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STI FOR THE AMAZON SOCIO-BIOECONOMY

An assessment of knowledge in the region

In this edition:

The series of thematic bulletins takes place within the scope of the Bioeconomy Observatory (OBio); its mission is to support the development of the Brazilian bioeconomy, providing strategic intelligence to support decision-making in public, academic, and business policies and creating an integrated, structured and interactive space to orchestrate the creation, analysis, and sharing of knowledge about the bioeconomy. The Center for Management and Strategic Studies (CGEE) has launched thematic bulletins in this context. The fourth edition's theme assesses socio-bioeconomic development in the Amazon region.

This bulletin considers the following definition of the bioeconomy:

The bioeconomy comprises all economic activity derived from bioprocesses and bioproducts that contribute to efficient solutions in the use of biological resources—in the face of challenges in food, chemicals, materials, energy production, health, environmental services, and environmental protection—that promote the transition to a new model of sustainable development and the well-being of society (ODBio, 2020; own translation).

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The first edition of the thematic bulletin on the bioeconomy presented a global overview of the main topics covered in scientific publications on the bioeconomy. The second edition focused on Brazilian scientific production, analyzing 8,951 national articles related to the topic. For the third edition, the theme of the Amazon bioeconomy was chosen, encompassing the entire region, to meet a clear demand and understand the opportunities this megadiverse biome offers. A total of 23,752 scientific articles on the integrality of the Amazon were collected from around the world, of which 10,228 were by Brazilian authors—the country that publishes the most in the region. The third bulletin's repercussions highlighted the need to investigate this region's innovative capacity and potential in greater depth. In this fourth edition, we have provided an assessment of knowledge and science, technology, and innovation (STI) to support the development of the Amazonian socio-bioeconomy.

The next sections of this bulletin will present a brief contextualization of the importance of developing a diagnosis of knowledge in the region, followed by three overviews: human resources in STI, scientific production by institutions in the Legal Amazon, and access to the genetic heritage and associated traditional knowledge of the Amazon biome and notifications of finished products based on them. Finally, the conclusions based on the overviews are presented.

1. Amazonian socio-bioeconomy: What do we need to know?

The bioeconomy as a path to sustainable development has increasingly gone from a wish to a national strategy. Discussions in national and international contexts have focused on using the vast availability of biomass and rich socio-biodiversity to promote a cleaner and more prosperous economy.

More recently, the bioeconomy has been discussed within the framework of the G20 through the G20 Bioeconomy Initiative (GIB), aiming to build a common understanding and define high-level principles on the subject (G20, 2024). At the national level, around 17 ministries have some initiatives focused on the bioeconomy. The Ministry of the Environment (MMA), one of the main articulators, is leading the inter-ministerial discussions with other spheres of the business sector, civil society, and academia on constructing the National Bioeconomy Plan The Ministry of Science, Technology, and Innovation (MCTI) is designing the next National STI Strategy, which will have the bioeconomy as a strategic axis. At the sub-national level, we can cite the example of the establishment of Pará's Bioeconomy Plan.

Despite the enormous potential in all regions of the country, the Amazon biome has been receiving special attention when developing a bioeconomy biodiversity. The territory of the Legal Amazon (AML) covers more than 4 million km^2, which corresponds to almost 60% of the national territory (IBGE, 2022),

is the largest reservoir of fresh water and the most important forest block for climate regulation on the planet (NOBRE, C.A. *et al.*, 2023), 2023), is estimated to be home to around 15%-25% of the world's biodiversity (HUBBELL *et al.*, 2008), as well as being home to more than 29 million inhabitants, 1.7 million of whom are indigenous people belonging to 198 peoples (FUNAI, 2022). The dual importance of the Amazon as a carbon store - in the context of climate change and its potential to develop an advanced bioeconomy based on its extraordinary socio-biodiversity - points to an obvious path that deserves to be pursued.

This rich biome, which regulates ecosystem services worldwide, mainly due to its role in global water dynamics, is being increasingly threatened. A recent study with Brazilian authors — on the cover of the renowned scientific journal *Nature* — clarified the risks of threat to the biome. Uncontrolled deforestation combined with climate change could lead to a point of no return by 2050. This point of no return mainly involves the changing water dynamics of the region and its impacts on various parts of the world:

> The *feedback* mechanisms that increase forest resilience lose their strength and are replaced by other feedbacks that increase the risk of a critical transition (Flores B.M. *et al.*, 2024; own translation).

Another expected consequence is the forest reversing the carbon capture process, making it a CO_2 emitter.

Another study that pointed out the risks related to the biome was the *Nova Economia da Amazônia (New Economy of the Amazon)*, coordinated by WRI Brasil (NOBRE, C.A. *et al.*, 2023). The study showed projections of four scenarios for the Amazon, combining restrictions on deforestation and emissions estimated at 7.7 $GtCO_2$ to comply with the Paris Agreement's 1.5°C scenario: 1) reference scenario with no restrictions; 2) scenario in which deforestation is not restricted, but the condition of limiting total emissions is imposed; 3) scenario in which emissions were not restricted, but the condition of zero deforestation was imposed; and 4) with both restrictions. The study shows how the Amazon depends on deforestation efforts and decarbonization technologies (Figure 1).

