary flow from sector i of the Rest of Brazil (RBr) to sector j of State (E) and Z^{ERBr} is the monetary flow from sector i of State (E) to sector j of the Rest of Brazil (RBr) [16]. In matrix form, these flows would be represented by Equation (1):

$$Z = \begin{bmatrix} Z^{EE} & Z^{ERBr} \\ Z^{RBrE} & Z^{RBrRBr} \end{bmatrix} \quad (1)$$

In Equation (1), Z^{EE} and Z^{RBrRBr} represent matrices of intra-regional monetary flows, and Z^{ERBr} and Z^{RBrE} represent matrices of inter-regional monetary flows. The final demands are also displeased by region. Therefore, according to $A = Z(\hat{X})^{-1}$, the matrix for the n sectors is constructed, where A represents the matrix of intra-regional technical production coefficients (Equation 2), Z is the matrix of intermediate inputs (Equation 1) and Equation (4) shows regional final demand.

$$A = \begin{bmatrix} A^{EE} & A^{ERBr} \\ A^{RBrE} & A^{RBrRBr} \end{bmatrix} \quad (2)$$

$$X = \begin{bmatrix} X^{E} \\ X^{RBr} \end{bmatrix} \quad (3)$$

$$Y = \begin{bmatrix} Y^{E} \\ Y^{RBr} \end{bmatrix} \quad (4)$$

The complete interregional input-output system is represented by:

$$(I - A)X = Y \quad (5)$$

In Equation (5), I is the identity matrix (the diagonal is formed by ones and the remaining zeros) and the other terms were described previously. Equation (5) can be rewritten in the form of regionalized matrices:

$$\left\{\begin{bmatrix} I & 0 \\ 0 & I \end{bmatrix} - \begin{bmatrix} A^{EE} & A^{ERBr} \\ A^{RBrE} & A^{RBrRBr} \end{bmatrix}\right\}\begin{bmatrix} X^{E} \\ X^{RBr} \end{bmatrix} = \begin{bmatrix} Y^{E} \\ Y^{RBr} \end{bmatrix} \quad (6)$$

By carrying out these operations, the basic model necessary for the inter-regional analysis proposed by [15] is obtained, resulting in the inter-regional Leontief system of the form:

$$X = (I - A)^{-1}Y \quad (7)$$

In Equation (7), we have that the matrix $(I - A)^{-1}$is the inverse of Leontief called B with bij elements, and the equation can be written as:

$$\begin{bmatrix} X^{E} \\ X^{RBr} \end{bmatrix} = \begin{bmatrix} B^{EE} & B^{ERBr} \\ B^{RBrE} & B^{RBrRBr} \end{bmatrix}\begin{bmatrix} Y^{E} \\ Y^{RBr} \end{bmatrix} \quad (8)$$

It is possible to estimate indicators for each sector of the economy based on direct technical coefficients and the inter-regional inverse Leontief matrix (Miller and Blair, 2009).

Indicators based on the input-output matrix

Using the direct coefficients and the inverse Leontief matrix, it is possible to estimate, for each sector of the economy, how much employment is generated directly and indirectly in total and by education for each monetary unit produced for final demand[14], that is:

$$GV_j = \sum_{i=1}^{n} b_{ij} v_i \quad (9)$$

In equation (9), GV_j is the value of the multiplier, that is, total impact, direct and indirect, on the variable in question; b_{ij} is the ijth element of the inverse Leontief matrix and v_i is the direct coefficient of the variable of interest $v_i = \frac{V_i}{X_i}$) which is the relationship between the variable of interest (V_i) per unit of sectoral production (X_i).

The production multiplier shows how much is produced for each monetary unit of final demand, defined by Equation (10):

$$MP_j = \sum_{i=1}^{n} b_{ij} \quad (10)$$

In Equation (10), MP_j is the production multiplier of the j-th sector of the Leontief matrix and the other variables were previously defined. MP_j represents the total impact, direct and indirect, of the variable in question for a variation of one unit in final demand.

To estimate the spillover of multipliers it is necessary to decompose the indicators based on the input-output matrix (total effect) into regional and inter-regional effects, this will allow analyzing the impact of the variation in sectoral final demand on the variable of interest inside and outside the region of origin of the sector[14]. The total effect represents the total impact on the economy, which is required to meet the variation of one unit in the final demand of sector j. Subsequently, the relationship between the inter-regional effect and the total effect is estimated, normally calculated as a percentage.

To estimate the direct local impacts in each municipality in the state of Parana, the direct coefficient value of the variable of interest (v_i) is multiplied by the municipal final demand values obtained in the input-output matrix. In this way, it is possible to obtain direct impacts on yerba mate producing municipalities to assess economic and social sustainability within each location. The results are preferably presented on maps due to the large set of results.

