Iosr Journal Of Agriculture And Veterinary Science (Iosr-Javs)
E-Issn: 2319-2380, P-Issn: 2319-2372. Volume 17, Issue 12 Ser. 1 (December. 2024), Pp 47-54
Www.Iosrjournals.Org

Economic, Social And Environmental Indicators Of Medicinal, Aromatic And Condimental Crops In Brazil

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Abstract:
Medicinal, aromatic and spice crops play a fundamental role in communities' economic, social, cultural, and ecological spheres. Currently, the most important uses are in the pharmaceutical, perfume, cosmetics, toothpaste, soap, beverage, and food industries. This study aims to estimate the economic, social, and environmental impacts of Brazil's medicinal, aromatic, and spice crops production sector. Specifically, it intends to calculate indicators based on the input-output matrix of the research's focus sector and other agricultural sectors for comparative analysis regarding job creation, income, taxes, carbon dioxide, blue water consumption, and its intersectoral linkage indexes. The increase of one million dollars in final demand in the Medicinal, Aromatic, and Spice Crops sector generates around 1.15 million dollars in production, 920,000 dollars in income and 16.85 job positions, showing economic and social importance with the greatest direct effect on production in the countryside (over 80%). From an environmental point of view, the same amount of final demand generates 5.5 kt of CO2eq and consumes 447,000 cubic meters, relatively high values compared to the other agricultural sectors listed in the study. Therefore, the sector presents challenges in developing sustainable techniques to reduce blue water consumption and carbon dioxide emissions. Moreover, the intersectoral linkage indexes indicate the low use of inputs and the use of the sector's products as raw materials by other industrial sectors capable of earning value to the production chain. Developing the medicinal, aromatic, and spice crops sector requires new production techniques to increase productivity sustainably, and investment policies are needed. The trend towards consuming natural and healthy products encourages using raw materials in industrial processes, earning value for the production chain.
***Key Word**: Sustainability; Agribusiness; Input-output; Production chain.*

Date of Submission: 15-12-2024 Date of Acceptance: 25-12-2024

I. Introduction

Medicinal, aromatic, and spice crops play a fundamental role in local communities' economic, social, cultural, and ecological spheres worldwide. Currently, the most important uses are in the pharmaceutical, perfume, cosmetics, toothpaste, soap, beverage, and food industries (Pergola et al., 2024). Most pharmaceutical companies have started registering patents on medicinal plants and their derivatives, as around 40% of newly approved medicines over the last two decades are formulated from natural sources. Various socio-economic factors influence the importance of these crops, both locally and internationally. The world trade in botanical products is $32.702 billion, and the Asian market is $14.505 billion with around 6.634 million tons, corresponding to a value between 44.35% and 53.13% of the world trade in terms of value and volume, respectively. China leads the market with a 1.48% share of world exports, and India is the second largest exporter with an 8.75% share of Asian trade. Despite the enormous economic potential, there are challenges to the production chain development, such as the difficulty of adapting crops to different regions, low prices, unavailability of intermediate markets, underdeveloped cultivation technology and low availability of cultivation resources and genetic materials (Riaz et al., 2021; Kazem, 2024).

Production can encompass different parts of the plants, and the harvesting process must be carried out according to phenology and use, observing the sanitary care required to obtain quality. Processing (drying, milling, preparing extracts, and obtaining essential oils) is usually carried out close to the production site due to the perishability of the raw material. After harvesting, the plants can be sold fresh, i.e. without going through industrial processes. However, the different parts of the plant (flowers, stems, leaves, or roots) usually undergo post-harvest care, storage and drying before reaching the consumer. Plant parts are transformed into different products in more complex industrial processes, preserving compounds of interest, such as dried extracts or fluids used to manufacture medicines, food supplements, and other products. Through distillation or pressing processes, essential oils are extracted from plants, which involves the extraction of volatile compounds used in cosmetics, perfumery, and aromatherapy. To achieve this, the plants must have a high content of essential oils, which depends on specific agricultural practices, such as harvesting at the right time and using appropriate extraction techniques. The purity and concentration of the oils are critical factors for the quality of the product, and storage must occur under conditions that prevent the degradation of the volatile compounds. Absolute is a concentrated form of plant extract obtained through methods such as solvent extraction. It is mainly used in perfumery and the manufacture of luxury products (Corrêa and Scheffer, 2014; Carvalho, 2015; Haber and Clemente, 2013; Fronza et al., 2021; González-Minero et al., 2023).