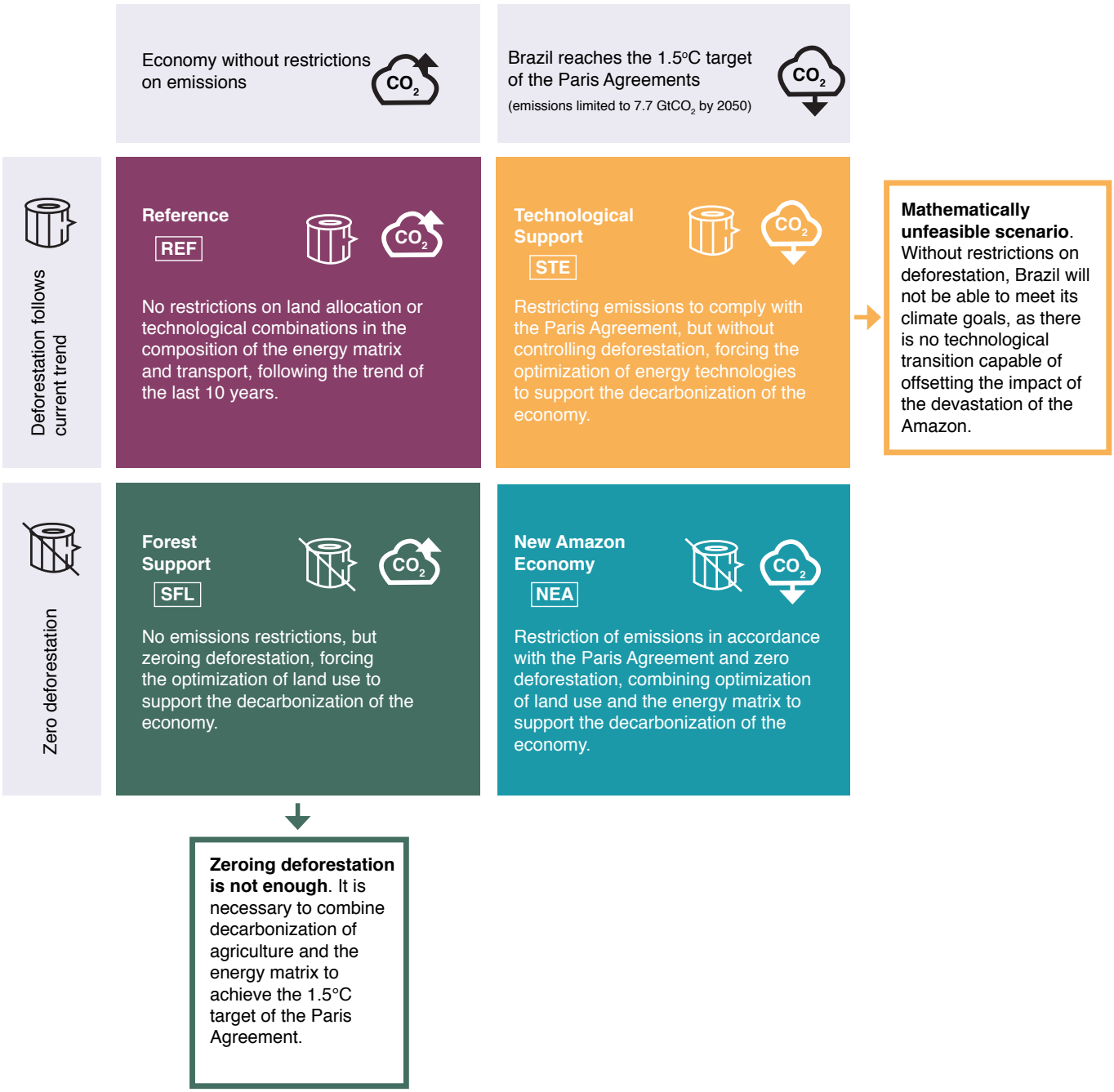


Figure 1 – Economic scenarios from the New Economy of the Amazon study

Source: NOBRE, C.A. *et al.* (2023)

Preventing the arrival of the catastrophic point of no return is already a national mission from the point of view of obligation. However, the same process can occur from the point of view of opportunity. A sustainable standing forest economy that values the region's rich socio-biodiversity is a precious opportunity.

There are various ways of measuring the value of a biodiversity bioeconomy. The World Bank published a study estimating the value of the Amazon rainforest at US$317 billion (WORLD BANK, 2023). The *New Economy of the Amazon* study estimates that Brazil alone could generate an additional 8.2 billion dollars annually by 2050, concerning existing economic activities, by investing in socio-bioeconomies (NOBRE, C.A. *et al.,* 2023). The World Bioeconomy Forum (2022) provides a global perspective in its report, *The Status of the Global Bioeconomy*, in which it is estimated that the value of the world bioeconomy will be in the order of US$ 4 trillion (WORLD BIOECONOMY FORUM, 2022) and that Brazil will play an important role in this scenario (FGV, 2024).

Both the risks and the potential of the biome point to the development of a bioeconomy in the region. Suppose this bioeconomy is to be truly sustainable. In that case, it must be based on innovation but with knowledge, science, technology, and innovation linked to issues specific to the biome, such as the heterogeneous environment (four Amazons in one Amazon: conserved, deforested, under pressure, and urban) and the valuable diversity of peoples and customs. It will be only then possible to achieve the measured potential.

The first step is to know what exists today. What is the current diagnosis of the Amazon region for the development of the bioeconomy? In addition to the studies already mentioned, others also provide specific recent assessments of the region, such as the study *Bioeconomy in the Amazon—Conceptual, Regulatory and Institutional Analysis* (AMAZÔNIA 2030, 2022), in which national and international policies and strategies dedicated to the topic were mapped. The main regulatory frameworks (Figure 2) and governance institutions related to the activities in Brazil were analyzed. Mention should also be made of the book Infraestrutura para o Desenvolvimento Sustentável da Amazônia (Infrastructure for the Sustainable Development of the Amazon) (ABRAMOVAY, 2022) and the study Educação em Perspectivas Contextos e Caminhos para a Amazônia Legal (Education in Perspectives - Contexts and Paths for the Legal Amazon) (Uma Concertação pela Amazônia, 2023).