The Parana – Rest of Brazil input-output matrix was estimated based on studies that detail the preparation of inter-regional matrix estimates[17,18, 19]. The sectors of interest for the present study were disaggregated from activities that originally existed in the input-output matrix, in this way, the Yerba Mate Extraction sector was disaggregated from the original Forestry Production and Extractivism sector, just as the Yerba Mate Cultivation sector was disaggregated. based on data from the original sector Agriculture and the Agro-industry of yerba mate, it was disaggregated from the original sector called Other food products. The data

and information to disaggregate the sectors of the yerba mate agro-industrial complex were obtained from the National Supply Company, which provides the costs of yerba mate production and the costs of the yerba mate agro-industry[11, 20].

III. Result

The results of the economic, social and environmental sustainability indicators of the links in the yerba mate agro-industrial complex in the state of Parana are divided into two levels, state and municipal, as the impacts are different in the localities due to the concentration of production in the southern region. At the state level, multipliers of employment, production, income, taxes and carbon dioxide emissions from the burning of fossil fuels were estimated for the sectors that belong to the yerba mate agro-industrial complex and compared to the economy average. At the municipal level, the direct impacts of job and income generation were estimated to verify the relative importance of cultivated and extractive yerba mate production in the local economy. Furthermore, the relative impact of the tax incentive called Tax on the Circulation of Ecological Goods and Services was analysed, a tax benefit program for municipalities that preserve water sources and native forest areas. Within this program, 5% of the amount collected in the state is divided between the localities that preserve water sources and native forests. In the case of industry, the large number of companies, processing capacity and interdependence of raw materials between municipalities, including exports to other states, made it difficult to estimate the local impact of yerba mate processing.

Economic, social and environmental indicators of the yerba mate agro-industrial complex sectors in the state of Parana - Brazil

The results of the multipliers of employment, production, income, taxes and carbon dioxide due to the burning of fossil fuels in the sectors of the yerba mate agro-industrial complex were tabulated and compared with the economic averages. The values obtained allow carrying out an economic, social and environmental analysis of the economic activities (sectors) directly involved in the production and processing of yerba mate.

In Table 1, the values refer to the capacity to generate jobs (employment multiplier) for the variation in sectoral final demand of one million reais. For cultivated Yerba Mate, 17.58 jobs were generated in the economy as a total effect in 2018, with 14.83 jobs being generated in the field (agriculture), 1.38 jobs in Parana and 1.38 in the Rest of Brazil. Brazil. The indirect effect occurs through the purchase of inputs to feed the production system, whether in the state or in the rest of Brazil. The results for job creation for extractive Yerba Mate were 14.39 total jobs, of which 12.36 were direct, 1.26 in the state of Parana and 0.76 in the Rest of Brazil. The values obtained are lower than for cultivated Yerba Mate, as extractivism uses fewer inputs. The processing of yerba mate (Agro-industry) had 15.17 total jobs, with 4.09 direct, 6.21 indirect in Parana and 4.87 in the Rest of Brazil.

Table 1: Employment multiplier in the sectors of the yerba mate agro-industrial complex in the state of Parana, 2018. Jobs generated from the increase of one million reais in sectoral final demand.

Sectors	Effects				Spillover
	Direct Parana	Indirect Parana	Indirect Rest of Brazil	Total	
Cultivated yerba mate	14.83	1.38	1.38	17.58	8%
Extractive yerba mate	12.36	1.26	0.76	14.39	5%
Yerba mate agro-industry	4.09	6.21	4.87	15.17	32%
Average state economy	9.43	3.11	2.30	14.85	16%

It is important to note that the employment generation capacity values of the sectors of the yerba mate agro-industrial complex in total values are close to or above the economy average, which was 14.85. The spillover effect concerns the share of the inter-regional effect in relation to the total and shows the dependence on inputs from outside the region to feed the production system of the analysed sector. The average Spillover of sectors of the state economy, 16%, is greater than to produce yerba mate (cultivated or extractive), which varies from 5% to 8%. The 32% spillover from the yerba mate agro-industry is twice the average for the economy. The results show that around a third of the jobs generated by the industrialization of yerba mate appeared outside the state of Parana. Studies could be carried out to reduce this dependence, which is related to raw materials, energy, packaging, transport, financial services and other inputs from outside Parana to move the regional agro-industry.

The results for the production multiplier of the sectors of the yerba mate agro-industrial complex (Table 2) show that processing stands out for this indicator, despite the greater spillover effect. Agro-industry generated 2.29 million reais in the economy for a million reais increase in final demand, of which R$0.64

million outside Parana. The cultivated yerba mate sector generated R$ 1.56 million and the extractive yerba mate around R$ 1.25 million for the same variation in final demand, but with spillovers of less than 20% and 8%, respectively.

Table 2: Production multiplier of sectors of the yerba mate agro-industrial complex in the state of Parana, 2018. Values in millions of reais generated from the increase of one million reais in sectoral final demand.