Initial research on the subject dates to the 50s, and the geographical focus of the literature is on India, followed by China. Studies are more numerous on agronomic aspects, cultivation techniques, characterization, and germination, but the most quoted articles address health and its essential oils' beneficial properties. Regarding the socio-economic weight of the research conducted on these crops, they represent only 1% of the total academic publications, but the results show that they are important income sources for several local communities. There is a need to increase the estimation of ecosystem services in the production chain and the environmental impact assessment of the entire supply chain (Pergola et al., 2024).

In Brazil, medicinal, aromatic, and spice crops play an important role in the economy, society, and the environment. Cultivating these plants offers different benefits beyond their commercial value, encompassing health, cultural tradition and environmental sustainability. From an economic point of view, it represents a significant source of income for thousands of rural producers. The market for these products is vast, and the growing demand for natural and organic products has driven this sector's growth, creating business opportunities and jobs, especially in countryside areas. Furthermore, Brazil has great biodiversity and the potential to become a world leader in producing and exporting these products, contributing to the country's trade balance (Corrêa and Scheffer, 2014; Haber and Clemente, 2013).

On a social level, the production of these plants is closely related to the traditions and cultures of various communities, especially indigenous communities. These communities have ancestral knowledge about the use and sustainable management of medicinal and aromatic plants, knowledge that can be preserved and valued through formal production. Furthermore, the cultivation of medicinal plants can provide economic autonomy for these communities, helping to reduce poverty and improve quality of life. The widespread use of these plants can also promote public health by offering natural and accessible alternatives for treating various diseases. The environmental benefits result from organic production and the possibility of these plants being grown in agroforestry systems, which promote biodiversity conservation, improve soil quality, and protect water resources. Moreover, the cultivation of native plants helps to preserve endangered species and restore degraded ecosystems. The use of sustainable agricultural practices reduces the need for chemical inputs, contributing to the health of the environment and the people who live and work in these areas (Corrêa and Scheffer, 2014; Carvalho, 2015; Haber and Clemente, 2013; Fronza et al., 2021).

Considering the market potential and impacts on society, this study aims to estimate the economic, social, and environmental impacts of Brazil's medicinal, aromatic, and spice crops production sector. Specifically, it intends to calculate indicators based on the input-output matrix of the study's focus and other agricultural sectors for a comparative analysis of job creation, income, taxes, carbon dioxide, blue water consumption, and intersectoral linkage indexes. The study results are a set of information and empirically estimated data that can be used to formulate public policies to encourage the production of medicinal, aromatic, and spice crops and direct public and private investment in the production, processing, and marketing of products from the sector.

II. Material And Methods

The input-output matrix is an analytical tool used to understand the interrelationships between different sectors of an economy. It describes how a sector's output depends on the inputs provided by other sectors and how their products are distributed within the economic system. The matrix is organized in a table, where each row and column represent economic sectors. The rows show the inputs each sector receives, and the columns indicate the outputs each sector supplies to other sectors or final consumption. The components of the matrix are the productive sectors belonging to the macro sectors of agriculture, industry and services, and final demand, which comprise government, households, exports and investment expenditures.

The use of the input-output tool covers economic, social, and environmental analysis. It allows analysis of how shocks in one sector can affect other sectors and the economy, facilitating the formulation of economic policies. The impacts are estimated for variables such as production, employment, income, wages, taxes, carbon dioxide emissions, and water consumption. In terms of planning, it can help governments make decisions about investments, incentives, and development policies by better understanding economic dependencies. It helps identify key economic development sectors, guide investments, support policies, and assess sustainability and environmental impacts, as they can be used to calculate the ecological footprint of different sectors, helping to identify more sustainable practices.

Therefore, the input-output matrix was used to estimate the variable's simple multiplier (or generator) based on Miller and Blair (2009). To begin the calculations to obtain the inverse Leontief matrix, we must estimate A, known as the technical coefficients' matrix.

