

## **COP30 Challenges: Where are employment and income in the Brazilian bioeconomy (2011–2021)**

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### **Abstract**

This article addresses the lack of comparable metrics to guide analysis of the bioeconomy in Brazil, a topic that has been treated as a driver of development and climate change but lacks comparable metrics to guide policies and investments. This article aims to measure and characterize the 100% BIO core using microdata from the RAIS (2011–2021) based on two indicators: the core's share of formal employment and its share of the wage bill. This is a quantitative-descriptive study, with sectoral (CNAE) and territorial breakdowns and an assessment of the temporal evolution of these indicators. The results show stability in the share of formal employment at a constant level and a similar share of the wage bill, with a slight increase at the end of the series. Behind this average stability, spatial reconfiguration is observed, with relative gains in the Central-West and South regions, associated with agro-industrial densification, and a loss of traction of traditional primary complexes in states in the Southeast and Northeast. At the sectoral level, the transformation links linked to biomass stand out, such as food and beverage processing, slaughter and dairy, and the pulp and paper chain. In new agricultural fronts, formal employment remained resilient in the 2020–2021 biennium, but gaps persist between employment and income participation where local processing is incipient. In light of these findings, the two indicators used allow prioritizing territories and monitoring initiatives by revealing where the 100% BIO core generates not only formal jobs but also a greater share of income. The study's contribution is to offer standardized and replicable measurement with administrative data, enabling sectoral and territorial comparisons and continuous monitoring of the Brazilian bioeconomy.

**Keywords:** Bioeconomy; Biological Base; Spatial Distribution; Formality, COP30.

### **Resumo**

Este artigo enfrenta a ausência de métricas comparáveis para orientar a análise da Bioeconomia no Brasil, assunto esse que tem sido tratada como vetor de desenvolvimento e clima, mas carece de métricas comparáveis para orientar políticas e investimentos. Este artigo visa mensurar e caracterizar o núcleo 100% BIO utilizando microdados da RAIS (2011–2021), a partir de dois

indicadores: participação do núcleo no emprego formal e participação do núcleo na massa salarial. Trata-se de estudo quantitativo-descritivo, com recortes setoriais (CNAE) e territoriais e avaliação da evolução temporal desses indicadores. Os resultados mostram estabilidade da participação no emprego formal em patamar constante e participação da massa salarial próxima, com leve elevação ao final da série. Por trás dessa estabilidade média, observa-se reconfiguração espacial com ganho relativo de regiões do Centro-Oeste e do Sul, associado ao adensamento agroindustrial, e perda de tração de complexos primários tradicionais em estados do Sudeste e Nordeste. No plano setorial, destacam-se os elos de transformação vinculados à biomassa, como processamento de alimentos e bebidas, abate e laticínios, e a cadeia de celulose e papel. Em novas frentes agrícolas, há resiliência do emprego formal no biênio 2020–2021, mas persistem hiatos entre participação no emprego e na renda onde o processamento local é incipiente. À luz desses achados, os dois indicadores empregados permitem priorizar territórios e acompanhar iniciativas ao revelar onde o núcleo 100% BIO gera não apenas postos formais, mas também maior parcela da renda. A contribuição do estudo é oferecer mensuração padronizada e replicável com dados administrativos, viabilizando comparações setoriais e territoriais e o monitoramento contínuo da bioeconomia brasileira.

**Palavras-chave:** Bioeconomia; Base Biológica; Distribuição espacial; Formalidade, COP30.

## 1. Introduction

The bioeconomy has consolidated its place on the scientific and public agendas by linking the use of renewable biological resources with innovation, productivity and sustainability ( Carbonell et al., 2021; Ollinaho , Kröger , 2023; Gama, Brasileiro, 2024) In Brazil, this field connects to unique comparative advantages, notably the greatest biodiversity on the planet (housing between 10% and 15% of all known species) (Carbonell et al., 2021; Barbosa et al., 2021; Brasil, 2023a; Queiroz-Stein et al., 2024), consolidated agro-industrial chains and a conceptual debate that directly affects the measurement of employment and income and the territorial reading of opportunities (Willerding et al., 2020). The literature distinguishes axes that combine biotechnology, bioresources, and bioecology, which requires a clear definition of the bioeconomic core for measurement purposes (Lima, Pinto, 2022; Souza et al., 2023; Gama, Brasileiro, 2024)<sup>1</sup>. The breadth of definitions has direct implications for sectoral targeting and indicator development; therefore, distinguishing between entirely bio-based activities and activities with partial biomass inputs is essential for accurate analyses. In the context of COP30, this article presents the 2011–2021 series on bioeconomy employment

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<sup>1</sup> This conceptual breadth is considered the main problem in the bioeconomy metadiscourse and requires a clear definition of the bioeconomic core for measurement and evaluation purposes. The lack of unified criteria results in challenges in classifying activities (Lima, Pinto, 2022; Ollinaho, Kröger, 2023; Gama, Brasileiro, 2024).

and income from a territorial perspective; the challenge for the conference is to align targets and instruments with verifiable indicators of job creation and wages.

In this study, the emphasis is on fully bio-based activities, that is, cases in which all added value is attributed to the bioeconomy (Lima, Pinto, 2022; Serigati, Possamai, Diz, 2023). This approach follows a typology adopted in recent literature, which contrasts this core with segments that have only partial participation of biological inputs, not explored here<sup>2</sup>. The operationalization uses CNAE 2.0, with explicit selection of the classes that comprise the 100% bio-based set. This distinction is necessary to calculate the fully bio-based activities and to understand the full impact of the bioeconomy value chain in Brazil, which, according to Lima and Pinto (2022), can represent approximately 20% of Brazilian GDP. Despite the advances in literature and the accumulation of international and national experiences, there remains a lack of a transparent and replicable operationalization of the 100% BIO core to measure formal employment and income in Brazil, with comparability between states and a spatial interpretation that connects sectoral specialization and labor market performance. This absence tends to limit the dialogue between policy formulation, business strategies, and evidence on the territorial distribution of employment and wages in the primary and downstream sectors (Lima, Pinto, 2022; Moscon et al., 2024; Ansanelli et al., 2025)

Given this scenario, this study aims to measure and characterize the relevance of the bioeconomy in the Brazilian formal labor market, focusing on state-level comparisons and a spatial interpretation of productive specialization. This study uses microdata from the Annual Social Information Report (RAIS) between 2011 and 2021<sup>3</sup>. The database covers almost all formal employment, allowing for the estimation of state-level indicators of participation in bio-based employment and income and the mapping of municipal specialization by dominant bio-based group, highlighting asymmetries between employment and income with implications for qualification and value-added policies.

Thus, this study aims to answer the following questions: (i) What is the importance of employment and wages in the 100% BIO core sector, and how are they distributed across Brazil between 2011 and 2021? (ii) Which groups of activities in the 100% BIO core sector stand out

<sup>2</sup>Activities with partial participation of biomass inputs (*bio-based* bias less than 100%): Where only part of the production is composed of biological inputs (Lima; Pinto, 2022)

<sup>3</sup>However, it is necessary to recognize the limitations of RAIS for the period, including the break in the historical series in 2022 due to the migration of 77% of establishments to eSocial, which generates "artificial" variations in the links and requires caution in direct comparisons with previous years.

by state and municipality, and how did this composition evolve at the beginning and end of the series? The analysis is based on two indicators: formal employment and wages in the 100% BIO core sector. Estimated by state and mapped at the municipal level, these indicators enable complementarity by providing inputs for the COP30 goals and guide the prioritization of territories and groups of activities with greater job and income generation.

Following this introduction, the text presents a literature review, emphasizing the breadth and controversies of the bioeconomy concept and its implications for measuring employment and territorial distribution. The methodology is then detailed, including sources, construction of the CNAE dictionary, and definition of indicators. The following section presents results and discussion, highlighting the mapping of linkage intensity and the panels of the dominant BIO group by municipality, in addition to the state series. Finally, the conclusion revisits implications for training policies, technological induction, and reduction of regional asymmetries.

## 2. Literature review

The conceptual foundations of ecological economics were established by Georgescu-Roegen (1966), especially in works published between 1966 and 1977 (Cechin, Veiga, 2010; Mejias, 2019; Barbosa et al., 2021; Gama, Brasileiro, 2024). He highlighted the intrinsic connection between economics and biological systems and highlighted the unsustainability of economic growth in the face of limited natural resources and waste generation, in light of the second law of thermodynamics (Mejias, 2019; Barbosa et al., 2021). His ideas, by emphasizing the entropic nature of the economic process, gained repercussion in Europe and challenged the dominant neoclassical economics (Gama, Brasileiro, 2024).

However, the bioeconomy, as a more formal concept, emerged in the 1990s as an economic alternative that leveraged biotechnological advances in industrial contexts. It began to be recognized globally as a way to address environmental and social challenges through the sustainable management of natural resources, evolving into a sustainable economic model based on renewable resources (Willerding et al., 2020). In the early 2000s, the prefix "bio" was officially combined with "economy" in an American *Biomass document Research and Development Board* (2001), which approached the bioeconomy as a "revolution" and a "technological return to a sustainable past" (Pavone, 2012; Gama, Brasileiro, 2024). In Europe, the first document to present a new bioeconomy configuration was a 2002 European

Commission strategic report, focusing on the technological development of new bio-based products and the replacement of fossil resources (Gama, Brasileiro, 2024). The European Commission has since supported the bioeconomy with a focus on biorefining and bio innovations. The concept of "green jobs" was also revitalized internationally in 2008, following the green economy paradigm, with a new occupational profile focused on environmental management and sustainable innovation (Moscon et al., 2024).

Carbonell documents et al. (2021), Germany implemented its first national bioeconomy strategy in 2011. Since then, around 50 countries, including 15 from the European Union and Nordic countries, have incorporated the bioeconomy into their strategic policies <sup>4</sup>. In 2015, the First Global Bioeconomy Summit, held in Berlin, consolidated an operational definition: bioeconomy refers to the production, use, and conservation of biological resources, integrated with scientific knowledge, technologies, and innovation, with the purpose of offering information, products, processes, and services in multiple sectors of the economy, with an orientation towards sustainability (Scheiterle et al., 2018; Barbosa et al., 2021). In the same year, the UN 2030 Agenda, with its 17 Sustainable Development Goals, was presented and came into force in 2016, establishing a global framework for sustainable development (Brasil, 2023a; Gama, Brasileiro, 2024). This agenda even dialogues with proposals from the Georgescu-Roegen Minimum Bioeconomic Program aimed at sustainable development (Gama, Brasileiro, 2024). Works such as Gama and Brasileiro (2024), Rodrigues et al. (2024), and Oliveira et al. (2024) highlight Bugge et al. (2016), in which they organize the bioeconomy into three complementary visions, as shown in Table 1:

**Table 1:** Conceptual architecture of the bioeconomy (summary)

<b>Biotechnological vision</b>	It is based on the premise that innovation in biological sciences can boost economic growth and job creation through the use of biomass in more environmentally efficient processes and products. The OECD describes this agenda as a change in economic and social structure aimed at capturing new growth and well-being benefits by exploiting latent value in biological products and processes (Gama, Brasileiro, 2024). From this perspective, biotechnology functions as an instrument for implementing the bioeconomy, with impacts on human health and agricultural and livestock productivity.
<b>Bioresources vision</b>	It moves from "how to innovate" to "what to produce," focusing on bio-based goods and bioenergy. It involves processing and converting biomass, creating specific value chains, and replacing non-renewable inputs with renewable biological resources. This path combines growth and sustainability objectives and

<sup>4</sup>The decade from 2010 to 2020 saw a gradual increase in publications on the topic, with significant growth from 2015 onwards, and a greater number of publications in 2019 (Gama, Brasileiro, 2024).

	includes the use of forest bioactive substances for new production segments. Brazil fits in here by seeking to capture value from its biological resources (Barbosa et al., 2021).
<b>Bioecological vision</b>	It shifts the emphasis to ecosystem integrity and the optimization of nutrient and energy use, establishing a circular model that reduces the need for external inputs. This perspective harks back to the Georgescu-Roegen tradition, associated with ecological economics and the implications of entropy for economic activity, with a focus on sustainability and social well-being that goes beyond linear metrics like GDP (Mejias, 2019; Barbosa et al. 2021; Gama, Brasileiro, 2024).