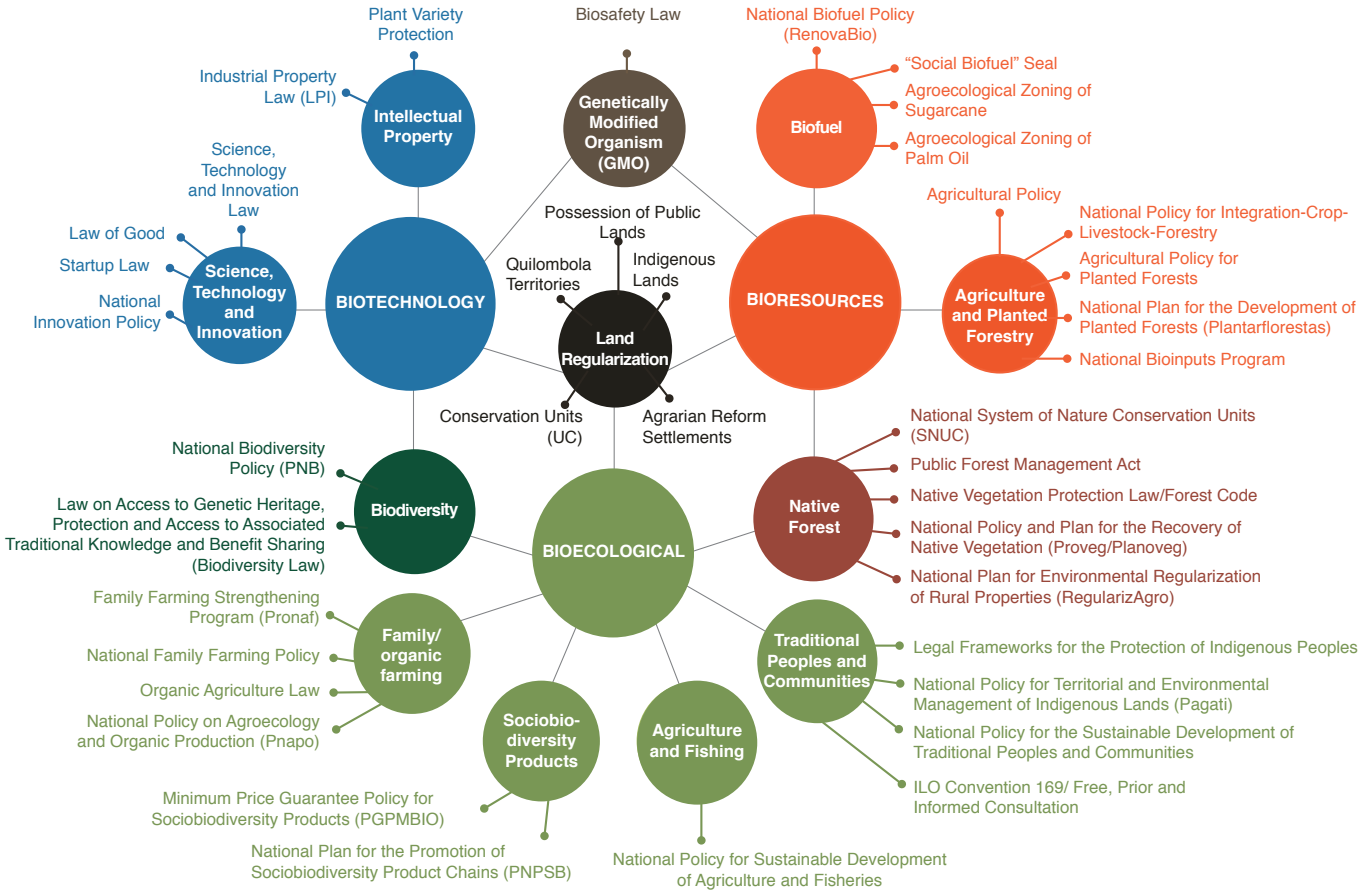


Figure 2 – Main regulatory frameworks in the three visions of the bioeconomy

Source: CPI/PUC-Rio, 2022.

These and other various efforts have been made to explore the different areas of knowledge to fill in the gaps or even the pieces of a great puzzle of knowledge that needs to be assembled to see an assessment of the Amazon region. The development of the region's bioeconomy will depend on these many different pieces of knowledge. For example, *box* 1, produced in partnership with CGEE's Space Technology Observatory (OTE), shows how essential space technologies are for controlling and monitoring the Amazon region.

Box 1 – Space Technology Observatory

The Space Technology Observatory (OTE) is an initiative of the Center for Management and Strategic Studies (CGEE). It aims to monitor the development of space technologies worldwide, identify trends and technological opportunities in this sector, and generate information on technologies of interest to the Brazilian space sector.

To disseminate this information, the OTE publishes biannual bulletins and annual volumes of the *Strategic Documents for the Space Sector* series, which deal with aspects of technologies of national interest in greater detail. In addition, preliminary designs of artifacts linked to the space sector are produced in addition to these volumes. For example, projects for a remote sensing satellite and small satellite launch vehicles have been produced.

The *Brazilian Imager for Swir Applications* (Brisa), shown in Figure 3, is a small satellite whose mission is to produce images of the Earth's surface in the visible and short *wave infrared* (SWIR) electromagnetic spectrum bands. Brisa will use a standardized, low-cost orbital platform known as a CubeSat. CubeSats are satellites built from a cube-shaped structure with a 10 cm edge that defines a U unit. Larger satellites (2U, 3U, 6U, etc.) can be formed by combining two or more U units.