The element Z_{nxn} (intermediate consumption with n sectors) is the matrix of monetary flows from sector i (row) to sector j (column), X_n is the vector of sectoral production, and its values are used to estimate $(\hat{X})^{-1}$ (diagonalised inverse matrix), which has the inverse sectoral production values $\left(\frac{1}{x_i}\right)$ on the main diagonal and the rest of the zeros. Anxn is the matrix of technical coefficients that can be calculated by:

$$A = Z(\hat{X})^{-1} \tag{1}$$

The input-output system can be expressed as follows:

$$(I - A)X = Y \tag{2}$$

Equation (2) uses Y, which is sectoral final demand, I is the identity matrix, which has the values one on the main diagonal and the rest of the zeros, and the other elements have been defined previously. The elements of Equation (2) can be rearranged as follows:

$$X = (I - A)^{-1}Y \tag{3}$$

The Leontief inverse matrix is given by:

$$L = (I - A)^{-1} \tag{4}$$

The elements of the L matrix (Leontief matrix) and its elements are l_{ij}.

The production multiplier, which indicates how much is produced for each monetary unit spent on final consumption, is defined as:

$$MP_j = \sum_{i=1}^{n} l_{ij} \tag{5}$$

Equation (5) uses MP_j which is the production multiplier of the j^{th} sector and the other variables are defined as above.

From the direct coefficients and the inverse Leontief matrix, it is possible to estimate for each sector of the economy how much water is generated directly and indirectly for each monetary unit produced for final demand (Miller and Blair, 2009). The simple multiplier of the variable of interest for Brazil's sectors is calculated by:

$$M_j = \sum_{i=1}^{n} l_{ij} v_i \tag{6}$$

The direct coefficients of the variable are estimated by:

$$v_i = \frac{V_i}{x_i} \tag{7}$$

Equation (6) uses M_j which is the simple multiplier of the variable that shows the total impact, direct and indirect, on the variable of each j sector; l_{ij} is the ij^{th} element of the Leontief inverse matrix, and v_i is the direct coefficient of variable V. It is noteworthy that the estimated indirect effect occurs within the analysis region (intra-regional effect) and other regions (inter-regional effect). In Equation (7), v_i is the direct coefficient for the i sector variable, V_i is the value assigned to each i sector, and x_i is the value for sectoral production.

Using Leontief's inverse matrix and following Rasmussen (1956) and Hirschman (1958), it is possible to estimate backward linkage indexes, which measure the demand for inputs, and forward linkage indexes, which estimate the demand for the sector's products as raw materials by other economic activities. Thus, defining l_{ij} as an element of the inverse Leontief matrix L, L^* as the average of all the elements of L; and L_{*j}, L_{i*} as the sum of a typical column and row of H, respectively, then the indexes would be as follows:

Backward linkage indexes (power of dispersion):

$$U_j = \left[L_{*j}/n\right]/L^* \tag{8}$$

Forward linkage indexes (dispersion sensitivity):

$$U_i = [L_{i*}/n]L^* \tag{9}$$

Values greater than 1 for the above indexes relate to above-average sectors and key economic growth sectors.

The database used was Gloria (2024), which provides Brazil's input-output matrix with 120 sectors and economic, social, and environmental satellite accounts with data on Earned Value, Production, employment, blue water consumption and greenhouse gas emissions. For more information on the database used in this work, see Lenzen et al. (2017) and Lenzen et al. (2022).

III. Results And Discussion

Figure 1 shows Brazil's agricultural sector participation in the production value in 2020. It can be noted that the largest sector was Leguminous crops and oilseeds, with 25.9% of the total. This sector includes soy production, the main export item, along with its by-products (oil and bran), and beans, one of the main products in the Brazilian diet. Next in the ranking are 'Other cereals' (14.6%), 'Vegetables, roots and tubers' (13.5%), 'Sugar cane' (9.7%), and 'Maize' (8.9%).

The Medicinal, aromatic and spice crops sector accounts for 0.7% of the total production. Despite the low relative value, there is potential to increase the production, industrialization and export of these products at a national level, considering the large participation of family farming, which provides around 70% of the food consumed in the country and which is the basis of production in several countries, as was verified in the literature review. Developing the production chain by expanding the use of medicinal, aromatic and spice crops in the food, pharmaceutical, hygiene and cleaning industries and other possibilities could increase intermediate consumption (inputs), stimulating production in the countryside and generating effects on employment, income, production, and taxes.