Sectors	Effects				Spillover
	Direct Parana	Indirect Parana	Indirect Rest of Brazil	Total	
Cultivated yerba mate	1.00	0.25	0.31	1.56	20%
Extractive yerba mate	1.00	0.16	0.10	1.25	8%
Yerba mate agro-industry	1.00	0.66	0.64	2.29	28%
Average state economy	1.00	0.41	0.39	1.80	22%

The Gross Domestic Product (GDP) comprises remuneration for work, payment to capital and tax collection on production. The results of the GDP multiplier of the links of the yerba mate agro-industrial complex in Parana are in Table 3. The highest value obtained was for the extractive yerba mate sector with R$ 952 thousand for the increase of R$ 1 million of final demand, with a Spillover of 5%. Next, Yerba Mate cultivated with R$ 826 thousand (13% spillover) and processing (Agro-industry) with R$ 772 thousand (33% spillover). The production of yerba mate, whether extractive or cultivated, generated a higher GDP than the average for the state economy, with the advantage of less spillover. The smaller inter-regional effect and spillover of extractivism is explained by the smaller need for inputs to move the production process. The relatively high indirect effect of GDP generation in the yerba mate agro-industry sector shows the greater acquisition of inputs, including those from other regions. The results of the GDP multiplier show the economic sustainability of yerba mate production, especially extractive production.

Table 3: Income multiplier (Gross Domestic Product) of the sectors of the yerba mate agro-industrial complex in the state of Parana, 2018. Values in thousand reais generated from the increase of one million reais in sectoral final demand.

Sectors	Effects				Spillover
	Direct Parana	Indirect Parana	Indirect Rest of Brazil	Total	
Cultivated yerba mate	633	86	106	826	13%
Extractive yerba mate	835	72	44	952	5%
Yerba mate agro-industry	200	315	257	772	33%
Average state economy	463	189	155	808	19%

Table 4 contains the values of the tax multiplier for the sectors of the yerba mate agro-industrial complex in the state of Parana. The highlight for the generation of taxes is the processing (yerba mate agro-industry), because despite the spillover effect of 34%, the total value of R$ 88 thousand for the increase in final demand by R$ 1 million is greater than for the agricultural or extractive production (56 and 22 thousand reais, respectively) and the economy average (R$ 70 thousand). The regional effects (in Parana) of the generation of taxes show that processing is an important link for the indicator and that the increase in state processing capacity, with a decrease in the sending of raw materials to other regions of the country, could increase the tax generation.

Considering the spillover effect of the links in the yerba mate agro-industrial complex, the extractive yerba mate sector has a lower percentage value than the average for the economy and other links, but the total impact of R$ 21.92 thousand is relatively smaller. In this sense, cultivated Yerba Mate generates an advantage in relation to tax generation.

Table 4: Tax multiplier for sectors of the yerba mate agro-industrial complex in the state of Parana, 2018. Values in thousand reais generated from the increase of one million reais in sectoral final demand.

Sectors	Effects				Spillover
	Direct Parana	Indirect Parana	Indirect Rest of Brazil	Total	
Cultivated yerba mate	28.59	10.46	16.95	55.99	30%
Extractive yerba mate	12.18	5.32	4.42	21.92	20%
Yerba mate agro-industry	36.65	21.54	30.12	88.31	34%
Average state economy	36.96	14.27	19.20	70.43	27%

Table 5 shows the results for the generation of carbon dioxide for a variation of one million reais in the final sectoral demand of the sectors of the yerba mate agro-industrial complex. The total values are lower than the economy average (74 tons per year), with the extractive (native) yerba mate sector having a lower environmental impact according to the indicator (28 tons per year). Furthermore, it must be considered that extractivism seeks to conserve areas for economic use and that causes important social impacts. The largest direct impact occurs for cultivated Yerba Mate (34 tons) and the most important inter-regional impact occurs through processing (26 tons of CO_2 in the rest of Brazil). The estimated values show that the yerba mate agro-industrial complex is more environmentally sustainable than the average economy, with contributions in terms of job and income generation.

Table 5: Carbon dioxide multiplier due to the burning of fossil fuels in the sectors of the yerba mate agro-industrial complex in the state of Parana, 2018. Values in tons generated from the increase of one million reais in sectoral final demand.

Sectors	Effects				Spillover
	Direct Parana	Indirect Parana	Indirect Rest of Brazil	Total	
Cultivated yerba mate	34.32	11.19	14.46	59.97	24.11%
Extractive yerba mate	17.02	6.35	4.17	27.54	15.14%
Yerba mate agro-industry	10.20	22.98	26.15	59.32	44.08%
Average state economy	39.94	14.39	19.62	73.95	38.33%

Impacts on municipalities in the state of Parana of yerba mate production

Based on the results of the economic indicators that multiply Gross Domestic Product (GDP) and employment in the sectors of the yerba mate agro-industrial complex, it is possible to estimate the impacts (direct effect) in the municipalities of the state of Parana. Figure 5 presents two maps with the results of the Gross Domestic Product (Figure 5A) and the share of GDP generated by the production of yerba mate in the Agricultural GDP generated by the production of yerba mate (cultivated and extracted) in the Agricultural GDP of the Municipalities of the state of Parana (Figure 5B) in 2018. Absolute values refer to millions of reais of Gross Domestic Product and participation in percentage values.