Source: prepared by the author, 2025.

The conceptual breadth of the three perspectives directly affects measurement. Different choices of segmentation alter the universe of activities and, therefore, employment and income indicators. For purposes of comparable sectoral and territorial analysis, recent literature recommends specifying a bioeconomic core with transparent inclusion/exclusion criteria. For this article, the fully biologically based segment (100% bio core) is adopted, in contrast to segments with partial participation of biological inputs (Serigati, Possamai, Diz, 2023). This delimitation increases traceability and reduces ambiguities, an essential condition for constructing historical series and territorial indicators that adhere to public policy goals.

### **2.1 Scope and controversies of the bioeconomy in Brazil, with effects on employment and territorial distribution**

The bioeconomy, understood as the production and use of renewable biological resources, waste and co-products to generate high value-added goods, such as food, feed, bioproducts and bioenergy, constitutes a strategic axis for sustainable development in Brazil (Carbonell et al., 2021; Lima, Pinto, 2022). Due to its extensive natural capital endowment and high biomass availability, the country is often positioned as a world power in bioeconomy (Carbonell et al., 2021). With the greatest tropical biodiversity on the planet, which brings together around 20% of known species, including 116,000 animals and 55,000 plants, Brazil has unique conditions to exercise leadership on this topic (Barbosa et al., 2021; Carbonell et al., 2021). According to Barbosa et al. (2021), the domestic scope includes agriculture, livestock, forestry, fishing, food, pulp, paper, and segments of the chemical, biotechnology, and energy industries. In 2019, the bioeconomy accounted for about 20% of GDP (Barbosa et al., 2021; Carbonell et al., 2021). The expansion of this agenda, however, faces conceptual disputes and complex effects on the labor market and territorial income distribution (Brazil, 2023).

The concept is polysemic and the subject of dispute, especially in Brazil, where it is necessary to distinguish sustainability-oriented arrangements from practices that reinforce extractive logics (Ollinaho, Kröger, 2023; Gama, Brasileiro, 2024; Queiroz-Stein et al., 2024). According to Gama and Brasileiro (2024), the debate arises in the tension between economic growth and effective sustainability. Critics point out that aligning policies and markets without social and environmental safeguards can increase pressure on common goods and territories. In this context, it is proposed to differentiate the "plantation economy," based on monocultures and intensive exploitation, from the "zociobiodiverse economy," anchored in sustainability, traditional knowledge, and social inclusion (Ollinaho, Kröger, 2023).

Controversy persists over the adoption of the term in Brazil; for example, classifying Amazonian Forest economies as a bioeconomy on the same level as soybean monocultures leads to misunderstandings. Large agribusiness groups have influenced the national agenda, labeling Indigenous and agroforestry practices as bioeconomy and linking them to heavily extractive sectors (Gama, Brasileiro, 2024). In response, social movements advocate an "ethics of unacceptability" for activities that deforest, pollute, and threaten livelihoods, while valuing the knowledge of Indigenous peoples and local communities (Gama, Brasileiro, 2024; Barbosa et al., 2021). According to Carbonell, et al. (2021), regulation is a necessary condition for sustainable trajectories, with the advancement of molecular biology techniques and opportunities linked to biodiversity repositioning biosafety and access to genetic heritage as decisive issues. Law 13.123/2015 established a self-declaration system to reduce barriers to research and stimulate related economic activities. It is, therefore, necessary to ensure the integrity of processes, compliance, and benefit sharing with traditional communities and indigenous peoples, in line with international trends (Carbonell, et al., 2021).

At the institutional level, the National Confederation of Industry introduced the topic in 2013 with "*Bioeconomy: Agenda for Brazil's Development*," which boosted economic, social, and environmental discussions (Mejias, 2019; Barbosa et al., 2021; Queiroz-Stein et al., 2024). As an offshoot of the National Strategy for Science, Technology, and Innovation 2016–2022, the government launched action plans in biotechnology and bioeconomy, while the Biodiversity Law improved rules for access to genetic heritage and stimulated sustainable production chains (Barbosa et al., 2021; Carbonell et al., 2021). The federal government, through the Ecological Transformation Plan (launched in 2023), established the bioeconomy as one of the structural pillars for the country's productive and sustainable development (Brazil, 2023). This plan is

integrated into the programs of the 2024-2027 Multi-Year Plan (PPA) and aims to mobilize and redirect public and private investments. To this end, the government seeks to develop the Brazilian Sustainable Taxonomy and, in May 2023, established the framework for issuing thematic sovereign bonds to finance the ecological transition. The magnitude of the financing effort aligns with the estimated annual investment requirement of 3.5% to 4% of GDP between 2020 and 2050 for Brazil to achieve climate neutrality.

**Table 2: Overview of bioeconomic approaches in Brazil**

<b>Bioenergy</b>	The country has consolidated its leadership since Proálcool in 1975 and the National Program for the Production and Use of Biodiesel in 2005 (Muçouçah, 2009; Carbonell et al., 2021). In 2022, renewable sources represented 47.4% of the Brazilian energy matrix, compared to 16% on a global average, which highlights the relevance of ethanol, biodiesel and bioelectricity (Carbonell et al., 2021; Brasil, 2023a). Law 13,576/2017, RenovaBio, guides expansion with sustainability criteria. Internationally, bioenergy has a significant impact on job creation, accounting for approximately half of the jobs reported in the sector (Verdes, 2008).
<b>Agribusiness</b>	Agriculture, livestock, forestry, and fishing account for a significant portion of the industry. In 2018, the sector accounted for approximately 21% of GDP, 20% of employment, and 42.4% of exports. Grain production grew 293% between 1990 and 2018, from 58 to 228 million tons, while planted area increased 63%, from 38 to 62 million hectares. The productivity gains helped prevent deforestation of 87 million hectares during the period (Carbonell, et al., 2021).
<b>Chemical biologically based</b>	The portfolio is expanding, with a focus on renewable plastics and installed industrial capacity. Brazil is among the ten largest chemical industries in the world and maintains the fourth most important industrial sector in its production base, which favors the scalability of bio-based solutions (Carbonell, et al., 2021).
<b>Recycling (circular dimension)</b>	In 2006, 10.3 billion aluminum cans were recovered, resulting in an estimated annual savings of 1,976 GWh, enough to power a city with over one million inhabitants. Globally, the recycling chain supports approximately 12 million jobs, with Brazil, China, and the United States participating (Verdes, 2008).

Source: prepared by the author, 2025.

Regarding economic scope, the bioeconomy involves primary activities and industrial segments of food, pulp, paper, chemicals, biotechnology, and energy. General equilibrium exercises estimate a share of close to 20% in value generation in Brazil, GDP-BIO (Lima, Pinto, 2022; Carbonell et al., 2021). This capacity stems from extensive agricultural crops and biodiversity, which is home to between 10% and 15% of known species and provides a basis for innovation in bioproducts and bioprocesses. To exploit opportunities, it is important to promote technological densification and increase competitiveness on a sustainable basis (Willerding et al., 2020). According to Carbonell et al. (2021), innovation coevolves across five interconnected dimensions: raw materials, technologies, products, business models, and

regulation. In Brazil, however, this process must be aligned with new market demands, using *big data*, artificial intelligence, and genetics.

However, the productive rearrangements associated with the bioeconomy affect the generation and quality of employment unequally (Moscon et al., 2024). Green jobs, understood as decent positions that contribute to reducing emissions and/or environmental improvement, become a reference in the transition (Muçouçah, 2009; Ansanelli et al., 2025). In 2022, green activities showed greater formality, 86%, and higher average income compared to environmentally sensitive activities, 59% formality (Moscon et al., 2024). In 2008, formal green jobs were estimated at 2,653,059, equivalent to 6.73% of the formal total (Muçouçah, 2009; Ansanelli et al., 2025). Between 2012 and 2022, the proportion of formal links in green activities, around 17% of the total, remained stable (Moscon et al., 2024). Furthermore, bioeconomic expansion raises questions about inequality and labor. Agricultural modernization and automation, associated with Industry 4.0, tend to reduce the likelihood of job retention in highly automated agricultural occupations, while higher education increases this probability (Fernandes et al., 2024). In the Amazon, many bioproducts maintain low technological density, such as *fresh fruits* and unpurified oils, with a strong influence on origin marketing in value addition (Willerding et al., 2020).

Despite job creation, agriculture has low average pay, R\$621.61 in 2006, indicating sectoral heterogeneity and polarization (Brasil, 2007). Vulnerability to automation is high; for example, as discussed by Fernandes et al. (2024), in 2019, approximately 88% of formal workers in the sector were in occupations with a high probability of automation; in these occupations, the expected probability of maintaining employment is 6.66% lower. Education has the greatest positive impact, with individuals with a bachelor's degree having an 11.21% higher probability of remaining employed compared to those with primary education. Nevertheless, the territorial distribution of activities is heterogeneous and often accentuates regional inequalities (Souza et al., 2023; Brasil, 2023a). Therefore, reducing these disparities is the objective of the Brazilian Sustainable Taxonomy (TSB) (Gama, Brasileiro, 2024). The differences appear in income indicators, as raised by (Brasil, 2023) average income in the Federal District is 213% higher than that of Maranhão.

At the regional level, the following production and innovation hubs stand out: (i) the Amazon region being the main area for the bioeconomy with a “socio-environmental” focus, with bioindustry and biotechnology networks centered in Manaus and other state capitals

(Willerding et al., 2020; Oliveira et al., 2024). However, there is an economic, social and cultural imbalance between hub cities and the interior. As Willerding observes et al. (2020), scientific production remains more concentrated in basic research, with less translation into technological development and intellectual property; (ii) Southeast region, Campinas meets the conditions for a world-class innovation ecosystem in bioeconomy, supported by high expenditures in R&D. The State of São Paulo, according to Carbonell et al. (2021) expenditure intensity higher than that of European countries such as Italy, Spain, and Portugal; (iii) MATOPIBA as a front for *commodity* -oriented agricultural expansion, with a concentration of formal jobs in western Bahia and southern Maranhão. However, the formal market showed resilience between 2020 and 2021, but the structure remains heterogeneous, with inequalities in wealth distribution (Loayza, Reis, Jesus, 2024). Given the territorial disparity, according to Perroux's (1977) pole theory, in which more representative agglomerations concentrate economic, political, and population activity, there is a need for coordination between regional, national, and international structures to intensify commercial, scientific, and technological exchanges (Perroux, 1977; Willerding et al., 2020; Souza et al., 2023).

At the global level, the bioeconomy has been treated as a strategy for sustainable food and agriculture. According to FAO (2024), its advancement requires international collaboration and cooperation, oriented toward addressing global challenges and disseminating environmentally sound technologies. In this context, as discussed by the World Bank (2024), the idea of a Just Transition for workers and communities becomes imperative, with a view to ensuring that the ecological transformation is socially inclusive. In this scenario, the measurement of work takes on a prominent role, as evidenced by studies on Green Jobs, whose methodologies classify sectors according to emissions and their capacity to generate new green occupations and technologies (Winkler et al., 2024; Ansanelli et al., 2025). For this reason, incorporating the social dimension and sustainability criteria becomes a prerequisite for designing and evaluating policies (World Bank, 2024). In Brazil, a National Bioeconomy Strategy has already been established (FAO, 2024; Brazil, 2024a). The document is grounded in the values of justice, ethics and inclusion, and it makes explicit objectives such as reducing inequalities, promoting regional development, expanding education and professional training, stimulating entrepreneurship and generating new jobs while preserving sustainability (Brazil, 2024a, 2024b). The emphasis on social and environmental indicators is explained by the fact that multiple national bioeconomy strategies adopt common sustainability targets, and Brazil

seeks to strengthen its bioeconomy in alignment with the Sustainable Development Goals, SDGs (FAO, 2024).