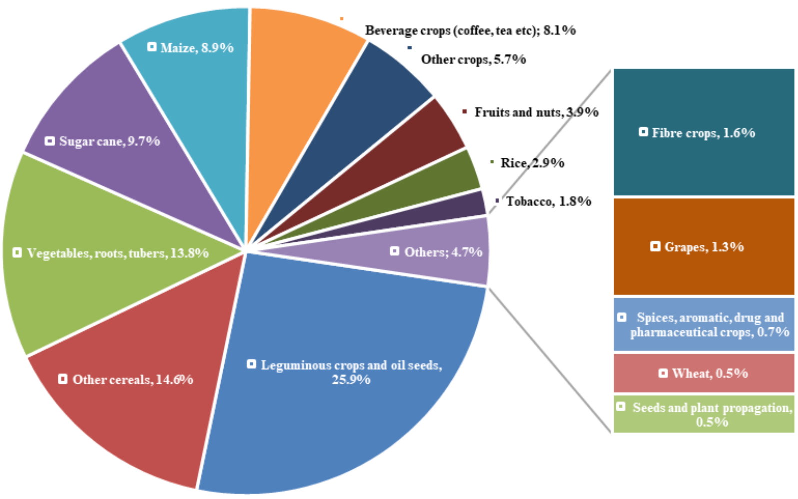

Figure 1: Share of Brazil's agricultural sectors in production value, 2020

The medicinal, aromatic, and spice crops sector plays an important role in the economy, society, and the environment. Figure 2 illustrates the main data on the sector, with a production value of US$ 678 million and a US$ 576 million income in 2020, this sector contributes significantly to the economy. It generates job positions for approximately 51,000 people, showing its relevance in the labor market. The social importance of the sector lies in the creation of direct and indirect job positions, benefiting local communities and improving the quality of life for those involved in the production and distribution of these plants. The sector's blue water consumption was 303 million cubic meters in 2020, indicating the need for sustainable agricultural practices to ensure the availability of water resources. Emissions were 3,706 kt of CO_2, which makes it essential to adopt agricultural practices that minimize the carbon footprint, such as using more efficient cultivation techniques.

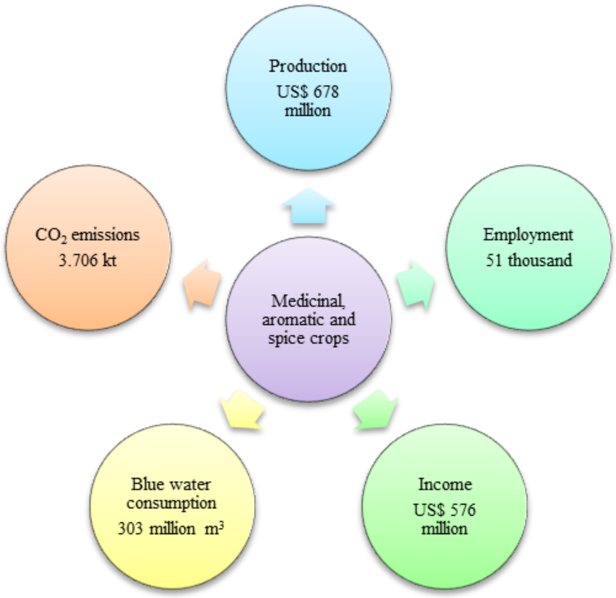

Figure 2: Basic data on Brazil's medicinal, aromatic, and spice crops sector, 2020.

Table 1 shows the results of the economic, social, and environmental indicators estimates based on the input-output matrix of Brazil's medicinal, aromatic, and spice crops sector in 2020. These data refer to the direct and indirect effects generated by a US$1 million increase in final demand in the sector. Figure 3 illustrates the share of direct effects (on the sector) and indirect effects (inputs). Considering the economic impacts, the total production multiplier effect of 1.15 indicates that for every US$ 1 million increase in sectoral final demand, total production increases by US$ 1.15 million. This shows that the sector can generate considerable additional value in the economy. The income multiplier effect showed a total value of 0.92, meaning that for every US$ 1 million increase in demand, the income generated is US$ 920 thousand. This indicator suggests that the sector contributes significantly to income generation, benefiting the production workers. Both multipliers had a greater direct effect (over 80%), as shown in Figure 3, so most of the impact shall occur in the sector (production in the countryside), contributing to rural development.

The intersectoral backward linkage index is 0.58, indicating that the medicinal, aromatic, and spice crops sector has a low demand for inputs from other sectors in its production chain, as the average for all sectors is equal to one. The Rasmussen-Hirschman (RH) forward linkage index is 0.51, suggesting that the sector's output is used as an input at a low intensity, as the economy's average is one. The values of the intersectoral linkages indexes show potential for the sector's products to be used as raw materials for the sectors listed in the literature review, the food industry, pharmaceuticals and cosmetics, hygiene, and cleaning. The employment multiplier estimates the sector's social impact on the Brazilian economy. With a total multiplier effect of 16.85, an increase in the sector's final demand of US$1 million would generate 16.85 jobs. This is an important indicator, as it demonstrates the sector's potential to create jobs, helping to reduce unemployment and improve living conditions. Figure 3 shows that most of these jobs arise in the countryside through the direct effect (over 80%), which is important for job position creation in rural areas.