Figure 5A shows that there were 6 municipalities with GDP generation from yerba mate production greater than R$ 18.5 million in 2018. Considering the relative impact of income generation from yerba mate, there were four municipalities for which around one third of the municipal Gross Domestic Product was represented by the production of cultivated and extractive yerba mate. The seven Municipalities with the greatest impact on income were Cruz Machado (R$ 59 million in income), São Mateus do Sul (R$ 57 million in income), Bituruna (R$ 32 million in income), General Carneiro (R$ 22 million in income), Paula Freitas (R$20 million), Inácio Martins (R$19 million in income) and Prudentópolis (R$14 million). The results show that around a third of the Agricultural Gross Domestic Product depends on the production of yerba mate, whether extractive or cultivated, in the localities of Cruz Machado (36%), Bituruna (35%) and Inácio Martins (33%). Other municipalities with important impacts were Porto Vitória (30%), General Carneiro (22%), São Mateus do Sul (21%) and União da Vitória (21%).

The results show that there are seven locations with at least 20% of the Agricultural GDP dependent on the production of yerba mate. If processing is carried out in the region, this implies that the generation of income and employment will have significant impacts and the agro-industrial complex will be one of the most important for the municipalities identified in the analysis.

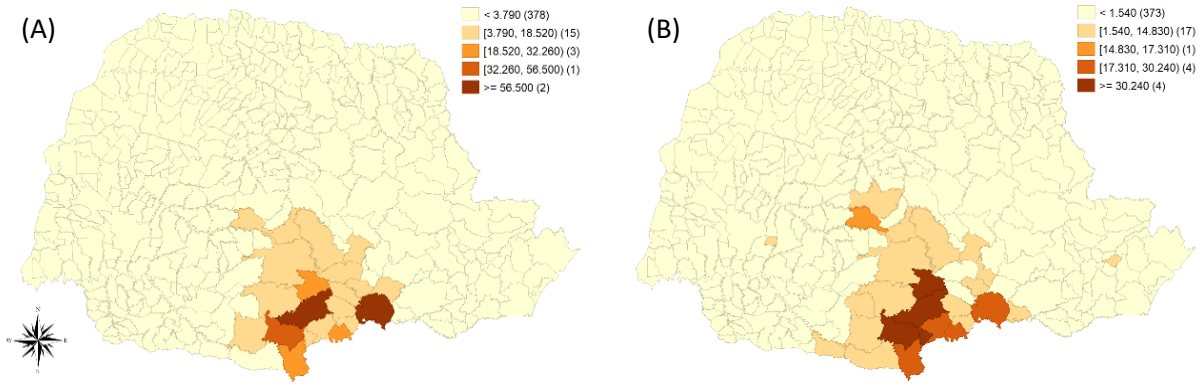

Figure 5: Direct impacts on the generation of Gross Domestic Product in municipalities in the state of Parana due to the production of yerba mate (cultivated and extracted) in absolute values in millions of reais (Figure A) and percentage participation in the Municipal Agricultural Gross Domestic Product (Figure B), 2018.
Source: research results.

Figure 6 shows the impacts of job creation through yerba mate production and participation in relation to the total population in municipalities in the state of Parana in 2018. The maps and tables can be analysed together. The seven locations with the greatest impact are Cruz Machado (992 jobs), São Mateus do Sul (956 jobs), Bituruna (539 jobs), General Carneiro (297 jobs), Paula Freitas (312 jobs), Inácio Martins (232 jobs) and Prudentópolis (255 jobs).

The main social contribution of the yerba mate agro-industrial complex is the generation of local jobs, as cultivated and extractive production is based on family farming. Therefore, the emergence of new rural jobs helps to keep the population in the countryside while encouraging the preservation of native forests.

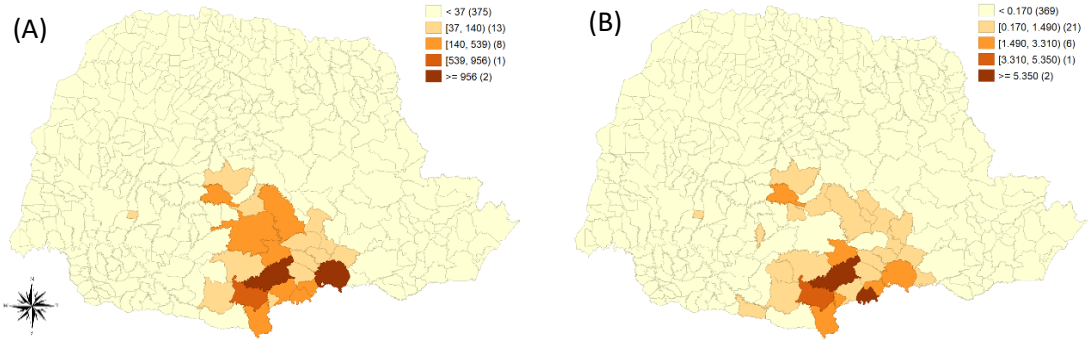

Figure 6: Direct impacts on the generation of jobs in municipalities in the state of Parana due to the production of yerba mate (cultivated and extractive) in absolute values in jobs (Figure A) and percentage share in the total inhabitants of the municipality (Figure B), 2018.
Source: research results.