In general, the bioeconomy in Brazil offers ample room for action, but its implementation requires addressing structural challenges (Brasil, 2023a). Overcoming conceptual controversies requires differentiating between extractive arrangements and proposals centered on sociobiodiversity, with fair benefit sharing and effective community participation (Carbonell et al., 2021). The success of the sector depends on the convergence of the State, companies, academia and civil society (Willerding et al., 2020; Barbosa et al., 2021), in line with the *Quintuple Helix model* (Carayannis et al., 2012; Willerding et al., 2020)<sup>5</sup>. According to Brasil (2023a), the construction of a Brazilian Sustainable Taxonomy, with explicit priority on reducing regional inequalities and generating decent work, is a decisive step towards guiding a coherent and socially just transition. To this end, the literature converges in pointing out that consistent public policies are needed to qualify the workforce for new technological demands (Moscon et al., 2024; Fernandes et al., 2024) and ensure that ecological transformation results in inclusive and sustainable development in social terms (Verdes, 2008; Brasil, 2023a).

### 3. Methods and procedures

The Annual Social Information Report (RAIS) is a source of statistical data that acts as an annual census to monitor and characterize the formal labor market in Brazil, covering approximately 97% of this segment (Brasil, 2007; Muçouçah, 2009) and due to its structure, informal and self-employed workers are excluded. However, the microdata were obtained from the Database platform and subjected to cleaning, standardization, and aggregation routines in the RStudio software. For the analyses, the reference date was used through an active employment indicator on December 31, characterizing the stock of formal employment relationships between 2011 and 2021. For this purpose, the database consists of the reference year, municipal identifiers (code of the municipality of the workplace and, alternatively, the municipality of the establishment), CNAE 2.0 classification in the class (4 digits) when the data

<sup>5</sup> The *Quintuple Helix model* is an “innovation” *framework* that expands previous models by explicitly including Environment and Society as drivers of knowledge production (Carayannis et al., 2012). It is based on the interaction of academia, business, government, society and the environment, and is used to guide social and economic development.

in the subclass granularity (7 digits) was aggregated to the corresponding 4 digits, and average monthly remuneration of the relationship<sup>6</sup>.

In this study, focused on the bioeconomic nucleus, the CNAE 2.0 divisions were delimited based on activities considered 100% bio-based, following the tabulation of Lima and Pinto (2022) and Serigati, Possamai and Diz (2023) applying the method used by Souza et al. (2023). To this end, the typology of goods representative of the bioeconomy of Lima and Pinto (2022) is adopted, which organizes the cut into two axes: fully bio-based activities, in which all added value is attributed to the bioeconomy; and activities whose production chains incorporate only a portion of biomass and biologically derived inputs, in which case only a fraction of the product is accounted for as bioeconomic. This study focuses on the first axis, without detailing the second component, as evidenced in Table 3, the delimitation of the bioeconomy was made with a dictionary that maps four-digit CNAE classes into thematic groups A–K aiming to consolidate sectoral results without losing traceability by class and calculated by link<sup>7</sup>.

**Table 3:** Set of activities with 100% biological basis

Bio Group	Economic Activity	CNAE Class (4 digits)
A	Agriculture, including agricultural support and post-harvest	0111; 0112; 0113; 0114; 0115; 0116; 0119; 0121; 0122; 0131; 0132; 0133; 0134; 0135; 0139; 0141; 0142; 0161; 0163
B	Livestock, including support	0151; 0152; 0153; 0154; 0155; 0159; 0162; 0170
C	Forestry production, fishing and aquaculture	0210; 0220; 0230; 0311; 0312; 0321; 0322
D	Slaughter and meat products, including dairy and fishery products	1011; 1012; 1013; 1020; 1051; 1052; 1053
E	Sugar manufacturing and refining	1071; 1072
F	Other food products	1031; 1032; 1033; 1041; 1042; 1043; 1061; 1062; 1063; 1064; 1065; 1066; 1069; 1081; 1082; 1091; 1092; 1093; 1094; 1095; 1096; 1099
G	Beverage manufacturing	1111; 1112; 1113; 1121; 1122
H	Manufacture of tobacco products	1210; 1220
I	Manufacture of textile products	1311; 1312; 1313; 1314; 1321; 1322; 1330; 1340; 1351; 1352; 1353; 1354; 1359

<sup>6</sup> To locate formal ties, the municipality of the workplace was adopted as a rule. Using the municipality of the workplace as a territorial reference prioritizes ties to the territory where the occupation occurs; the municipality of the establishment is only used when the former is vacant. These procedures enabled the creation of standardized, time-comparable, and consistent panels for municipal maps, regional cross-sections, and descriptions of formal ties in the bioeconomy.

<sup>7</sup> The National Classification of Economic Activities (CNAE) is the official standard for statistics and identification of economic activities in Brazil. CNAE 2.0 was adopted by RAIS in 2006, although the initial publication included only the first 5 digits (class) (Brazil, 2007).

J	Manufacture of pulp, paper and paper products	1710; 1721; 1722; 1731; 1732; 1733; 1741; 1742; 1749
K	Biofuel production	1931; 1932

Source: prepared by the author based on Lima and Pinto (2022) and Serigati, Possamai and Diz (2023); 2025.

Given that this study analyzes the formal labor market in Brazil's bioeconomy segments and incorporates a spatial dimension by characterizing the distribution of formal employment across states in order to assess the importance of these segments in state economies, two indicators proposed by Souza et al. (2023) are adopted to capture the share in formal employment and the share in the wage bill. The first indicator,  $I_{po}$ , is the Share of Bioeconomy Formal Employment in the State Total, defined as the ratio between the number of formal employment relationships in core bioeconomy activities (100% BIO) and the total number of formal employment relationships in the state. The second indicator,  $I_{rend}$ , is the Share of the Bioeconomy Wage Bill in Total Formal Income, defined as the ratio between the wage bill generated by the bioeconomy and the total formal wage bill in the state. The corresponding expressions are given in Equations (1) and (2).

$$I_{po(e)} = \frac{\sum_{i=1}^n x_{i,e}}{\sum_{i=1}^n x_{i,e} + \sum_{i=n+1}^m x_{i,e}} \quad (1)$$

$$I_{rend(e)} = \frac{\sum_{i=1}^n r_{i,e}}{\sum_{i=1}^n r_{i,e} + \sum_{i=n+1}^m r_{i,e}} \quad (2)$$

Let  $\{1, 2, \dots, m\}$  be the set of all economic activities listed in CNAE 2.0. For each activity  $i$  in this set and for each state  $e$ , the number of formal links in activity  $i$  in state  $e$  is defined  $x_{i,e}$  as  $r_{i,e}$  as the corresponding wage bill. In the adopted system, the activities  $i = 1, \dots, n$  belong to the bioeconomy (100% BIO core) and the activities  $i = n + 1, \dots, m$  form the complement in the CNAE 2.0 universe. The indicators  $I_{po(e)}$  and  $I_{rend(e)}$  quantify the relative participation of the bioeconomy in formal employment and in the state's own wage bill, maintaining consistency with Souza et al. (2020).  $I_{po(e)} \in [0,1]$  and  $I_{rend(e)} \in [0,1]$  values close to 0 indicate low participation of the bioeconomy in the state's occupational or income structure, values close to 1 indicate high concentration in these segments.

For average monthly remuneration, null or missing values were excluded from statistics that depend on salary, preserving employment counts when necessary. Monetary values were

converted to 2021 reais based on the annual IPCA (Brazilian Consumer Price Index). To characterize the profile of formal bioeconomic employment relationships, two annual data sets (2011 and 2021) were generated, including state, municipality, CNAE group A–K, and demographic and work variables (age, sex, race/color, education, length of formal employment, and hours worked).

#### 4. Results and discussion

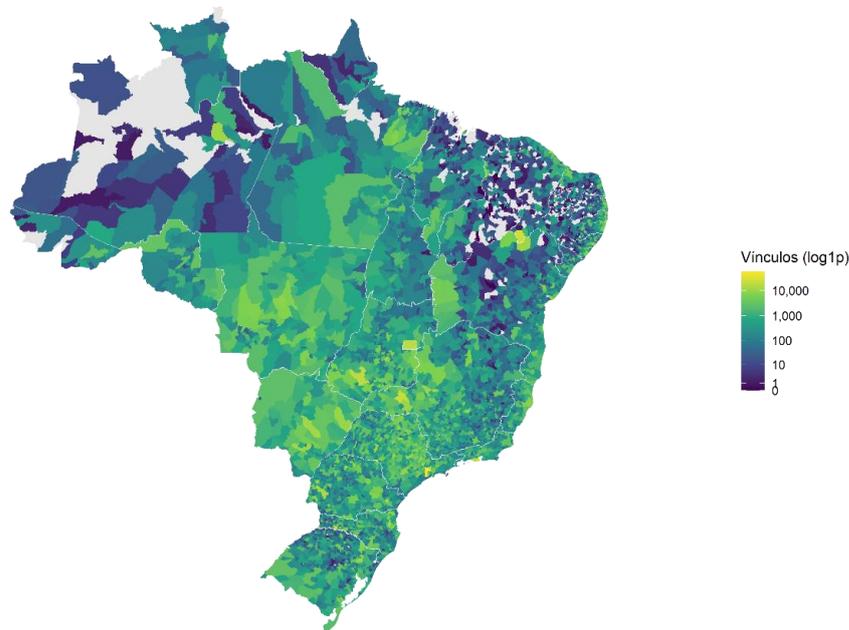
Figure 1, of formal links of the 100% BIO basket in 2021, reveals a continuous arc of high density that starts in the South and advances through the interior of the Southeast, anchored by agro-industrial complexes and processing chains of biological origin (Serigati, Possamai, Diz, 2023; Souza et al., 2023). This concentration reflects the prominence of entirely biologically based activities, classified in the Primary and Bioindustry segments, in areas that have historically consolidated themselves as hubs of economic development (Lima, Pinto, 2022; Souza et al., 2023). Western Santa Catarina and Paraná, the interior of São Paulo, and the Triângulo Mineiro region form broad patches, resulting from the combination of agricultural production, slaughterhouses and dairy plants, sugar, food and beverage, textile, and pulp and paper manufacturing (Lima, Pinto, 2022; Souza et al., 2023). In Paraná, for example, the workforce is concentrated in this West-Southwest axis, characterized by the importance of the agroindustrial segment (Lima, Pinto, 2022; Loayza, Reis, Jesus, 2024). In the interior of São Paulo, the Campinas vector emerges as a prominent innovation ecosystem for the bioeconomy (Carbonell et al., 2021).

The Central-West region has clear poles in southern and eastern Mato Grosso, southwestern Goiás, and Mato Grosso do Sul, where the densification of grain, meat, and biofuels sectors is creating formal employment along logistics corridors. The emphasis on biofuels, such as ethanol, is central in this region, as large-scale production, by replacing gasoline, helps mitigate carbon emissions (Muçouçah, 2009). MATOPIBA forms an additional corridor in western Bahia and southern Maranhão and Piauí, expressing more recent agricultural frontiers, with the growing installation of processing units (Loayza, Reis, Jesus, 2024).