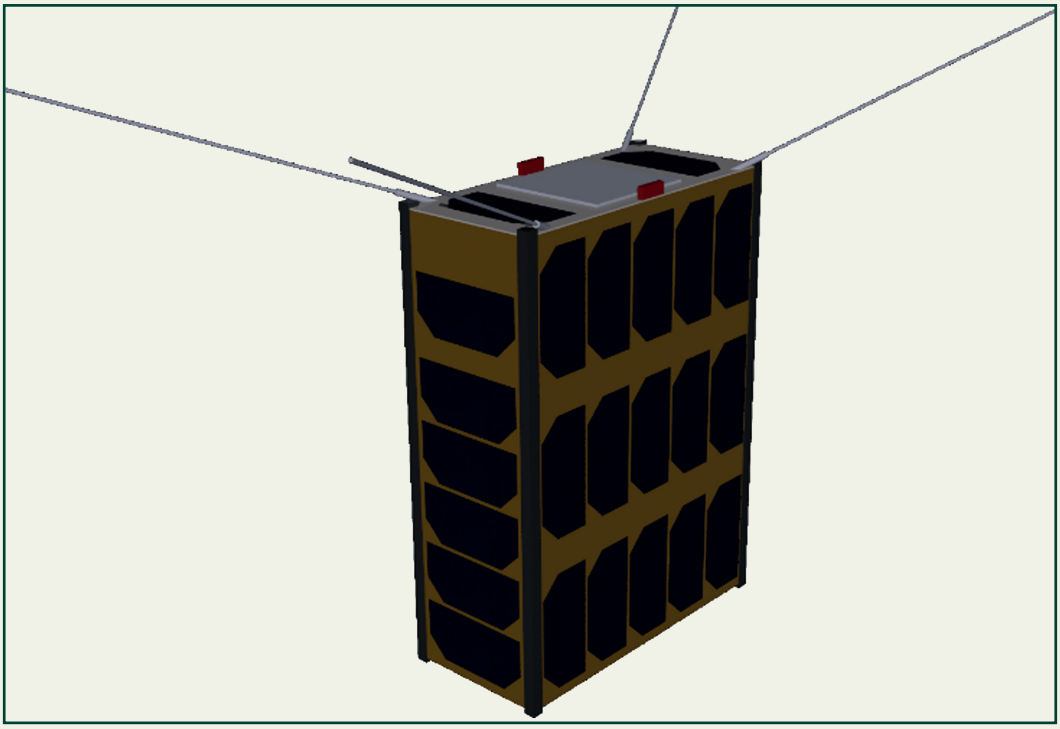


Figure 3 – Artist's rendering of BRISA, *CubeSat* 6U (30 cm x 20 cm x 10 cm)

Source: OTE/CGEE.

Information obtained by the OTE, which included the identification of national competencies capable of developing this satellite, supported the design of the Brisa project. Brisa's imaging capabilities are of particular interest to the Amazon region and enable applications such as:

Environmental monitoring – SWIR bands are valuable for monitoring environmental changes and assessing the impact of human activities on the Earth's surface. SWIR images can detect subtle changes in vegetation cover, including deforestation, urban sprawl, and variations in soil moisture. By analyzing SWIR data over time, information can be obtained on long-term trends to support environmental management and conservation efforts.

Detection of rural property invasion – Satellite images in the visible and SWIR bands can identify changes in the vegetation pattern and illegally built structures. Texture analysis, edge detection, and object classification can be used to identify suspected areas of invasion.

Quantifying deforestation - the visible and SWIR spectrum bands are useful for identifying deforested areas. Temporal analysis of the images can reveal changes in vegetation cover over time. Object classification algorithms and image segmentation techniques can be applied to quantify the extent and rate of deforestation in a given area.

Forest fire response - SWIR bands are especially useful for detecting and monitoring forest fires. SWIR sensors allow observations even in adverse conditions, such as faint smoke and fog, allowing for clearer images of fire-affected areas. By analyzing SWIR images, firefighters and emergency response teams can more effectively track the spread of fires, identify hotspots, and plan fire containment strategies.

Mining - SWIR images play a crucial role in mining activities. Different types of minerals display distinct spectral signatures in the SWIR band, which allows for identifying and mapping mineral reserves. They help direct exploration and mine planning. SWIR images are particularly useful for locating minerals that are difficult to detect using images in other spectral bands. Rock outcrop exposures manifest potential mineral deposits on the surface or underground.

Vegetation analysis - SWIR images are useful for distinguishing different vegetation types and assessing their health. The reflectance properties of healthy vegetation in the SWIR band differ from those of stressed or diseased vegetation. By analyzing SWIR data, researchers and agricultural experts can identify areas of concern, monitor vegetation health, and make land management and crop yield forecasting decisions.

Another OTE project that could interest the Amazon region is the Veículo Nacional para Transporte Orbital [National Orbital Transportation Vehicle] (VeNTO). Designed to launch small satellites (up to 40 kg), such as *CubeSats*, from the Alcântara Launch Center (CLA), it will be able to explore the possibilities of launching satellites in low-inclination orbits, which are interesting for covering the Amazon employing remote sensing satellites, collecting environmental data, etc.

Knowing the importance of evidence-based planning for a low-carbon economy, the Bioeconomy Observatory contributes to collecting key information focused on STI. This edition brings three new overviews. The first focuses on human resources education in STI, focusing on the programs, education, and work of masters and doctors in the region. The second report complements the results of the third bioeconomy bulletin, which presented the world's scientific production on the Amazon and now shows the scientific output of the main STI institutions established in the Legal Amazon. Finally, the third overview presents unpublished data on using genetic heritage and associated traditional knowledge in the Amazon biome, and the resulting products.

2. Human resources for the Amazon region's science, technology, and innovation

Based on the discussion of innovation competencies, this bulletin aims to elucidate the Amazon region's capabilities in terms of human resources for STI. Here, the expression "human resources for STI" will consider the specialization of professionals at the master's and doctoral levels and the programs that educated them. The aim is to present an overview of the Amazon region comprehensively, without a thematic section, since the bioeconomy is interdisciplinary and since the skills required to develop an Amazon bioeconomy go beyond the technical aspects of generating bioproducts, considering the establishment of public policy capacities, business models, socio-technical, regulatory, institutional and technical-administrative capacities, among others.

> Although the number of masters and doctors represents a very small portion of the workforce, they are essential to any country's ability to absorb, transform, produce knowledge, and generate innovations. In addition, they are crucial to the training or qualification of other human resources. For all these reasons, they are vital for increasing the productivity and competitiveness of the Brazilian economy and raising citizens' quality of life in areas such as health. (CGEE, 2019; own translation)

Therefore, this section aims to collect data on masters and doctors in the nine states of the Legal Amazon as part of the elements that need to be identified in assessing innovation capacities for developing an Amazonian socio-bioeconomy.

Initially, data was collected on postgraduate programs for the Amazon region and Brazil. Figure 4 shows the evolution of the number of master's and doctoral programs in Brazil (left axis) and the same evolution only for the Amazonian states (right axis). The increase in the number of master's degree programs in the Amazon region is growing faster than the country's average. However, the absolute figures are lower than in other regions of Brazil.[1] The profile seems to align with the national average for doctorates.