In relation to the generation of direct jobs in the field for the production of yerba mate, the participation values (%) of these jobs in the total municipal population are in Figure 6B. Greater relative importance is noted in the municipalities of Paula Freitas 5.41%), Cruz Machado (5.35%), Bituruna (3.31%), Porto Vitória (2.69%), General Carneiro (2.13%), São Mateus do Sul (2.10 %) and Inácio Martins (2.10%). It is important to note that the higher values of income generation and employment in yerba mate production in municipalities do not coincide with the ranking of relative importance (percentage share) of variables in municipal economies. Therefore, encouraging yerba mate cultivation, whether in field production or local industrialization, will have different impacts on municipalities and will be relatively greater where participation in the economy is more important.

Figure 7 illustrates, respectively, the values of Tax on the Circulation of Ecological Goods and Services (Ecological ICMS) received by municipalities in the State of Parana (reserve area and water sources) in Figure 7A in millions of reais annually and the share participation of the total ICMS values received by the locations in percentage terms in Figure 7B.

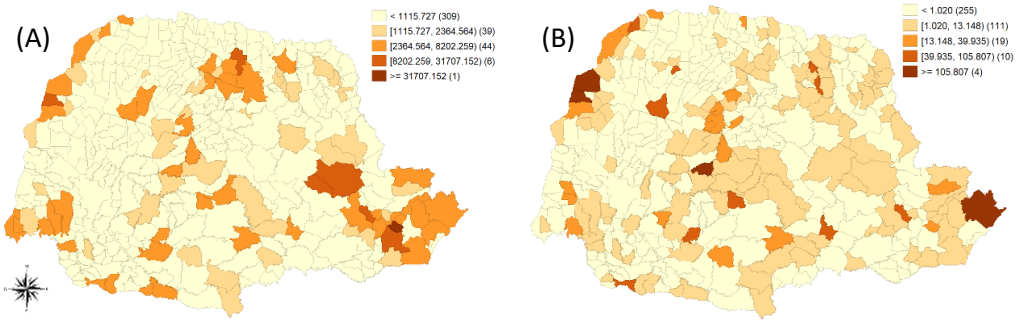

Figure 7: Value of Ecological ICMS received by municipalities in the State of Parana (A)
Source: research results.

In Figure 7A, it is noted that the values of the tax benefit for forest preservation represented values between less than one million reais for 309 municipalities. However, for seven municipalities the values were higher than 8.2 million reais. Considering that most municipalities are relatively small in economic terms, the relative impact of Ecological ICMS receipts must be assessed, therefore, Figure 8B shows the percentage values relative to the total ICMS. Preservation tax incentives represented doubling the value of taxes received from the state for four municipalities, according to Figure 7B. The results show that the transfer of the Ecological ICMS is important for relatively small municipalities in the state economy, however, it represents insignificant percentage values for the largest municipal economies.

IV. Discussion

The research results showed that from the sustainability point of view, the yerba mate agro-industrial complex present-ed a production multiplier for the Agro-industry that was greater than the average for the economy, the income multi-plier for extractive yerba mate was greater than the average for all sectors and the job creation capacity (job multiplier) of the complex's links are close to or above average. Considering carbon dioxide emissions, the extractive yerba mate pro-duction system is the best option to meet new environmental requirements and leverage new markets whose consumers are environmentally conscious. The indicators showed the economic, social and environmental sustainability of the yerba mate agro-industrial complex, mainly based on extractive raw materials.

The impact on production, employment, income, taxes and carbon dioxide emissions is different depending on the economic agents involved in the agro-industrial complex, such as producers, grass growers and governments (municipal and state). Furthermore, the sustainable production of extractive yerba mate has impacts on society with positive externalities on the environment. Increasing yerba mate productivity at the producer level with the adoption of new technologies involves access to technical assistance. The predominance of family farming with traditional cultivation methods is a characteristic of yerba mate production. Units with greater productivity can acquire new techniques with improved varieties, pest control and new methods[21].

The development of the yerba mate agro-industrial complex includes obtaining better prices for producers and opening new markets. Producer prices present greater volatility, which contributes to the instability of their income[22]. Price formation shows that downward variations impact the industry less than the producer. The industrial process, which includes sapeco, drying and crushing of yerba mate, presents the highest trade margin values. The industry's strategy is to cover the entire transformation process with vertical integration until it has its own herbs, with guaranteed quality and quantity of raw materials[23].