According to Loayza, Reis, and Jesus (2024), the resilience of the formal agribusiness labor market in MATOPIBA, which continued to grow in employment even during the pandemic period from 2020 to 2021, confirms the consolidation of this frontier as a pillar of the

national economy. Finally, capital cities and metropolitan regions "light up" when they host BIO industrial plants or logistics functions that orbit these chains (Oliveira et al., 2024). These urban centers play a relevant role, not only in distribution and services, but also by bringing together actors and research institutions, such as universities and R&D centers, necessary for the development of innovation ecosystems in the bioeconomy, although, in certain contexts, the economic exploitation of highly complex bioproducts is still incipient (Willerding et al., 2020; Carbonell et al., 2021; Brazil, 2023).

**Figure 1:** Regional distribution of 100% BIO formal ties (2021)



Note: The legend's logarithmic scale is crucial: it allows comparisons between metropolises and small municipalities within the same frame, but reduces visual contrasts between mid-levels. Source: Prepared by the author, based on the December 31 inventory (RAIS) via Database | Grid: geobr / IBGE, 2025.

In the Northeast, the distribution takes on a mosaic shape, with bright areas in the Sugar Forest Zone of Pernambuco and Alagoas, and in the Sub-Middle São Francisco, fruit farming in Petrolina and Juazeiro, contrasting with inland areas of low formal density. This regional disparity is in line with the characterization of agribusiness in the North and Northeast states, which are geared towards primary production, often with a predominance of small properties and less technological development (Souza et al., 2023). The contrast with the inland areas reflects the historical presence of informal, unpaid labor and small-scale production for self-consumption (Souza et al., 2023; Loayza, Reis, and Jesus, 2024). According to Brasil (2023a), fruit growing hubs, in turn, constitute specific agro-industrial niches that can structure formal

employment, in opposition to the climatic vulnerabilities and socioeconomic inequality that persist in much of the semi-arid region.

In the North, the light spots align with highway axes and expansion fronts in Pará, Rondônia, and Tocantins, reflecting the expansion of sectors such as agriculture and livestock farming in regions of the deforestation arc, often associated with monocultures (Oliveira et al., 2024). Extensive areas of the Amazon remain dark due to low population density, great distances, and a strong presence of occupations outside the formalization framework captured by RAIS. According to Willerding et al. (2020), this low formal density tends to highlight the low economic use of sociobiodiversity and the difficulty of generating formalized, higher-value jobs outside of large urban centers. The concentration of bioindustry in Manaus, Amazonas, and other state capitals reinforces the limitation of distant regions in adding value to rural production (Oliveira et al., 2024; Ansanelli et al., 2025).

In general, absolute volumes are concentrated in the South, Southeast, and Central-West, with significant relative gains in inland states. The Northeast and Amazon regions have a sparser distribution and are dependent on specific agro-industrial niches. This concentration is expected, according to Souza et al. (2023), because the South, Southeast, and Central-West regions are characterized by more modern agricultural activities, with greater use of formal employment contracts and higher average incomes<sup>8</sup>.

The state-by-state series, as shown in Table 4, confirms the spatial pattern observed in Figure 1. The formal bioeconomy maintains a large base in the South and Southeast, with a growing contribution from the Central-West. In 2021, six units accounted for just over half of the country's BIO linkages. Among them are SP (872.4 thousand; 23.2% of the total), MG (504.7 thousand; 13.4%), PR (361.1 thousand; 9.6%), SC (262.9 thousand; 7.0%), RS (250.7 thousand; 6.7%), and GO (219.9 thousand; 5.9%). MT (190.7 thousand; 5.1%) and BA (163.2 thousand; 4.3%) complete the upper block, in line with bio-based agroindustrial and processing chains that structure formal employment.

Nationally, the trajectory from 2011 to 2021 presents three phases: (i) advance until 2014, with 3.67 million links and a 1.1% increase compared to 2011; (ii) decline until 2016,

<sup>8</sup> Finally, it is worth remembering that the legend in log10 compresses extreme differences and that the reference is the stock on December 31, data from RAIS, which tends to underestimate seasonal links in locations where the peak occurs in previous months, and to neglect the significant portion of informal links in agribusiness, especially in the North and Northeast (Muçouçah, 2009; Souza et al., 2023; Loayza, Reis, Jesus, 2024; Fernandes et al., 2024).

with 3.52 million and a 4.1% reduction compared to the 2014 peak; (iii) recovery between 2017 and 2021, with 3.76 million and a 6.8% growth compared to 2016, that is, 3.6% above 2011. This behavior combines restructuring in traditional sugarcane-producing bases in the Southeast and Northeast with the consolidation of agro-industrial corridors in the South and Central-West. State variations reinforce the movement. The most intense expansions were observed in Mato Grosso, with a 30.8% increase; Goiás, 17.3%; MS, 18.1%; PR, 14.4%; and SC, 21.3%; in addition to Pará, 21.5%; and Tocantins, 42.6%, in the northern arc. There was stability with a slight gain in Minas Gerais, 6.1%, and Rio Grande do Sul, 6.2%. There were declines in São Paulo, a 7.9% drop, and Rio Grande do Sul, 16.7%, as well as a significant reduction in Alagoas, 40.6%.

Alagoas' 40.6% drop aligns with the sugar sector's contraction, as environmentally driven mechanization cuts low skilled jobs (Muçouçah, 2009). São Paulo and Rio de Janeiro also declined, though from high bases (Loayza, Reis, Jesus, 2024). In Mato Grosso and Goiás, growth tied to population gains and the densification of slaughterhouses, dairy, ethanol, and food and beverage plants drove a Central West rise in formal agribusiness employment, bucking the national decline, anchored in larger, more tech intensive farms (Loayza, Reis, Jesus, 2024; Souza et al., 2023). Santa Catarina and Paraná reinforce the southern agroindustrial belt and growth polarization in Paraná, while Pará, Rondônia, and Tocantins expand along farming and processing frontiers, consistent with above average green job growth in the North and Center West (Souza et al., 2023; Ansanelli et al., 2025)<sup>9</sup>.

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<sup>9</sup> It is worth noting that the data correspond to the stock on December 31, RAIS, which confers a downward bias and underestimates seasonal links in locations where peaks occur in previous months (Muçouçah, 2009; Brasil, 2007). High percentage variations in units with a small base, such as RR, 79.9%, partly reflect the reduced denominator at the beginning of the series.

**Table 1:** Formal links in bioeconomy segments, by state, between 2011 and 2021

<b>UF</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>	<b>2016</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>	<b>2020</b>	<b>2021</b>
<b>AC</b>	6,029	5,857	6,055	6,518	7,028	7,396	7,338	6,846	5,997	5,879	6,159
<b>AL</b>	102,497	96,132	85,476	75,340	72,435	71,124	67,550	62,358	54,839	58,003	60,915
<b>AP</b>	2,211	2,114	2,252	2,201	2,215	2,063	2,121	2,200	1,808	1,797	1,883
<b>AM</b>	14,927	15,920	16,894	16,417	17,356	15,224	15,110	15,337	13,778	14,045	15,250
<b>BA</b>	150,038	149,206	150,809	152,381	148,685	148,421	151,200	154,451	149,977	153,078	163,216
<b>CE</b>	83,264	83,933	85,256	87,968	86,172	80,320	78,599	78,832	75,657	76,702	79,487
<b>DF</b>	18,347	19,604	18,655	18,508	17,898	17,264	17,107	16,944	16,888	16,976	18,075
<b>ES</b>	57,945	56,725	58,460	59,443	58,380	54,445	56,520	57,296	57,241	54,877	57,837
<b>GO</b>	187,519	197,327	207,694	211,507	206,538	202,714	209,775	208,629	205,540	210,753	219,903
<b>MA</b>	37,160	36,326	34,911	35,106	33,940	33,743	32,621	32,997	31,723	34,278	35,775
<b>MG</b>	475,747	469,056	484,864	483,049	478,466	470,751	477,149	478,911	473,034	477,521	504,691
<b>MS</b>	116,552	123,598	125,232	127,280	126,837	127,501	126,059	128,972	128,036	133,695	137,643
<b>MT</b>	145,770	147,097	157,825	159,524	157,709	156,925	168,849	175,410	179,901	182,782	190,698
<b>PA</b>	77,170	79,622	81,223	84,382	84,563	82,424	86,542	87,984	82,279	86,108	93,728
<b>PB</b>	48,306	46,784	48,014	48,072	46,229	45,220	44,742	44,859	43,333	44,423	43,647
<b>PE</b>	155,208	146,208	145,606	150,076	140,495	137,895	138,844	137,960	133,815	133,255	142,912
<b>PI</b>	17,291	18,509	18,207	19,207	19,080	17,655	18,331	20,322	19,745	18,980	21,479
<b>PR</b>	315,579	303,663	326,718	334,355	334,440	316,173	329,330	327,158	332,026	347,818	361,057
<b>RJ</b>	90,670	91,839	89,175	90,680	88,195	82,691	80,680	78,514	76,326	73,931	75,499
<b>RN</b>	41,298	40,268	41,258	40,947	40,329	40,157	40,181	40,156	37,844	38,184	40,926
<b>RO</b>	25,661	27,540	28,366	29,215	29,669	28,936	32,066	32,396	32,277	32,252	31,947
<b>RR</b>	2,044	2,278	2,563	2,598	2,627	2,704	2,466	2,649	2,972	3,183	3,678
<b>RS</b>	236,051	227,982	233,942	237,499	238,520	236,559	234,864	237,773	234,158	241,035	250,747
<b>SC</b>	216,755	203,244	222,803	225,139	220,237	218,901	228,603	230,870	237,167	251,292	262,853
<b>SE</b>	31,273	31,014	29,676	31,284	29,662	28,162	27,548	27,285	24,838	26,470	29,343
<b>SP</b>	946,770	941,926	930,786	908,866	901,644	861,741	876,563	858,043	853,523	852,294	872,445
<b>TO</b>	23,553	25,181	26,641	28,777	30,040	30,058	29,669	30,039	29,272	31,448	33,579

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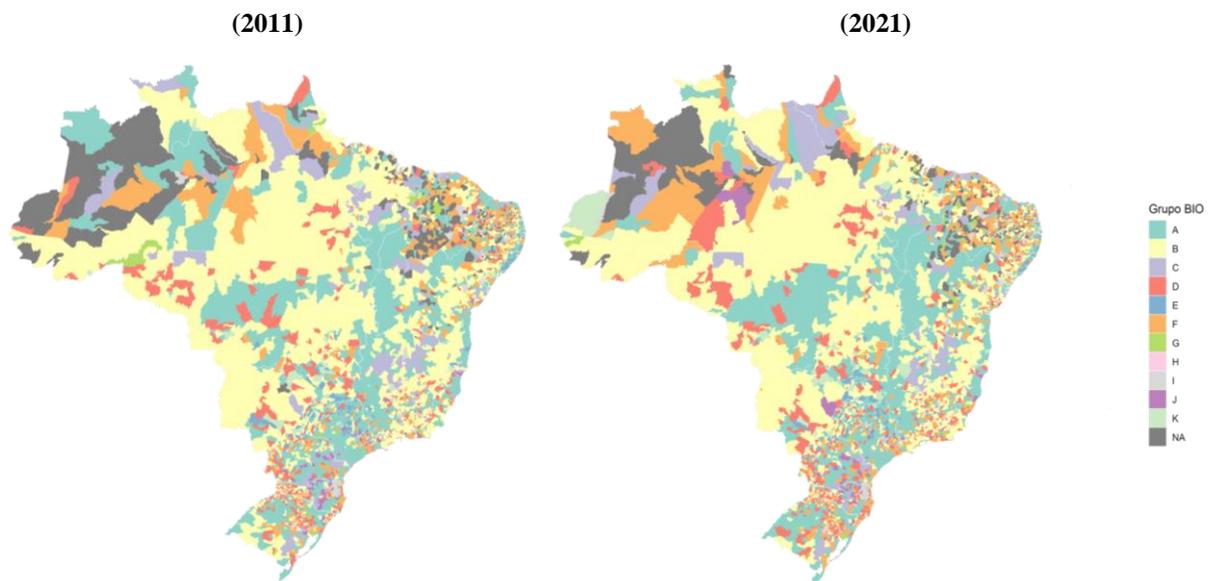
<b>BR</b>	<b>3,625,635</b>	<b>3,588,953</b>	<b>3,659,361</b>	<b>3,666,339</b>	<b>3,619,389</b>	<b>3,517,167</b>	<b>3,580,427</b>	<b>3,575,191</b>	<b>3,533,994</b>	<b>3,601,059</b>	<b>3,755,372</b>
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Source: prepared by the author, based on the inventory 12/31 (RAIS) 2011-2021, 2025.