Table 1: Economic, social and environmental indicators based on the input-output matrix of Brazil's Medicinal, aromatic, and spice crops sector, 2020. Values generated by an increase in final sectoral demand of US$ 1 million.

Multipliers	**Effect**		
	direct	**indirect**	**Total**
Production[1]	1.00	0.15	1.15
Employment[2]	14.33	2.52	16.85
Income[1]	0.85	0.07	0.92
Greenhouse gases[3]	5.46	0.04	5.50
Blue Water[4]	446.94	0.26	447.2
Intersectoral linkage indexes[5]			
RH index backwards	-	-	0.58
RH index forward	-	-	0.51

[1] Amount in millions of dollars, [2] Number of job positions, [3] Kilotons (kt), [4] Thousands of m^3, [5] Index with an average of one (120 sectors).

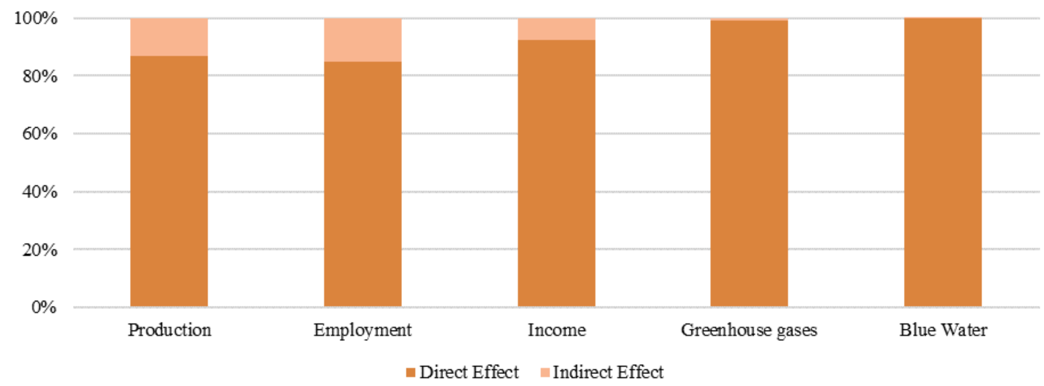

Figure 3: Share of direct and indirect effects on the value of multipliers in the Medicinal, aromatic, and spice crops sector, 2020.

Regarding environmental indicators, greenhouse gas emissions, and demand for blue water, greenhouse gas emissions have a total multiplier effect of 5.50 kilotons (kt) for every US$1 million increase in demand. Although the sector contributes to generating income and employment, it is necessary to adopt sustainable practices to minimize its environmental impact. The demand for blue water has a total multiplier effect of 447.2 thousand cubic meters (m^3) for every US$ 1 million increase in demand. This high-water consumption indicates the need for efficient policies and practices in the use of water resources, especially in the countryside, as Figure 3 shows that almost all blue water consumption and greenhouse gas emissions occur in this sector.

The results show that the medicinal, aromatic, and spice crops sector is economically significant, contributing to production and income generation. With a total multiplier effect on production of 1.15 and income of 0.92, it shows a robust capacity to generate additional economic value, especially in the countryside, which is important for sustainable economic growth. Job position creation is one of the most important aspects of the sector, with an employment multiplier of 16.85, showing that the sector contributes to economic growth and social development, providing jobs and improving the quality of life for many people. Although the sector has environmental impacts, as shown by greenhouse gas emissions (5.50 kt) and the high-water demand (447.2 thousand m^3), these impacts highlight the need for more sustainable practices. Adopting agricultural techniques that save water resources and have lower carbon emissions is essential to minimize negative environmental effects. Public policies that encourage the efficient use of resources and the adoption of sustainable technologies are fundamental to balancing economic and social benefits with environmental preservation.

Table 2 shows economic, social, and environmental indicators for several agricultural sectors in Brazil in 2020, based on the input-output matrix. The values reflect the impact of a US$ 1 million increase in final demand in the sector. The medicinal, aromatic, and spice crops sector has a production multiplier effect of 1.15, lower than sectors such as rice (2.99) and maize (2.36). Although important, it indicates that the impact on production is relatively minor compared to these sectors. The Rasmussen-Hirschman (RH) intersectoral linkages indexes show that the medicinal, aromatic, and spice crops sector is moderately dependent on other sectors (RH Backward = 0.58) and is equally important as a supplier to other sectors (RH Forward = 0.51).