As verified in the results of the present study, extractive yerba mate is of organic origin, without the use of pesticides or other chemical inputs. For the producer, product differentiation is an alternative to guaranteeing better prices. However, producers are unaware of the certification processes because there is a lack of information and external support, however, they want to adapt their properties to possible economic and environmental gains[24]. There is a need to develop marketing actions to inform the strong ecological characteristics present in the product, little noticed by consumers. Therefore, the different certifications, especially organic production, are little known in the agro-industrial complex while internal consumers are not aware of the sustainable process of the yerba mate agro-industrial complex[25].

For the yerba mate agro-industrial complex to benefit from greater sustainability, mainly with extractive yerba mate as demonstrated in the present study, the traceability process must be implemented so that the consumer can be sure of the origin and transit of the product. Certification can be a part of this process. This will lead to better prices for the product and raw materials and the opening of new markets.

Because of the better quality and sustainability of extractive yerba mate, there is a price premium for yerba mate produced in the shade compared to cultivated, however, this difference is decreasing over time. Furthermore, the possibility of certifying the raw material can be a strategy for obtaining a higher sales price,

however, the process is relatively ex-pensive for small producers. Producer prices present greater volatility, which contributes to income instability[22]. Price formation shows that downward price variations impact the industry less than the producer[23].

Herb producers seek to acquire raw materials in the quantity and quality necessary for the good development of the business, opening new markets, especially exports and certification. The results of actions to achieve industry objectives imply obtaining higher product quality, increased sales and customer trust in its quality. The greater need for raw mate-rials for export can boost producer prices, in addition to generating employment, income and taxes throughout the agro-industrial complex.

Society benefits from maintaining the forest in the shaded production of yerba mate, which is capable of mitigating car-bon dioxide emissions. The planting of new Araucaria plants and other plant species that contribute to the sustainable production of yerba mate. Mate presents characteristics of sustainability and healthy appeal that are still little explored among consumers. Corporate socio-environmental responsibility is a recurring theme and used as a green institutional marketing strategy to boost sales. The use of green marketing would be a powerful tool to raise awareness among consumers and identify challenges within the agro-industrial complex, which could not go unnoticed[26]. The social im-pacts resulting from stimulating final demand for healthy product characteristics and sustainable production are the improvement of the population's health and environmental awareness.

Certification is a part of a product's traceability system, as a traceability system makes it possible to identify problems in the production process, control risks, improve and guarantee product quality, comply with marketing requirements and know all stages of production to ensure transparency. The author states that in the yerba mate production chain there is no homogeneity in the product standard, which makes the necessary expansion of the consumer market difficult[27].

V. Conclusion

The methodology proved to be suitable for analyzing the proposed problem of measuring the economic, social and environmental sustainability of the yerba mate production chain in its largest producer in the world, the state of Parana, in Brazil. The results showed that the input-output tool made it possible to estimate several indicators to com-pare different production systems and local impacts (state and municipal), which constitutes an important methodological and empirical contribution in assessing the sustainability of production chains.

The results of the indicators based on the input-output matrix of the sectors of the yerba mate agro-industrial complex in the state of Parana showed that the links present different characteristics and economic, social and environmental impacts. Compared to the average values of the state economy, the yerba mate agro-industrial complex is considered more sustainable, as it presented lower relative values of carbon dioxide emissions due to the burning of fossil fuels in all links, greater generation of jobs in production cultivated, greater income generation from extractive yerba mate and greater generation of total taxes from Agro-industry, in addition to contributing to increased production and preservation of the mixed rainforest.

The sustainable production of yerba mate through the extractive system was proven by the analysis of economic, social and environmental indicators based on the input-output matrix. To explore the marketing benefits arising from production sustainability, it is necessary to implement a traceability system, as currently raw materials of different origins and types are processed together without identification.

The traceability and expansion of the consumer market will make it possible to increase producer prices and generate jobs and income in municipalities in the state of Parana where the extractive system is important. The agro-industry will benefit from market expansion, especially exports to countries where consumers are more demanding in quality and sustainability. Local governments will receive the tax benefits arising from the preservation of the native forest. For consumers, there will be access to a natural, high-quality product with beneficial health properties.

New studies can be developed to overcome the challenges for producers and the herb industry to obtain organic certification and others necessary to reach more demanding markets from an environmental point of view and to increase links with importing countries.

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References

[1]. Godoy, R.C.B.; Deliza, R.; Gheno, L.B.; Licodiedoff, S.C.; Frizon, N.T.; Ribani, R.H.; Santos, G.G. Consumer Perceptions, Attitudes And Acceptance Of New And Traditional Mate Tea Products, Food Research International 2013, 53, 801-807. Https://Doi.Org/10.1016/J.Foodres.2013.02.054.