Complementing Figure 1's intensity, Figure 2 qualifies the productive specialization of the bioeconomic core. In each municipality, the class with the highest number of formal ties in the RAIS is identified, where the BIO Group nomenclature follows the pattern in Table 3. Thus, this perspective reveals the chain that leads local employment, differentiates primary areas from agroindustrial processing areas, and serves as a bridge between the spatial distribution and the state trajectory in Table 3.

**Figure 2:** BIO predominance by municipality, formal ties, 2011 and 2021



Note: The legend's logarithmic scale is crucial: it allows comparisons between metropolises and small municipalities within the same framework, but reduces visual contrasts between medium-sized sectors. Source: Prepared by the author, based on the December 31 inventory (RAIS) via Database | Grid: geobr / IBGE, 2025.

The 2011 cross-section shows a broad predominance of *A* and *B* in the interior of the country, with a strong presence in the Central-West and parts of the North and Northeast. This configuration of primary employment in the North and Northeast tends to reflect a production profile with greater aptitude for the primary segment, often associated with small properties and less technological development (Souza et al., 2023; Fernandes et al., 2024). In contrast, even in 2011, primary activities in the Central-West were already linked to large properties and greater technological development (Souza et al., 2023). *C* occupies portions of the Amazon and coastal stretches. However, the extensive forested areas in the Amazon have a low density of formal employment, which implies low economic exploitation of sociobiodiversity and the challenge

of converting this natural wealth into formal economic wealth (Willerding et al., 2020; Oliveira et al., 2024).

In the South and in areas of the Southeast interior, an agro-industrial belt is observed anchored in *D* and *F*, in line with the consolidation of the agro-industrial segment in these regions, responsible for the majority of formal agribusiness jobs in mesoregions of Paraná, for example (Souza et al., 2023). While *E* is concentrated in the sugarcane axes, Zona da Mata of Pernambuco and Alagoas and the interior of São Paulo, reinforcing the historical importance of the Southeast in the production of bioenergy, ethanol, is pointed out in the literature as a reduction in carbon emissions by replacing gasoline (Muçouçah, 2009; Carbonell et al., 2021). *I* forms patches in the Agreste and northern backlands, *H* is organized in the southern tobacco corridor, *J* is fixed in the South with points in Espírito Santo and Bahia, *K* appears punctually. As observed by Lima and Pinto (2022), the Bioindustry, as a whole, although essential for value aggregation, still exhibited a more localized distribution in 2011.

In 2021, the opposition between "frontier primary" and "consolidated agroindustry" remains, albeit redesigned. *D* and *F* extend along logistics corridors in the South and Central-West, with a regional specialization in agro-industrial hubs with urban-industrial linkages (Souza et al., 2023). *A* and *B* are advancing in MATOPIBA and pockets of the North-Central region, consolidating the role of this agricultural frontier geared toward commodity production. The 14.1% growth in formal employment in the primary sector in this region, even from 2019 to 2021, demonstrates the dynamism and resilience of these frontier activities (Loayza, Reis, and Jesus, 2024). *C* remains associated with Amazonian and coastal areas, *J* consolidates in the South and radiates nuclei in the Center-South, *G* emerges in urban hubs with the beverage industry, reflecting the concentration of bioindustries and logistics functions in urban centers and the exploitation of agglomeration economies and supporting infrastructure (Souza et al., 2023; Oliveira et al., 2024). Finally, *E*, *I*, and *H* lose geographic extension in several microregions. One justification for the retraction of *E*, sugar, according to Muçouçah (2009), stems from the mechanization of sugarcane harvesting and industrial restructuring, processes that have reduced formal jobs in traditional sugarcane-growing states.

The indicator  $I_{po}$  quantifies the share of 100% bio-based employment in total formal employment. Between 2011 and 2021, Brazil maintained a level close to 8%, from 7.97% to 7.98%, with a U-shaped movement. A slight decline was observed until 2014, to 7.53%, followed by a continuous recovery until 2020, to 8.14%, and then leveling off in 2021. This

level, while stable, indicates that bio-based activities, the Primary and Bioindustrial Segments, support a significant portion of formal employment, consistent with estimates that place the bioeconomy as responsible for approximately 20% of value generation in Brazil (Lima, Pinto, 2022).

Regionally, the Central-West region maintains high levels, the South remains above 10% in several states, and the Northeast exhibits heterogeneity, combining historically sugarcane-growing areas and agroindustrial hubs with states with a more diversified base. In 2021, the largest shares are concentrated in the Central-West: Mato Grosso, 21.33%, Mato Grosso do Sul, 20.33%, and Goiás, 14.30%, levels similar to or higher than those of 2011. This leadership reflects the region's consolidation as a dynamic hub of high-tech agribusiness and the expansion of the formal agribusiness labor market, in contrast to the decline observed in national agribusiness employment (Loayza, Reis, Jesus, 2024). In the South, Paraná, 11.41%, and Santa Catarina, 10.85%, maintain high levels, confirming the consolidation of the southern agro-industrial belt, in which the profile of formal links is concentrated in the agro-industrial and agro-services segments (Souza et al., 2023).

In the Southeast, Minas Gerais grew marginally, 10.10%, São Paulo fell to 6.50%, and Rio de Janeiro remained low, 2.00%. In the Northeast, the contrast is striking. Alagoas fell from 21.02% to 12.03%, Pernambuco fell from 9.54% to 8.87%, Ceará to 5.43%, and Paraíba to 6.78%. Bahia maintained a stable and upward trajectory, 7.15%, and Sergipe closed at 7.73%. The marked decline in Alagoas and the decline in São Paulo, according to Muçouçah (2009), tend to be directly associated with the restructuring of historical complexes, such as the sugar mill, and the mechanization of sugarcane harvesting, which, while contributing to reducing emissions, eliminates low-skilled jobs.

In the North, relative expansion was observed in Rondônia, from 7.31% to 10.68%, Tocantins, from 9.78% to 11.54%, and Pará, from 7.54% to 8.31%, while Amazonas and Amapá fluctuated at low levels. Roraima rose from 2.24% to 3.37%. The relative growth in these northern regions, together with the Central-West and part of the Northeast, converges with the trend of increasing green jobs, axes of the bioeconomy, above the national average in the period (Ansanelli et al., 2025). The low participation in states such as Amazonas and Amapá, in turn, reiterates that, despite the broad potential, the formal use of sociobiodiversity remains limited, and employment is concentrated in urban centers, such as Manaus.

The results in Table 5 reinforce the spatial interpretation. Primary specialization is growing in regions of the Center-North, such as MATOPIBA, which saw significant job growth in the primary sector and withstood the COVID-19 crisis, while agroindustrial processing is consolidating in the Center-South (Loayza, Reis, Jesus, 2024). Where sectors such as sugar and textiles lost traction, relative participation shrank, although organic employment remained significant in absolute terms. In short, the decade combined stability in the national weight of the formal bioeconomy with intra-regional rearrangements. There are gains in the southern agroindustrial axis and in the northern arc, and a reduction in centrality in some historical complexes in the Northeast and Southeast. This redesign of employment raises the question of whether wages follow (or not) the same direction, distinguishing territories where processing adds value from those where primary processing predominates.

Table 6  $I_{rend}$  shows the fraction of the wage bill linked to the 100% bioeconomic basket in relation to total formal income. Nationally, the indicator remains stable, with a slight increase from 5.77% (2011) to 6.05% (2021) and a peak in 2020 (6.10%). This trajectory, combined with  $I_{po}$ , tends to indicate that the bioeconomy maintains a relative weight in formal labor income throughout the decade, with variations associated with sectoral restructuring and short-term shocks that affected economic segments differently (Machado et al., 2021; Lima, Pinto, 2022).

The highest levels are concentrated in the Center-West and South, with MT (18.33% in 2021), MS (16.73%) and GO (12.40%) maintaining high shares of state income from the bioeconomy; in the South, SC (9.10%), PR (9.23%) and RS (7.00%) maintain a prominent position. The largest increases occur in RO (+3.63%) and TO (+2.65%), followed by MS (+1.29%), PR (+0.72%), RS (+0.77%), MG (+0.64%), and GO/MT (+0.69/+0.75%), which are in line with agro-industrial densification in slaughter, dairy, and food, as well as with greater local value capture in processing, which reinforces employment-income links and sustains high levels in these states (Lima; Pinto, 2022; Souza et al., 2023). The literature warns that trajectories guided by biomass volume, without inclusive governance arrangements, can increase distributive asymmetries, a relevant point for interpreting the gains in the Central-West (Lima, 2022).

In the Southeast, Minas Gerais advanced to 7.60% and São Paulo fell to 5.48%, while Rio de Janeiro remained low (1.21%), reflecting a less intensive production structure in bio-based chains. This contrast is consistent with chains such as sugarcane, in which the lack of

diversification into bioproducts and cascading use limits the effects on jobs and wages, reducing the relative weight when the sectoral cycle cools down, as is the case in São Paulo (Scheiterle et al., 2018) In the Northeast, BA grew to 5.29%, but AL fell from 16.30% to 8.67% (-7.63%), with declines also in PB (4.72%), PE (6.07%) and CE (4.03%). The situation is consistent with the shrinkage of traditional complexes and with qualification requirements that tend to concentrate “green” jobs in urban-industrial hubs, hindering regional diffusion (Muçouçah, 2009; Souza et al., 2023; Ansanelli et al., 2025).

North and borders: RO (8.10% in 2021) and TO (7.88%) registered significant gains, while PA fluctuated around 5%–5.3%. Evidence for 2020–2021 in MATOPIBA describes the creation of formal jobs, a change in the hiring profile, and greater female participation, which helps explain the increase in the share of the “bio” wage bill in the new frontiers, in line with the increases in RO and TO (Loayza, Reis, Jesus, 2024). At the same time, the spatial organization of the bioeconomy in the Amazon, with industrial concentration in capital cities and dispersed primary bases, limits linkages and territorial diffusion, which contributes to the stability observed in PA and to intraregional heterogeneities. The coexistence of a “plantation” hub and sociobiodiverse systems reinforces the need for policies that connect conservation, inclusion, and industrialization to sustain the indicator over time (Willerding et al., 2020; Ollinaho, Kröger, 2023; Moscow et al., 2024).