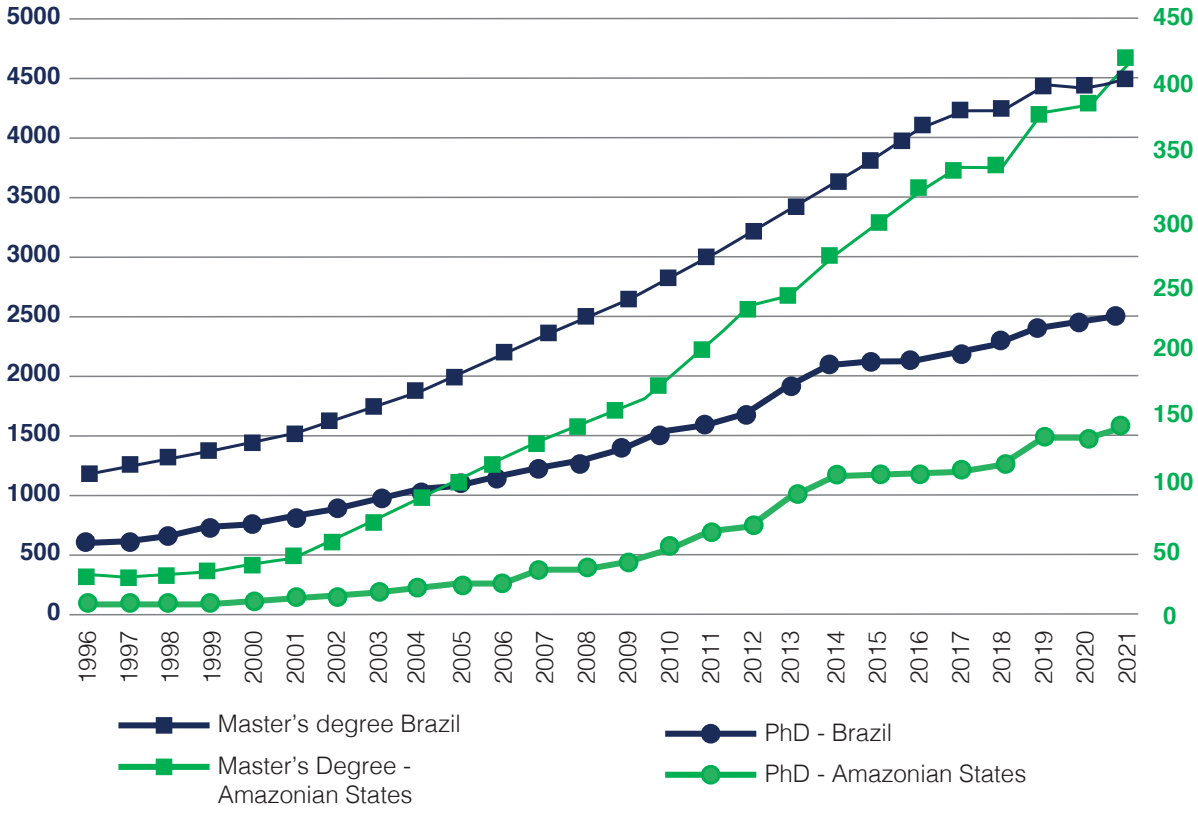


Figure 4 – Evolution of master's and doctoral programs for Brazil and the Amazon states

Source: Prepared by CGEE based on data from the Sucupira Platform - Capes/MEC (1996-2021). https://mestresdoutores2024.cgee.org.br

1 For more information, see the study Masters and Doctors available here.

Figure 5 shows the legal nature of these programs in Brazil and within the section of the Amazonian Federative Units (UF). The vast majority of programs in the Amazon region are federal, a different profile from the national average, with a significant presence of state and private institutions.