[2]. Heck, C.I.; Mejia, E.G. Yerba Mate Tea (Ilex Paraguariensis): A Comprehensive Review On Chemistry, Health Implications, And Technological Considerations. Journal Of Food Science 2007, 72, 138-151. Https://Doi.Org/10.1111/J.1750-3841.2007.00535.X

[3]. Gawron-Gzella, A.; Chanaj-Kaczmarek, J.; Cielecka-Piontek, J. Yerba Mate-A Long But Current History. Nutrients 2021, 13, P.3706. Doi: 10.3390/Nu13113706.

[4]. Gómez-Juaristi, M.; Martínez-Lópes, S.; Sarria, B.; Bravo, L.; Mateos, R. Absorption And Metabolism Of Yerba Mate Phenolic Compounds In Humans. Food Chemistry 2018, V. 240, P.1028- 1038. Https://Doi.Org/10.1016/J.Foodchem.2017.08.003

[5]. Mateos, R.; Baeza, G.; Sarriá, B.; Bravo, L. Improved Lcmsn Characterization Of Hydroxycinnamic Acid Derivatives And Flavonols In Different Commercial Mate (Ilex Paraguariensis) Brands. Quantification Of Polyphenols, Methylxanthines, And Antioxidant Activity. Food Chemistry 2018, V. 241, P.232-241. Https://Doi.Org/10.1016/J.Foodchem.2017.08.085

[6]. Riachi, L.G.; Simas, D.L.R.; Coelho, G.C.; Marcellini, P.S.; Ribeiro Da Silva, A.J.; Bastos De Maria, C.A. Effect Of Light Intensity And Processing Conditions On Bioactive Compounds In Maté Extracted From Yerba Mate (Ilex Paraguariensis A. St.-Hil.). Food Chemistry 2018, V. 266, P.317-322. Https://Doi.Org/10.1016/J.Foodchem.2018.06.028

[7]. Croge, C.P.; Cuquel, F.L.; Pintro, P.T.M. Yerba Mate: Cultivation Systems, Processing And Chemical Composition. A Review. Scientia Agricola 2021, V. 78(5), P.1-11. Https://Doi.Org/10.1590/1678-992x-2019-0259

[8]. Marques, A.C.; Denardin, V.F.; Reis, M.S.; Wisniewski, C. As Paisagens Do Mate No Planalto Norte Do Estado De Santa Catarina, Brasil. In: Dallabrida, V.R., Ed. Desenvolvimento Territorial: Políticas Públicas Brasileiras, Experiências Internacionais E Indicação Geográfica Como Referência. Liberars: São Paulo, Sp, Brazil (In Portuguese), 2014; 33-46.

[9]. Pires, D.A.C.K.; Pedrassani, D.; Dallabrida, V.R.; Benedetti, E.L. The Yerba Mate In The North Of Santa Catarina State: The Bioactive Compounds In Mate In The Region As Variable In Determining The Specifics Required For Recognition As A Geographical Indication. Desenvolvimento Regional Em Debate 2016, 6, 207-227 (In Portuguese, With Abstract In English). Https://Doi.Org/10.24302/Drd.V6i2.1212

[10]. Teixeira, A.M. Análise Da Indústria Ervateira Da Região Sudoeste Do Paraná, Por Meio Dos Arranjos Produtivos Locais. Dissertação (Mestrado). Pontifícia Universidade Católica De São Paulo, São Paulo, Brasil, 2006. 118p. Available Online: Https://Repositorio.Pucsp.Br/Jspui/Handle/Handle/1195 (Accessed On 21 February 2023)

[11]. Matieski, T.; Oldoni, H.; Luz, M. L. G. S; Luz, C. A. S.; Gadotti, G. I.; Gomes, M. C. Análise Técnica E Estudo De Viabilidade Econômica De Uma Agroindústria De Processamento De Erva Mate No Município De Casca - Rs. Agropecuária Técnica (Ufpb) 2015, 35, 18-23. Https://Doi.Org/10.25066/Agrotec.V36i1.21538

[12]. Ipardes. Instituto Paranaense De Desenvolvimento Econômico E Social. Bases De Dados Do Estado. 2023. Available Online: Http://Www.Ipardes.Gov.Br/. (Accessed On 17 January 2023)

[13]. Leontief, W. A Economia Do Insumo-Produto, 3rd Ed., Nova Cultural, São Paulo, 1988.

[14]. Miller, R. E.; Blair, P. D. Input-Output Analysis: Foundations And Extensions; Cambridge University Press, 2009. 750p.