**Table 5:** Formal ties in bioeconomy segments in relation to total formal ties ( $I_{po}$ ), in each state, between 2011 and 2021

State	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
$I_{po}$ AC	5.08%	4.82%	4.77%	4.99%	5.24%	5.87%	5.64%	5.45%	5.02%	4.70%	4.50%
$I_{po}$ AL	21.02%	19.56%	17.28%	15.02%	14.66%	14.93%	14.16%	12.78%	11.72%	12.63%	12.03%
$I_{po}$ AP	1.86%	1.73%	1.79%	1.67%	1.84%	1.68%	1.67%	1.67%	1.46%	1.50%	1.54%
$I_{po}$ AM	2.57%	2.70%	2.71%	2.65%	2.95%	2.79%	2.72%	2.69%	2.53%	2.55%	2.48%
$I_{po}$ BA	6.71%	6.69%	6.60%	6.51%	6.53%	6.95%	6.95%	7.01%	7.06%	7.29%	7.15%
$I_{po}$ CE	6.07%	6.05%	5.84%	5.79%	5.72%	5.73%	5.52%	5.49%	5.36%	5.58%	5.43%
$I_{po}$ DF	1.61%	1.68%	1.48%	1.42%	1.43%	1.40%	1.40%	1.45%	1.72%	1.49%	1.75%
$I_{po}$ ES	6.50%	6.22%	6.21%	6.23%	6.41%	6.37%	6.56%	6.58%	6.62%	6.39%	6.36%
$I_{po}$ GO	13.71%	13.83%	13.88%	14.10%	13.92%	14.20%	14.01%	13.98%	14.09%	14.74%	14.30%
$I_{po}$ MA	5.70%	5.41%	5.01%	4.95%	4.88%	5.03%	4.75%	4.58%	4.55%	4.92%	4.61%
$I_{po}$ MG	9.93%	9.65%	9.72%	9.68%	10.10%	10.36%	10.32%	10.23%	10.07%	10.28%	10.10%
$I_{po}$ MS	19.69%	20.33%	20.00%	19.83%	20.05%	20.53%	20.10%	20.35%	20.35%	21.33%	20.33%
$I_{po}$ MT	20.71%	19.97%	20.13%	20.05%	19.94%	20.65%	21.35%	21.20%	21.82%	22.20%	21.33%
$I_{po}$ PA	7.54%	7.68%	7.33%	7.47%	7.65%	7.96%	8.31%	8.22%	7.93%	8.34%	8.31%
$I_{po}$ PB	8.09%	7.71%	7.54%	7.32%	7.16%	7.37%	7.19%	7.20%	7.12%	7.46%	6.78%
$I_{po}$ PE	9.54%	8.74%	8.40%	8.61%	8.55%	8.86%	8.89%	8.76%	8.89%	9.12%	8.87%
$I_{po}$ PI	4.71%	4.74%	4.38%	4.44%	4.38%	4.24%	4.24%	4.69%	4.64%	4.74%	5.03%
$I_{po}$ PR	10.98%	10.17%	10.64%	10.73%	10.94%	10.69%	11.11%	10.87%	11.02%	11.70%	11.41%
$I_{po}$ RJ	2.12%	2.10%	1.98%	1.99%	2.03%	2.04%	2.04%	1.99%	2.02%	2.06%	2.00%
$I_{po}$ RN	7.13%	6.92%	6.87%	6.64%	6.79%	7.03%	7.03%	6.99%	6.67%	7.12%	6.97%
$I_{po}$ RO	7.31%	7.62%	7.81%	7.92%	8.42%	8.67%	9.40%	9.59%	9.65%	9.82%	10.68%
$I_{po}$ RR	2.24%	2.44%	2.79%	2.78%	2.74%	2.88%	2.46%	2.71%	3.02%	3.23%	3.37%
$I_{po}$ RS	8.23%	7.80%	7.76%	7.82%	8.15%	8.36%	8.30%	8.38%	8.41%	8.88%	8.75%
$I_{po}$ SC	10.86%	9.93%	10.37%	10.18%	10.25%	10.41%	10.71%	10.54%	10.62%	11.10%	10.85%
$I_{po}$ SE	8.15%	8.05%	7.39%	7.60%	7.44%	7.47%	7.14%	7.10%	7.27%	7.51%	7.73%
$I_{po}$ SP	7.19%	6.94%	6.73%	6.54%	6.70%	6.65%	6.79%	6.58%	6.63%	6.71%	6.50%
$I_{po}$ TO	9.78%	10.26%	10.39%	10.48%	11.01%	11.45%	10.56%	10.67%	10.97%	12.09%	11.54%

$I_{po}$ <b>BR</b>	<b>7.97%</b>	<b>7.70%</b>	<b>7.61%</b>	<b>7.53%</b>	<b>7.68%</b>	<b>7.80%</b>	<b>7.90%</b>	<b>7.82%</b>	<b>7.89%</b>	<b>8.14%</b>	<b>7.98%</b>
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Source: prepared by the author, based on the inventory 12/31 (RAIS) 2011-2021, 2025.

**Table 2:** Share of wages from bioeconomy segments in relation to total income ( $I_{rend}$ ), in each state, between 2011 and 2021

State	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
$I_{rend}$ <b>AC</b>	2.52%	2.36%	2.45%	2.50%	2.74%	3.41%	3.25%	2.96%	2.60%	2.26%	2.19%
$I_{rend}$ <b>AL</b>	16.30%	15.10%	13.03%	11.11%	10.83%	11.14%	10.36%	9.36%	8.37%	8.73%	8.67%
$I_{rend}$ <b>AP</b>	0.93%	0.86%	0.87%	0.79%	0.87%	0.98%	1.08%	0.76%	0.64%	0.67%	0.75%
$I_{rend}$ <b>AM</b>	1.82%	1.99%	1.96%	1.91%	2.06%	2.00%	1.97%	1.90%	1.70%	1.76%	1.76%
$I_{rend}$ <b>BA</b>	4.72%	4.77%	4.80%	4.61%	4.60%	4.88%	4.87%	4.96%	5.01%	5.25%	5.29%
$I_{rend}$ <b>CE</b>	4.59%	4.57%	4.53%	4.38%	4.30%	4.40%	4.20%	4.10%	3.95%	4.08%	4.03%
$I_{rend}$ <b>DF</b>	0.69%	0.78%	0.75%	0.72%	0.51%	0.52%	0.51%	0.51%	0.59%	0.51%	0.63%
$I_{rend}$ <b>ES</b>	4.41%	4.20%	4.27%	4.24%	4.29%	4.36%	4.53%	4.52%	4.48%	4.56%	4.52%
$I_{rend}$ <b>GO</b>	11.71%	11.91%	12.17%	12.27%	12.01%	12.24%	12.06%	11.73%	11.82%	12.42%	12.40%
$I_{rend}$ <b>MA</b>	4.19%	4.11%	4.10%	4.24%	3.96%	3.99%	3.77%	3.61%	3.49%	3.71%	3.67%
$I_{rend}$ <b>MG</b>	6.96%	7.00%	7.21%	7.11%	7.34%	7.62%	7.66%	7.58%	7.45%	7.66%	7.60%
$I_{rend}$ <b>MS</b>	15.44%	16.61%	16.58%	16.42%	16.51%	17.11%	16.45%	16.60%	16.21%	17.34%	16.73%
$I_{rend}$ <b>MT</b>	17.58%	17.08%	17.34%	17.40%	17.29%	17.56%	18.25%	18.31%	18.44%	19.04%	18.33%
$I_{rend}$ <b>PA</b>	5.12%	5.21%	4.91%	4.96%	5.09%	5.29%	5.65%	5.29%	4.96%	5.17%	5.34%
$I_{rend}$ <b>PB</b>	5.50%	5.37%	5.39%	5.20%	5.12%	5.29%	5.04%	4.98%	4.84%	4.99%	4.72%
$I_{rend}$ <b>PE</b>	6.73%	6.15%	5.85%	6.01%	5.99%	6.26%	6.14%	6.00%	6.04%	6.15%	6.07%
$I_{rend}$ <b>PI</b>	3.33%	3.42%	3.26%	3.17%	3.11%	2.97%	2.96%	3.24%	3.26%	3.33%	3.69%
$I_{rend}$ <b>PR</b>	8.51%	7.88%	8.22%	8.36%	8.53%	8.41%	8.77%	8.53%	8.63%	9.50%	9.23%
$I_{rend}$ <b>RJ</b>	1.32%	1.32%	1.23%	1.26%	1.29%	1.33%	1.31%	1.28%	1.25%	1.25%	1.21%
$I_{rend}$ <b>RN</b>	4.23%	4.09%	4.08%	3.93%	4.09%	4.23%	4.25%	4.18%	3.91%	4.11%	4.17%
$I_{rend}$ <b>RO</b>	4.47%	4.81%	5.08%	5.19%	5.62%	5.89%	6.53%	6.81%	6.90%	6.71%	8.10%
$I_{rend}$ <b>RR</b>	1.28%	1.48%	1.68%	1.68%	1.66%	1.53%	1.20%	1.27%	1.43%	1.54%	1.74%
$I_{rend}$ <b>RS</b>	6.23%	5.98%	5.98%	6.06%	6.35%	6.63%	6.54%	6.52%	6.55%	6.93%	7.00%
$I_{rend}$ <b>SC</b>	9.13%	8.32%	8.68%	8.45%	8.47%	8.58%	8.77%	8.66%	8.76%	9.22%	9.10%
$I_{rend}$ <b>SE</b>	4.64%	4.55%	4.21%	4.30%	4.41%	4.33%	4.14%	4.07%	4.43%	4.47%	4.82%

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<i>I<sub>rend</sub></i> <b>SP</b>	5.87%	5.81%	5.74%	5.60%	5.63%	5.73%	5.68%	5.42%	5.55%	5.70%	5.48%
<i>I<sub>rend</sub></i> <b>TO</b>	5.23%	6.04%	6.77%	6.41%	6.76%	7.33%	6.79%	6.84%	6.90%	8.07%	7.88%
<i>I<sub>rend</sub></i> <b>BR</b>	<b>5.77%</b>	<b>5.69%</b>	<b>5.69%</b>	<b>5.62%</b>	<b>5.69%</b>	<b>5.86%</b>	<b>5.91%</b>	<b>5.79%</b>	<b>5.86%</b>	<b>6.10%</b>	<b>6.05%</b>

Source: prepared by the author, based on the inventory 12/31 (RAIS) 2011-2021, 2025.

In short, the  $I_{po}$  is close to 8% over the decade and the  $I_{rend}$  is around 6%, with a slight increase until 2021. Where there is agro-industrial density (Southeast/South/Central-West), the  $I_{rend}$  advances relatively more; in primary or restructuring areas (part of the Northeast), the share of income grows less than that of employment, which reinforces the agenda of bioproduct diversification and cascading use. In this way, the spatial reconfiguration of the formal labor market in the bioeconomy, marked by the advance of primary specialization in regions such as MATOPIBA and the Arco Norte, in contrast with the consolidation of agro-industrialization in the Center-South, raises important questions for Brazil's climate and social agenda. The debate is timely in the context of COP30 in Belém, in the heart of the Amazon (Brazil, 2024a). In this setting, the National Bioeconomy Strategy, instituted in June 2024, sets guidelines aimed at reducing inequalities with a focus on regional development and on the inclusion of women and youth in bioeconomy value chains (FAO, 2024; Brazil, 2024a, 2024b).

A joint reading of employment and income reinforces this orientation. There is a gap in primary areas, in which the income participation index,  $I_{rend}$ , grows less than the employment participation index,  $I_{po}$ . This mismatch indicates the need to implement the objectives of the National Bioeconomy Strategy and of the ABC+ Sectoral Plan, 2020 to 2030, with emphasis on inclusive regional development. ABC+ seeks to foster adaptation to climate change and mitigation of greenhouse gases, GHG, while strengthening Technical Assistance and Rural Extension and professional training for the adoption of Sustainable Production Systems, Practices, Products and Processes, such as bioinputs and agroforestry systems (Brazil, 2021; Brazil, 2024a, 2024b). The expansion of practices such as the restoration of degraded pastures and integration systems, Crop, Livestock and Forest Integration and Agroforestry Systems, which are central targets of ABC+, increases resilience and contributes to GHG mitigation. It also creates room for productive diversification and for increases in employment and income among rural producers, especially in vulnerable regions (Brazil, 2021).

Based on this diagnosis, employment and income dynamics provide a concrete reference to articulate cross-cutting policies. Among the instruments, the Brazilian Sustainable Taxonomy, proposed to guide government and private activities, can direct green finance capital to territories and groups of activities with greater capacity to add value and reduce asymmetries. In this way, the bioeconomy advances in a fair and equitable manner, consistent with Brazil's sustainable development commitments and with the targets of its Nationally Determined Contribution (Brazil, 2021, 2023b, 2025). To understand where this employment

and this income are formed, Table 7 breaks down the 100 percent BIO core by BIO groups, macroregions and profiles of employment relationships.