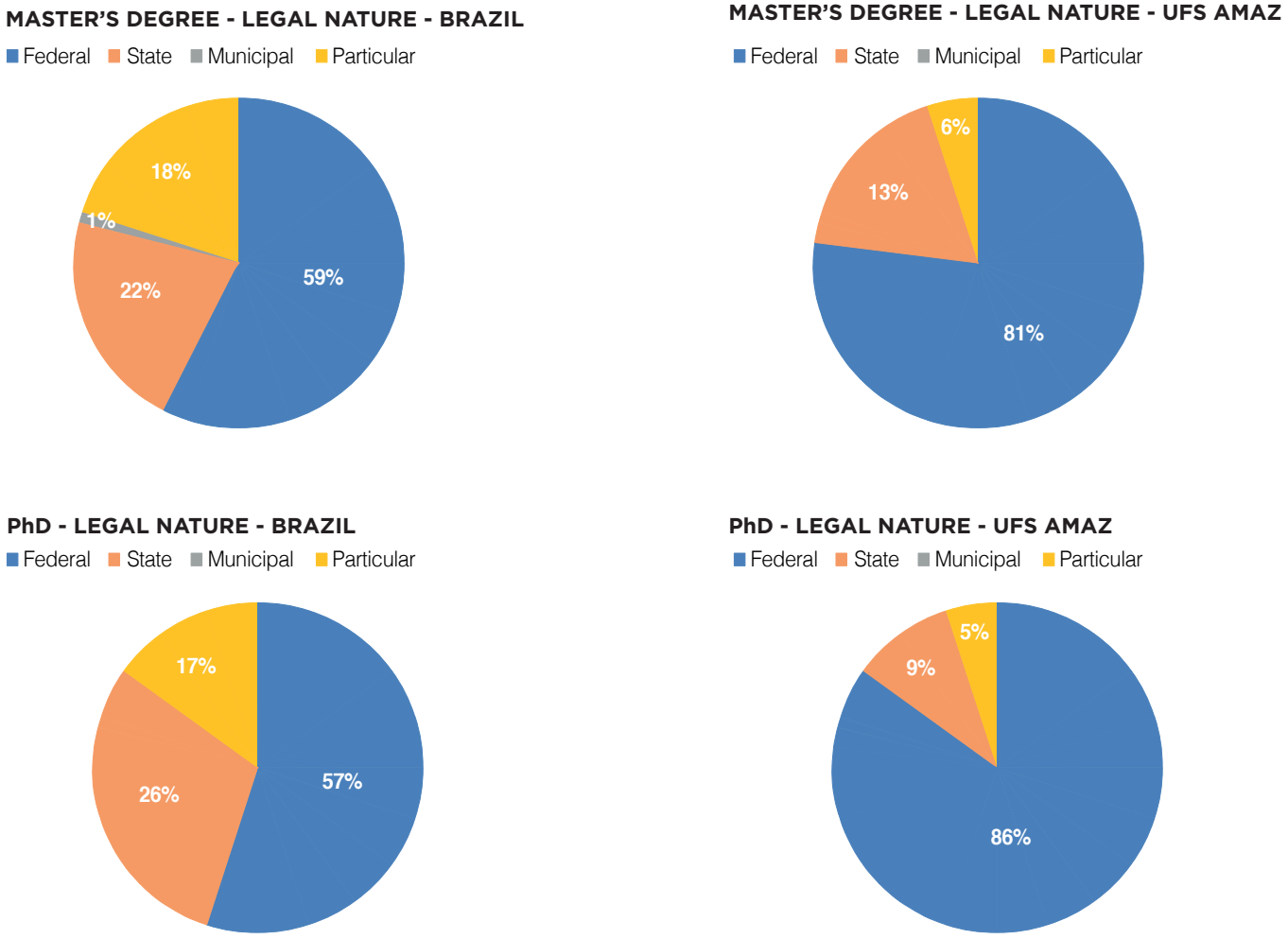


Figure 5 - Legal nature of master's and doctoral programs for Brazil and the Amazon states in 2021

Source: Prepared by CGEE based on data from the Sucupira Platform - Capes/MEC (1996-2021). https://mestresdoutores2024.cgee.org.br

Figures 6 and 7 show the percentage breakdown of master's and doctoral programs in Brazil and the Amazon states by major area of knowledge. In both cases, there are some differences with the national average, such as the greater participation of the biological sciences and multidisciplinary areas and the lower participation of the engineering areas.

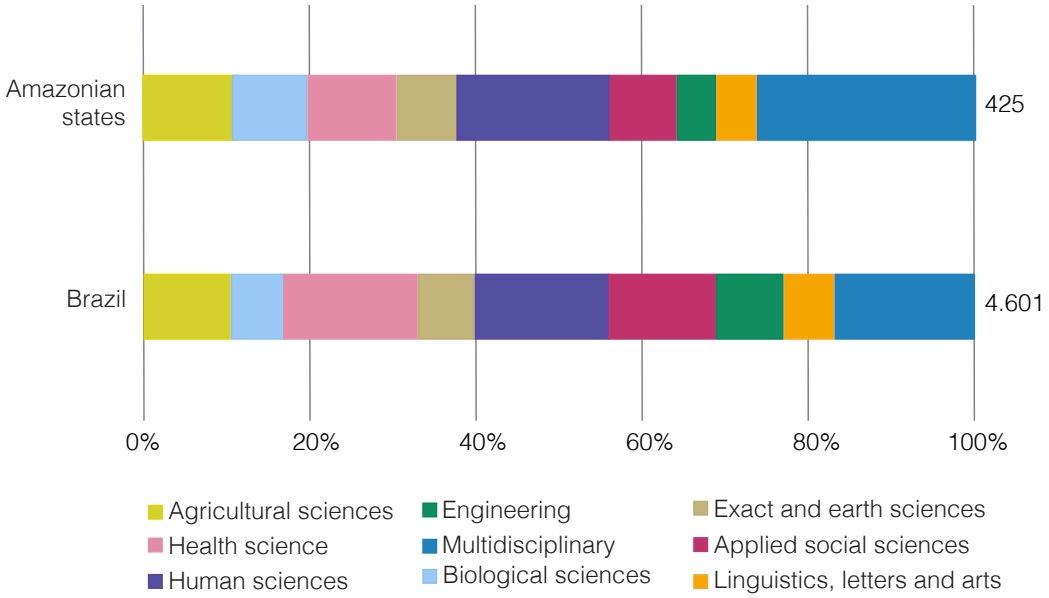


Figure 6 - Percentage breakdown of master's programs in Brazil and the Amazon states by major field of knowledge, 2021

Source: Prepared by CGEE based on data from the Sucupira Platform - Capes/MEC (1996-2021). https://mestresdoutores2024.cgee.org.br

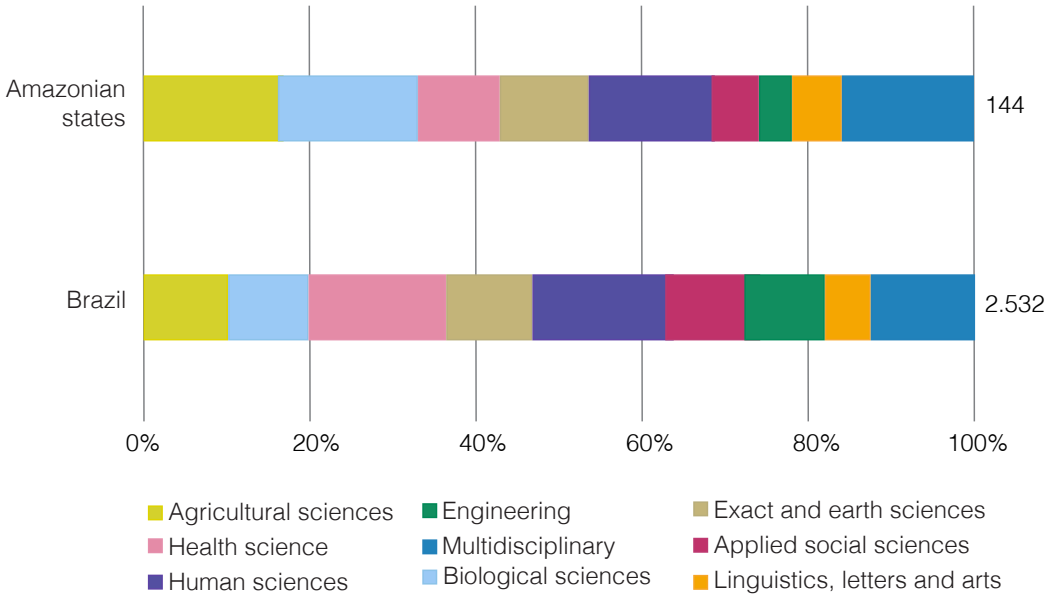


Figure 7 - Percentage breakdown of doctoral programs in Brazil and the Amazon states by major field of knowledge, 2021