The analyzed sector generated 16.85 jobs for every additional US$ 1 million in demand, standing out positively compared to sectors such as vegetables, roots, and tubers (2.81) but below maize (52.08) and leguminous crops and oilseeds (36.85). This sector had relatively high CO_2 emissions (5.50 kt), comparable to wheat (5.69 kt) and maize (6.04 kt), suggesting a need for more sustainable practices to reduce environmental impact. The use of blue water in the medicinal, aromatic, and spice crops sector is extremely high (447.20 thousand m^3), surpassing all other sectors, which indicates a high demand and the need for efficient management of water resources.

The higher values of the production multiplier (2.26), employment (52), and intersectoral linkage indexes for maize indicate a complex production chain, with the sector demanding inputs above the average for other economic activities (HR Backward = 1.2) and its product being a raw material for various industries (HR Forward = 1.17). The analysis is similar for the Wheat and Leguminous crops and Oilseeds sectors, but the first is for domestic consumption, and its industrialization occurs within the country. In the latter case, part of the production refers to soy, an export product partially marketed without processing to other countries, implying a lower value for the forward index and less capacity to generate job positions.

Table 2: Economic, social, and environmental indicators based on the input-output matrix of selected agricultural sectors, 2020. Values generated by an increase in final sectoral demand of US$ 1 million.

Sector	Multipliers					Intersectoral Linkage Indexes [5]	
	Production[1]	Employment[2]	Income[1]	CO_2[3]	Blue Water[4]	RH Backwards	RH Forward
Wheat	1.07	21.01	0.95	5.69	60.79	0.54	0.51
Maize	2.36	52.08	0.96	6.04	32.35	1.20	1.17
Other cereals	1.72	5.71	0.83	0.38	3.36	0.87	1.72
Leguminous crops and oilseeds	1.06	36.85	0.99	4.16	38.84	0.54	0.73
Rice	2.99	12.73	0.78	2.42	372.64	1.52	0.51
Vegetables, roots, and tubers	1.23	2.81	0.97	0.52	2.34	0.62	0.51
Medicinal, aromatic, and spice crops	1.15	16.85	0.92	5.50	447.20	0.58	0.51

[1] Amount in millions of dollars, [2] Number of job positions, [3] Kilotons (kt), [4] Thousands of m^3, [5] Index with an average of one (120 sectors).

A comparison of the economic indicators of the selected agricultural sectors and the medicinal, aromatic, and spice crops sector indicates that the latter has significant impacts in economic and social terms, especially for job position creation. However, its impact on total production is smaller compared to other prominent agricultural sectors. There is potential to use the products in different industries to generate by-products with greater earned value, such as cosmetics, pharmaceuticals, hygiene, cleaning, and food. From an environmental point of view, this sector presents considerable challenges related to high water consumption and CO_2 emissions. Policies and practices aimed at sustainability shall be essential to mitigate these impacts and promote more balanced development.

IV. Conclusion

The increase of one million dollars in final demand in the Medicinal, Aromatic, and Spice crops sector generates around 1.15 million dollars in production, 920,000 dollars in income and 16.85 job positions, showing economic and social importance with the greatest direct effect on production in the countryside (over 80%). From an environmental point of view, the same amount of final demand generates 5.5 kt of CO2eq and consumes 447,000 cubic meters, relatively high values compared to the other agricultural sectors listed in the study. Therefore, the sector presents challenges in developing sustainable techniques to reduce blue water consumption and carbon dioxide emissions. Moreover, the intersectoral linkage indexes indicate the low use of inputs and the use of the sector's products as raw materials by other industrial sectors capable of earning value to the production chain.

Developing the medicinal, aromatic, and spice crops sector requires new production techniques to increase productivity sustainably, and investment policies are needed. The trend towards consuming natural and healthy products encourages using raw materials in industrial processes, earning value for the production chain.

Further studies could be carried out on the subject, considering the economic, social, and environmental importance of different crops of medicinal, aromatic, and spice crops in the different regions of Brazil: North, Northeast, Southeast, Midwest, and South, and their potential uses in the pharmaceutical, food, cosmetics and hygiene, and cleaning industries.

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