At the sectoral level, there is a shift toward processing. Slaughter and meat products, including dairy and fishery products, increased their share by 21.4%, and other food products increased by 12.4%. Manufacture of pulp, paper, and paper products remained close to its initial level, down 2.0%, with a slight gain in relative share. In contrast, declines were recorded in Sugar manufacturing and refining, down 36.8%; Biofuel manufacturing, down 18.6%; Tobacco product manufacturing, down 30.1%; and Textile product manufacturing, down 20.0%. In the primary sector, there was a decline in Agriculture, including agricultural support and post-harvest, down 11.7%; and Forestry production, fishing, and aquaculture, down 23.2%. This movement, visible in Figures 1 and 2, explains cases where  $I_{po}$  remains elevated while the  $I_{rend}$  advances more slowly, the diffusion of employment in the BIO base does not automatically convert into wage mass, which tends to grow where the chains are organized as value networks, with cascading use and diversification of bioproducts (Scheiterle et al., 2018; File; Pinto, 2022; Souza et al., 2023).

**Table 3:** Profile of formal BIO ties by selected characteristics, Brazil, 2011–2021

Variable	2011		2021		Relative change in number of observations 2011–2021 (%)
	Number of observations	Percentage %	Number of observations	Percentage %	
<b>BIO Group</b>					
A - Agriculture, including agricultural support and post-harvest	1,815,205	28.58	1,602,812	26.94	-11.70
B - Livestock, including support	823,007	12.96	788,106	13.25	-4.24
C - Forestry production, fishing and aquaculture	280,350	4.41	215,207	3.62	-23.24
D - Slaughter and meat products, including dairy and fishery products	865,679	13.63	1,051,026	17.67	21.41
E - Sugar manufacturing and refining	575,307	9.06	363,746	6.11	-36.77
F - Other food products	864,282	13.61	971,325	16.33	12.39
G - Beverage manufacturing	187,829	2.96	161,423	2.71	-14.06
H - Manufacture of tobacco products	42,724	0.67	29,879	0.5	-30.07
I - Manufacture of textile products	435,105	6.85	348,163	5.85	-19.98
J - Manufacture of pulp, paper and paper products	245,387	3.86	240,578	4.04	-1.96
K - Biofuel production	217,142	3.42	176,668	2.97	-18.64
<b>Region</b>					
North	262,122	4.12	292,739	4.92	11.68
North East	1,126,422	17.73	950,664	15.98	-15.60
South	2,786,862	43.87	2,360,819	39.68	-15.29
Southeast	1,315,918	20.72	1,403,587	23.59	6.66
Midwest	860,693	13.55	941,124	15.82	9.34
<b>Characteristics of the individual</b>					
<b>Sex</b>					
Masculine	4,812,977	75.77	4,434,607	74.54	-7.86
Feminine	1,539,040	24.23	1,514,326	25.46	-1.61
<b>Age</b>					
10 to 14 years old	371	0.01	548	0.01	47.71
15 to 17 years old	55,152	0.87	36,538	0.61	-33.75
18 to 24 years old	1,380,371	21.73	1,101,940	18.52	-20.17
25 to 29 years old	1,172,940	18.47	927,576	15.59	-20.92
30 to 39 years old	1,860,090	29.28	1,702,304	28.62	-8.48
40 to 49 years old	1,193,879	18.8	1,277,224	21.47	6.98
50 to 64 years old	651,233	10.25	833,847	14.02	28.04
65 years or older	37,958	0.6	68,952	1.16	81.65

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<b>Race color</b>					
Whites and yellows	3,433,912	54.06	2,438,067	40.98	-29.00
Black and brown people	2,589,978	40.77	2,640,628	44.39	1.96
Others	328.127	5.17	870,238	14.63	165.21
<b>Education</b>					
Illiterate	171,162	2.69	98,750	1.66	-42.31
Up to 5th inc.	881,744	13.88	465,737	7.83	-47.18
5th co fund	761,137	11.98	343,038	5.77	-54.93
6. The 9. Fund	1,034,819	16.29	681,493	11.46	-34.14
Fund compl	939,617	14.79	723,167	12.16	-23.04
Average incompl	582,293	9.17	610,650	10.26	4.87
Average complete	1,654,536	26.05	2,557,010	42.98	54.55
Incompl . Sup.	113,172	1.78	122,941	2.07	8.63
Sup. Compl	209,463	3.3	340,376	5.72	62.50
Master's degree	3130	0.05	4,285	0.07	36.90
Doctorate	944	0.01	1,486	0.02	57.42
<b>Bond time</b>					
Up to 2.9 months	755,186	11.89	575,301	9.67	-23.82
3.0 to 5.9 months	1,152,403	18.14	930,870	15.65	-19.22
6.0 to 11.9 months	1,315,673	20.71	1,004,592	16.89	-23.64
12.0 to 23.9 months	1,004,250	15.81	875,890	14.72	-12.78
24.0 to 35.9 months	518,474	8.16	526,226	8.85	1.50
36.0 to 59.9 months	608,107	9.57	594,686	10	-2.21
60.0 to 119.9 months	592,398	9.33	760,701	12.79	28.41
120.0 months or more	405,526	6.38	680,667	11.44	67.85
<b>Contracted time</b>					
Up to 12 hours	8,888	0.14	95,835	1.61	978.25
1 to 3 pm	806	0.01	3,679	0.06	356.45
4 to 8 pm	23,100	0.36	55,141	0.93	138.71
9:30 pm to 9:30 pm	39,118	0.62	60,458	1.02	54.55
31 to 40 hours	121,819	1.92	213,315	3.59	75.11
41 to 44 hours	6,158,286	96.95	5,520,505	92.8	-10.36

Source: prepared by the author, based on the inventory 12/31 (RAIS) 2011 and 2021, 2025.

Territorially, the total number of formal bioindustry links in Brazil fell by 6.35%, with losses in the South (-15.3%) and Northeast (-15.6%) and gains in the North (+11.7%), Central-West (+9.3%), and Southeast (+6.7%). This trend is consistent with the internalization of agroindustry in the Central-West, the consolidation of processing hubs in the Southeast, and the expansion of northern fronts aligned with agriculture and processing niches. Evidence from 2020–2021 in MATOPIBA reports the creation of formal positions and changes in the hiring profile, in line with the expansion observed in border states; in the Amazon, the concentration of bioindustries in capital cities and the dispersion of primary bases limit territorial linkages, which helps to understand stabilizations in part of the North and intraregional heterogeneities (Willerding et al., 2020; Loayza, Reis, Jesus, 2024; Moscow et al., 2024; Queiroz-Stein et al., 2024)

The employment profiles indicate demographic and occupational restructuring. Female participation increases from 24.23% to 25.46%, and the age structure shifts to higher groups, with reductions in the 18–24 age group (–20.2%) and 25–29 age groups (–20.9%), relative stability in the 30–39 age group (–8.5%), and expansion in the 40–49 age group (+7.0%), 50–64 age group (+28.0%), and 65+ age group (+81.6%). This pattern is consistent with industrial and logistical relationships that require stable teams and specific qualifications, a recurring feature in bio-industrial activities and green occupations, where training and coordination requirements raise entry barriers and favor regions with a coordinated urban-industrial and agro-industrial base (Muçouçah, 2009; Souza et al., 2023; Ansanelli et al., 2025).

In terms of race/color, "White and Asian" participation decreased from 54.06 to 40.98%, "Black and Brown" increased from 40.77 to 44.39%, and "Others (Indigenous, unidentified, or unknown)" increased from 5.17 to 14.63%. Regarding education, there was a clear increase in qualifications. There was a decline in all age groups up to elementary school, a strong increase in the number of people with completed high school from 26.05 to 42.98%, and an increase in the number of people with completed higher education from 3.30 to 5.72%. Regarding the length of time in formal employment, the results were 60–119.9 months (+28.4 %) and 120 months or more (+67.9%). The set indicates accumulation of specific capital and organizational learning in bio plants and firms, consistent with processes of industrial densification, standardization of routines

and greater technical complexity of regional production arrangements (Lima; Pinto, 2022; Souza et al., 2023; Ansanelli et al., 2025).

In the contracted workday, 41–44 hours remain dominant, but their share falls from 96.95 to 92.80 %, with the expansion of reduced formats, such as up to 12 hours (+978%) and 31–40 hours (+75.1%). Although a minority, these modalities signal a reorganization of shifts, outsourcing of stages, and the growth of auxiliary services. Analytically, the combination of higher qualifications, longer tenure, and contractual diversification is consistent with the agroindustrial densification of the Center-South and the stabilization of  $I_{rend}$  the  $I_{po}$ . Where the transition to transformation links and related services advances, the gap between employment and wages tends to narrow; where primary sectors persist in decline, the share of income grows less than the share of employment, reinforcing the need for innovation policies and governance arrangements focused on value, territorial diffusion, and social inclusion (Scheiterle et al., 2018; Lima, 2022; File; Pinto, 2022; Souza et al., 2023).

## 5. Conclusion

This study mapped the 100% BIO core of the Brazilian bioeconomy based on the RAIS (2011–2021), showing a stable share of formal employment around 8% and a wage bill close to 6% with a slight increase until 2021. These average stabilities, however, indicate territorial reconfiguration, with a greater relative weight in the Center-West and South (associated with agro-industrial densification) and losses in traditional complexes such as sugar in selected states in the Southeast and Northeast. In new frontiers, such as MATOPIBA, formal employment remained resilient in the 2020–2021 biennium, consistent with recent expansion, but with gaps between employment and income participation where processing is incipient. In the Legal Amazon and parts of the semi-arid region, the combination of extensive primary production bases and the concentration of processing in a few urban centers persists, limiting local value capture.

The implications are direct for public policies and private strategies. Priority is given to bioindustrialization close to biomass sources, with cascading use, bioproduct diversification, and logistical integration; the adoption of verifiable targets and criteria anchored in IPO and IREND to guide territorial prioritization, credit, R&D, and public procurement; and the explicit differentiation between "plantation economy" arrangements and those based on sociobiodiversity, in order to avoid conceptual dilution in taxonomies

and reinforce socio-environmental safeguards. Where there is a relevant primary base but little local transformation, the agenda should combine workforce qualification, financing solutions for fixed assets, and governance instruments that reduce coordination costs throughout the supply chains. In light of COP30, scheduled for Belém in 2025, strategies that position sociobiodiversity as a pillar of regional development in the Amazon, with innovation, social justice and respect for Indigenous peoples and local communities, gain prominence, in line with recent public policy guidelines.

The institutional framework provides instruments to make these directions operational. The National Bioeconomy Strategy, established by Decree No. 12,044 of 2024, sets guidelines for reducing inequalities with a focus on regional development, education and professional training, promotion of entrepreneurship and the creation of new jobs. Its effectiveness will depend on the National Bioeconomy Development Plan, which needs to direct financial and economic instruments to strengthen sociobiodiversity activities and family farming in regional complexes with lower average income. The Brazilian Sustainable Taxonomy, under development, should guide public and private actors committed to decent work and the reduction of regional asymmetries.

Incorporating the findings of this study into the targets of the ABC+ Plan, 2020 to 2030, which addresses adaptation and emissions mitigation through Sustainable Production Systems, Practices, Products and Processes and includes a valuation and recognition program, creates alignment among technology promotion, credit and finance. This alignment is especially relevant for territories such as the Arco Norte and MATOPIBA, which show employment growth and require value addition and decentralized industrialization to reduce the income deficit and advance economic, social and environmental sustainability. In the Amazon, accelerating green infrastructure and technical assistance, as set out under Axis I of the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon, Sustainable Productive Activities, is a precondition for converting the forest's socioeconomic base into higher value added green jobs.