Source: Prepared by CGEE based on data from the Sucupira Platform - Capes/MEC (1996-2021). https://mestresdoutores2024.cgee.org.br

As mentioned in the introduction to this section, although the bioeconomy is an area that requires technological innovation - considering that it is based on the use of renewable biological resources - it is impossible to measure how the different thematic profile of the Amazon region affects its innovation process. A more in-depth analysis could identify technologies of interest and thus verify whether there are human resources, programs, and infrastructure in a specific area or sub-area of knowledge.

The number of master's and doctorate graduates reflects the profile in the postgraduate program charts. Figure 8 shows the evolution of the number of master's and doctorate graduates in Brazil (left axis) and the same evolution only for the Amazon states (right axis).

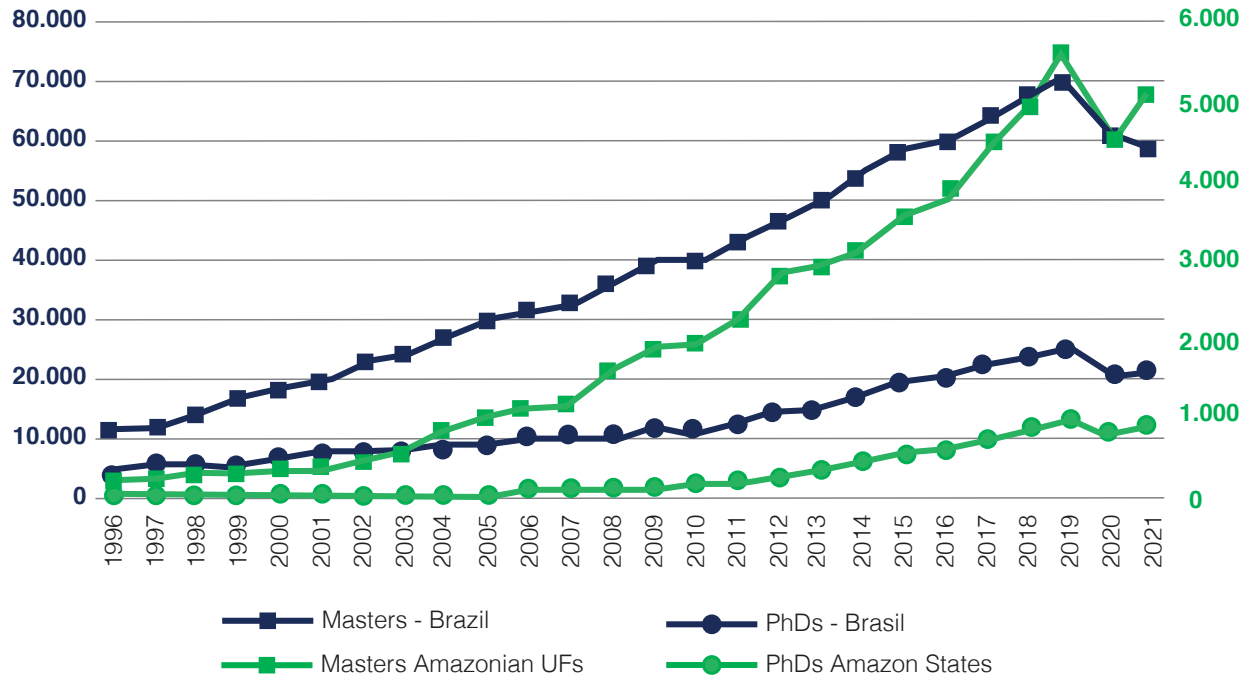


Figure 8 - Evolution of the number of masters and doctors in Brazil (left axis) and the same evolution for only the Amazon states (right axis)

Source: Prepared by CGEE based on data from the Sucupira Platform - Capes/MEC (1996-2021). https://mestresdoutores2024.cgee.org.br

Just as was done for the postgraduate programs, the percentage breakdown of the areas in which masters and doctors work in Brazil and the Amazon states by major area of knowledge was also checked. This result can be seen in both Figures 9 and 10. The biological sciences and multidisciplinary areas stood out from the national average, reflecting the most frequent areas in the programs. Once again, engineering degrees are proportionally fewer.