[15]. Isard, W. Inter-Regional And Regional Input-Output Analysis: A Model Of A Space-Economy. Review Of Economics And Statistics 1951, 33, 318-328. Https://Doi.Org/10.2307/1926459

[16]. Guilhoto, J. J. M. Análise De Insumo-Produto: Teoria E Fundamentos. Unpublished, Mpra_Paper_32566, 2011. Available Online: Http://Mpra.Ub.Uni-Muenchen.De/32566/2/Mpra_Paper_32566.Pdf. (Accessed On 12 March 2023)

[17]. Guilhoto J.J.M.; Sesso Filho U.A. Estimação Da Matriz Insumo-Produto A Partir De Dados Preliminares Das Contas Nacionais. Economia Aplicada 2005, 9, 277-299. Available Online: Http://Www.Usp.Br/Nereus/Wp-Content/Uploads/Metodologia-Guilhoto-Sesso-Ea-2005.Pdf (Accessed On 12 March 2023)

[18]. Guilhoto, J.J.M.; Sesso Filho U.A. Estimação Da Matriz Insumo-Produto Utilizando Dados Preliminares Das Contas Nacionais: Aplicação E Análise De Indicadores Econômicos Para O Brasil Em 2005. Economia & Tecnologia 2010, 6, 53-62. Http://Dx.Doi.Org/10.5380/Ret.V6i4.26912

[19]. Guilhoto J.J.M.; Azzoni, C.R.; Ichihara S.M.; Kadota, D.K.; Haddad, E.A. Matriz De Insumo-Produto Do Nordeste E Estados: Metodologia E Resultados. Banco Do Nordeste Do Brasil, Brasil, 2010. 289p. Available Online: Https://Papers.Ssrn.Com/Sol3/Papers.Cfm?Abstract_Id=1853629 (Accessed On 12 March 2023)

[20]. Conab. Companhia Nacional De Abastecimento. Available Online: Https://Www.Conab.Gov.Br/ (Accessed On 12 March 2023)

[21]. Goulart, Y.C.G.R. Fatores Que Afetam A Produtividade E Adoção De Tecnologias Na Cultura Da Erva Mate. Tese (Doutorado). Programa De Pós-Graduação Em Agronomia, Área De Concentração Em Produção Vegetal, Departamento De Fitotecnia E Fitossanidade, Setor De Ciências Agrárias, Universidade Federal Do Paraná. Ufpr, 2020. 107p. Available Online: Https://Acervodigital.Ufpr.Br/Handle/1884/70472?Show=Full (Accessed On 12 March 2023)

[22]. Conto, A.J.; Hoeflich V. A Formação Dos Preços No Sistema Produtivo Da Erva Mate No Estado Do Paraná. In: Congresso Sul-Americano Da Erva Mate, 1.; Reunião Técnica Do Cone Sul Sobre A Cultura Da Erva Mate, 2., 1997, Curitiba. Anais. Colombo: Embrapa-Cnpf, 1997. P. 404. Available Online: Https://Www.Alice.Cnptia.Embrapa.Br/Alice/Bitstream/Doc/299417/1/Formacaoprecos0001.Pdf (Accessed On 08 December 2022)

[23]. Balcewicz L.; Hoeflich, V. A Concentração Do Mercado Do Mate No Paraná E Misiones E Seus Efeitos Sobre A Evolução Dos Preços. In: Congresso Sul-Americano Da Erva Mate, 2.; Reunião Técnica Da Erva Mate, 3., 2000, Encantado. Anais. Porto Alegre: Comissão Dos Organizadores/Universidade Do Rio Grande Do Sul/Fundação Estadual De Pesquisa Agropecuária, 2000. P. 203-206. Available Online: Https://Www.Embrapa.Br/En/Busca-De-Publicacoes/-/Publicacao/301937/A-Concentracao-Do-Mercado-Do Mate-No-Parana-E-Misiones-E-Seus-Efeitos-Sobre-A-Evolucao-Dos-Precos (Accessed On 19 April 2023)

[24]. Kormann, M.C. Sustentabilidade Na Produção De Erva Mate E Os Sistemas De Certificação: Um Estudo Da Região De São Mateus Do Sul - Pr. Orientador: Carlos Alberto Cioce Sampaio, Coorientadora: Roberta Giraldi. 2019. 98 F. Dissertação (Mestrado Em Gestão Ambiental) - Universidade Positivo, Curitiba, 2019. Available Online: Https://Repositorio.Cruzeirodosul.Edu.Br/Jspui/Handle/123456789/1849 (Accessed On 02 March 2023)

[25]. Seramim, R. J.; Brandalise, L.T. A Percepção Ambiental Do Consumidor Considerando A Acv E Um Produto Da Indústria Da Erva Mate. Revista De Gestão Social E Ambiental 2016, São Paulo (Sp), 10, 19-36. Doi: 10.24857/Rgsa.V10i2.1127

[26]. Chandrashekhar, R. An Assignment On Green Marketing, Department Of Business & Industrial Management Veer Narmad South Gujarat University, 11 Section B, 2008.

[27]. Schuchmann, C.E.Z. Ações Para A Formulação De Um Protocolo De Rastreabilidade De Erva Mate. Dissertação (Mestrado). Universidade Federal Do Rio Grande Do Sul, 2002. 94p. Available Online: Http://Hdl.Handle.Net/10183/5298. (Accessed On 23 March 2023)