Limitations of the findings include the 100% BIO core and the reliance on formal employment relationships captured by RAIS, which may underestimate dimensions of sociobiodiversity and informal employment. Furthermore, the analysis concluded in 2021, not capturing subsequent changes in the agroindustrial cycle or new sectoral public policies. These limitations do not invalidate the results, but they signal caution in extrapolation and indicate clear areas for further development.

For future research, it is recommended to integrate complementary sources that capture informal links and extract productive chains (e.g., regional input-output matrices, sectoral administrative records, and foreign trade data), measure productivity and technological diffusion of bioeconomy segments, and assess the sharing of benefits in sociobiodiversity chains. The systematic incorporation of traceability and territorial impact metrics will facilitate the monitoring of targets and comparison between bioeconomy modalities.

In short, the decade analyzed was not one of rupture, but rather of reallocation of the "where" and "how" employment and income are generated in the 100% BIO core: a lesser role for traditional complexes undergoing restructuring and a greater weight for bioindustries connected to logistics corridors and technologically advanced agricultural fronts. Transforming this movement into inclusive prosperity requires accelerating three vectors: (i) bioindustrialization with cascading use and diversification of bioproducts; (ii) qualification oriented toward the technical and digital skills required by the transformation and logistics links; and (iii) governance that aligns competitiveness, conservation, and benefit sharing. With goals supported by *IPO* and *IREND* and a focus on chains that combine innovation, traceability, and fair distribution, the bioeconomy can establish itself as an effective axis for generating decent work and reducing regional asymmetries, in line with the policy portfolio the country intends to showcase in Belém in 2025.

## References

- Ansanelli, S. L. de M., Moraes, C. S. B. de, & Pigliararmi, D. C. J. (2025). Green jobs: Empirical evidence and methodological approaches. *Observatorio de la Economy Latinoamericana*, 23 (2), e9037. <https://doi.org/10.55905/oelv23n2-097>
- Barbosa, M.O., Rivas, A.A.F., Oliveira, L.A., & Buenafuente, S.M.F. (2021). Bioeconomy: A new path to sustainability in the Amazon? *Research, Society and Development*, 10 (10), e41101018545. <https://doi.org/10.33448/rsd-v10i10.18545>
- Brazil. National Bioeconomy Commission. (2024a). *National bioeconomy development plan: Contextualization chapter, preliminary version for CNBio's consideration*. Federal Government of Brazil.
- Brazil. Ministry of Agriculture, Livestock and Food Supply. (2021). *Sectoral plan for adaptation to climate change and low carbon agriculture 2020–2030: ABC+ operational plan*.
- Brazil. Ministry of Finance, Secretariat of Economic Policy. (2023a). *Brazilian Sustainable Taxonomy: Action plan for public consultation*. Brasília, DF: *Ministry of Finance*. <https://www.gov.br/fazenda/pt-br/orgaos/spe/taxonomia-sustentavel-brasileira/taxonomia-sustentavel-brasileira.pdf>

- Brazil. Ministry of the Environment and Climate Change. (2023b). *Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm), Phase V: Draft under public consultation*. Extraordinary Secretariat for Deforestation Control and Territorial Environmental Planning. [https://www.socioambiental.org/sites/default/files/noticias-e-posts/2023-06/PPCDAm\\_2023PDF\\_230605\\_074206.pdf](https://www.socioambiental.org/sites/default/files/noticias-e-posts/2023-06/PPCDAm_2023PDF_230605_074206.pdf)
- Brazil. (2024b). *Decree No. 12,044, of June 5, 2024, establishes the National Bioeconomy Strategy*. *Brazilian Federal Official Gazette*. Diário Oficial da União. [https://www.planalto.gov.br/ccivil\\_03/\\_ato2023-2026/2024/decreto/d12044.htm](https://www.planalto.gov.br/ccivil_03/_ato2023-2026/2024/decreto/d12044.htm)
- Brazil. Ministry of Labor and Employment, Secretariat of Public Employment Policies, Department of Employment and Wages, & General Coordination of Labor Statistics. (2007). RAIS 2006: Statistical data on employability in Brazil. Brasília, DF: *Ministry of Labor and Employment*. <https://acesso.mte.gov.br/lumis/portal/file/fileDownload.jsp?fileId=8A7C82C339979E2D01399BD70C1F7008>
- Bugge, M. M., Hansen, T., & Klitkou, A. (2016). What is the bioeconomy? A review of the literature. *Sustainability*, 8(7), 691.
- Carayannis, E. G., Barth, T. D., & Campbell, D. F. (2012). The Quintuple Helix innovation model: global warming as a challenge and driver for innovation. *Journal of innovation and entrepreneurship*, 1(1), 2.
- Carbonell, SAM, Cortez, LAB, Madi, LFC, Anefalos, LC, Baldassin Junior, R., & Leal, RLV (2021). Bioeconomy in Brazil: Opportunities and guidelines for research and public policy for regional development. *Biofuels, Bioproducts and Biorefining*, 15 (6), 1675–1695. <https://doi.org/10.1002/bbb.2263>
- Cechin, AD, & Veiga, JED (2010). Georgescu-Roegen 's ecological and evolutionary economics. *Brazilian Journal of Political Economy*, 30, 438-454.
- Fernandes, TLX, Trovão, CJB, Alves, JS, Fornazier, A., & Cruz, AA (2024). Determinants of job retention in times of Industry 4.0: The case of agriculture in Brazil. *Journal of Rural Economics and Sociology*, 62 (4), e274589. <https://doi.org/10.1590/1806-9479.2023.274589>
- Food and Agriculture Organization of the United Nations - FAO. (2024). *Bioeconomy for sustainable food and agriculture: A global opportunity — Position paper*. <https://doi.org/10.4060/cd1976en>
- Gama, A.P., & Brasileiro, T.S.A. (2024). Innovative territories of the bioeconomy: A conceptual approach through a systematic literature review. *Brazilian Journal of Economics*, 78, e122024. <https://doi.org/10.5935/0034-7140.20240012>
- Georgescu-Roegen, N. (1966). *Analytical economics: issues and problems*. Harvard University Press.
- Lima, CZ, & Pinto, TP (2022). *Bioeconomy GDP: Methods and supply relations* (Paper presented at the 50th National Economics Meeting – ANPEC, Fortaleza-CE, December 6–9, 2022). [https://www.anpec.org.br/encontro/2022/submissao/files\\_I/i11-b743dfcc33827840a1e0dccb6c56908.pdf](https://www.anpec.org.br/encontro/2022/submissao/files_I/i11-b743dfcc33827840a1e0dccb6c56908.pdf)
- Lima, MGB (2022). Just transition towards a bioeconomy: Four dimensions in Brazil, India and Indonesia. *Forest Policy and Economics*, 136, 102684. <https://doi.org/10.1016/j.forpol.2021.102684>
- Loayza, ACV, Reis, MVS, & Jesus, FR (2024). The formal agribusiness labor market in MATOPIBA during the pandemic period. *Journal of Economics and Agribusiness*, 22 (2). (No DOI provided). Repository: <https://repositorio.ufc.br/handle/riufc/79729>
- Machado, PG, Cunha, M., Walter, A., Faaij, A., & Guilhoto, JJM (2021). Biobased Economy for Brazil: Impacts and strategies for maximizing socioeconomic Benefits.

- Renewable and Sustainable Energy Reviews*, 139, 110573. <https://doi.org/10.1016/j.rser.2020.110573>
- Mejias, R.G. (2019). Bioeconomics and its applications. *ÍANDÉ: Sciences and Humanities*, 2 (3), 105–121. <https://doi.org/10.36942/iande.v2i3.87>
- Moscon, L.M., Costa, K.V. da, Pero, V., & Gesteira, P. (2024). *Green jobs in Brazil: Characterization and socioeconomic aspects of the labor market between 2012 and 2022* (Discussion Paper No. 004/2024). Institute of Economics, UFRJ. [https://www.ie.ufrj.br/images/IE/TDS/2024/TD\\_IE\\_004\\_2024\\_MOSCON\\_COSTA\\_PE\\_RO\\_SOUZA%20\(1\).pdf](https://www.ie.ufrj.br/images/IE/TDS/2024/TD_IE_004_2024_MOSCON_COSTA_PE_RO_SOUZA%20(1).pdf)
- Muçouçah, P.S. (2009). *Green jobs in Brazil: How many are there, where are they and how will they evolve in the coming years*. International Labour Organization. <https://www.ilo.org/pt-pt/publications/empregos-verdes-no-brasil-quantos-sao-onde-estao-e-como-evoluirao-nos>
- Oliveira, T.J.A., Ummus, M.E., Muñoz, A.E.P., & Vasco, K.D.L. (2024). A spatial perspective of bioeconomy in the Brazilian Amazon. *GEPEC Report*, 28 (2), 117–138. <https://doi.org/10.48075/igepec.v28i2.33222>
- Ollinaho, O.I., & Kröger, M. (2023). separating the two faces of “bioeconomy”: Plantation economy and sociobiodiverse economy in Brazil. *Forest Policy and Economics*, 149, 102932. <https://doi.org/10.1016/j.forpol.2023.102932>
- Pavone, V. (2012). Science, neoliberalism and bioeconomy. *Iberoamerican science magazine technology and society*, 7(20), 145-161.
- Perroux, F. (1977). The concept of development pole. *Regional economy: selected texts. Belo Horizonte: CEDEPLAR*, 145-156.
- Queiroz-Stein, G., Martinelli, F.S., Dietz, T., & Siegel, K.M. (2024). Disputing the bioeconomy-biodiversity nexus in Brazil: Coalitions, discourses and policies. *Forest Policy and Economics*, 158, 103101. <https://doi.org/10.1016/j.forpol.2023.103101>
- Rodrigues, D.C., Ribeiro, A.S., Silva, J.P.S., & Passador, C.S. (2024). Sociobioeconomy and social technology in the Amazon region: An integrated framework proposition. *Journal of Contemporary Administration*, 28 (6), e240223. <https://doi.org/10.1590/1982-7849rac2024240223.en>
- Scheiterle, L., Ulmer, A., Birner, R., & Pyka, A. (2018). From commodity- based value chains to biomass-based value webs: The case of sugarcane in Brazil's bioeconomy. *Journal of Cleaner Production*, 172, 3851–3863. <https://doi.org/10.1016/j.jclepro.2017.05.150>
- Serigati, FC, Possamai, RC, & Diz, LAC (2023). *Methodology for generating data on the bioeconomy labor market* (OCBio technical report). FGV EESP. [https://agro.fgv.br/sites/default/files/2023-06/eesp\\_relatorio\\_bioeconomia-ap1\\_v1.pdf](https://agro.fgv.br/sites/default/files/2023-06/eesp_relatorio_bioeconomia-ap1_v1.pdf)
- Souza, MPR, Ruths, JC, & Piffer, M. (2023). Formal labor market in agribusiness segments in the mesoregions of Paraná. *Journal of Management and Secretariat*, 14 (5), 7404–7428. <https://doi.org/10.7769/gesec.v14i5.2129>
- VERDES, E. (2008). *Green Jobs: Decent Work in a Sustainable and Low-Carbon World*. United Nations Environment Programme. *International Labour Organization. Sep.*
- Willerding, AL, Silva, LR, Silva, RP, Assis, GMO, & Paula, EVC (2020). Strategies for the development of the bioeconomy in the state of Amazonas. *Advanced Studies*, 34 (98), 145–166. <https://doi.org/10.1590/S0103-4014.2020.3498.010>
- Winkler, H., Di Maro, V., Montoya, K., Olivieri, S., & Vazquez, E. (2024). *Measuring green jobs: A new database for Latin America and other regions* (Policy Research Working Paper No. 10794). World Bank.
- World Bank. (2024). *Just transition taxonomy: Narrative report*.