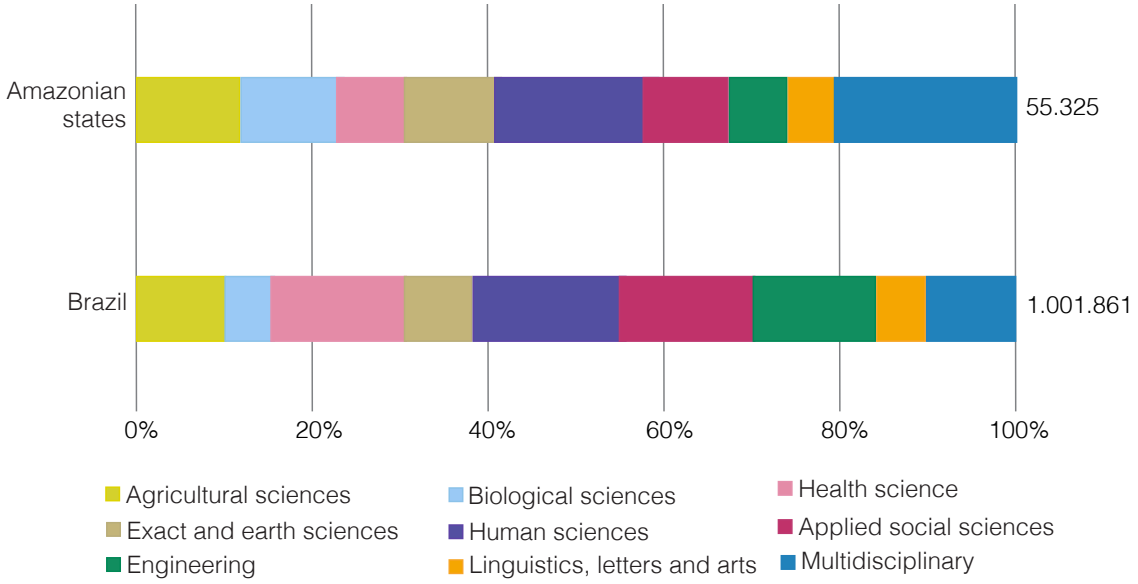


Figure 9 - Percentage share of master's degrees by major field of knowledge in Brazil and the Amazon states, 1996 to 2021

Source: Prepared by CGEE based on data from the Sucupira Platform - Capes/MEC (1996-2021). https://mestresdoutores2024.cgee.org.br

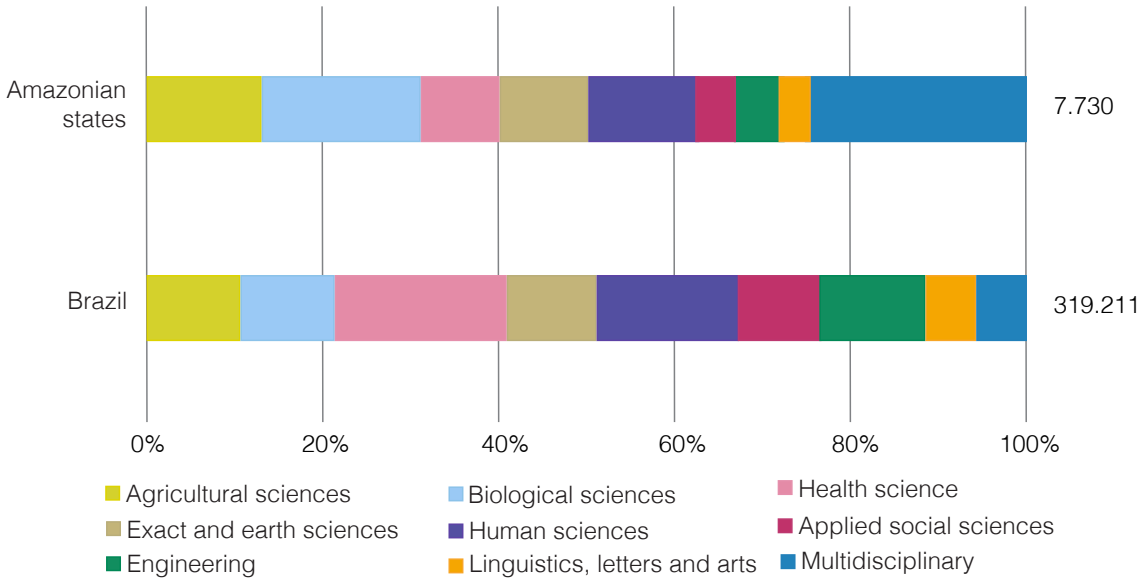


Figure 10 - Percentage share of doctoral degrees awarded in Brazil and the Amazon region by major field of knowledge, 1996-2021

Source: Prepared by CGEE based on data from the Sucupira Platform - Capes/MEC (1996-2021). https://mestresdoutores2024.cgee.org.br

Tracking the number of master's and doctoral graduates in the states of the Legal Amazon is important information for identifying the availability of such specialized human resources in the context of developing a bioeconomy. However, an analysis of these people's professional trajectories (formal employment) should be added to check whether they have remained in the region. It is also crucial to observe whether masters and doctors from other regions of the country have established formal jobs in the Amazon region.

One way of checking this is by locating the formal jobs of current masters and doctors. However, before presenting the analysis of formal employment rates, a few methodological observations are in order:

> When analyzing the formal employment rate of master's and doctoral graduates, the ratio between the number who graduated since 1996 and the number employed in the reference year, which ranged from 2009 to 2021, is considered. It is important to note that the complement to the formal employment rate does not correspond to the unemployment rate since the population of masters and doctors (M&D) without formal employment also includes graduates who, on the reference date, could be, for example, developing research projects with or without a scholarship, carrying out self-employed or self-employed work, undertaking as entrepreneurs or even living abroad. The master's population may still be studying for a doctorate. In any of these possibilities, the individual, despite being employed, has no formal employment relationship.
>
> Another important observation is that it was impossible to remove from the M&D population those who have already died or have retired and left the workforce. Therefore, analyzing the formal employment rate—the ratio between the number of formally employed in the reference year and the total number of M&D graduates since 1996—would tend to underestimate it over the years, as the base of graduates (the denominator of the ratio) grows continuously. In this way, the employment rate is analyzed only for those with 2— and 10-year degrees, reducing the chance of including people outside the workforce (CGEE, 2024; own translation).

The next three graphs, Figures 11, 12, and 13, show the flows of master's degree professionals "from" and "to" different Brazilian states. Figure 11 shows the flow of masters from non-Amazon states to Amazon states. The percentage on the right-hand side of the graph shows the share of these professionals from non-Amazon states in the total number of formal workers. It can be seen that São Paulo is the state from which most masters leave to work formally in the Amazon region. It is also worth noting that, for Tocantins, Roraima, and Maranhão, over 40% of the workforce comes from programs in non-Amazon states. It must be stressed that what is being verified is the flow from the UF where the degree was obtained to the location of formal employment, not the place of birth of this professional.

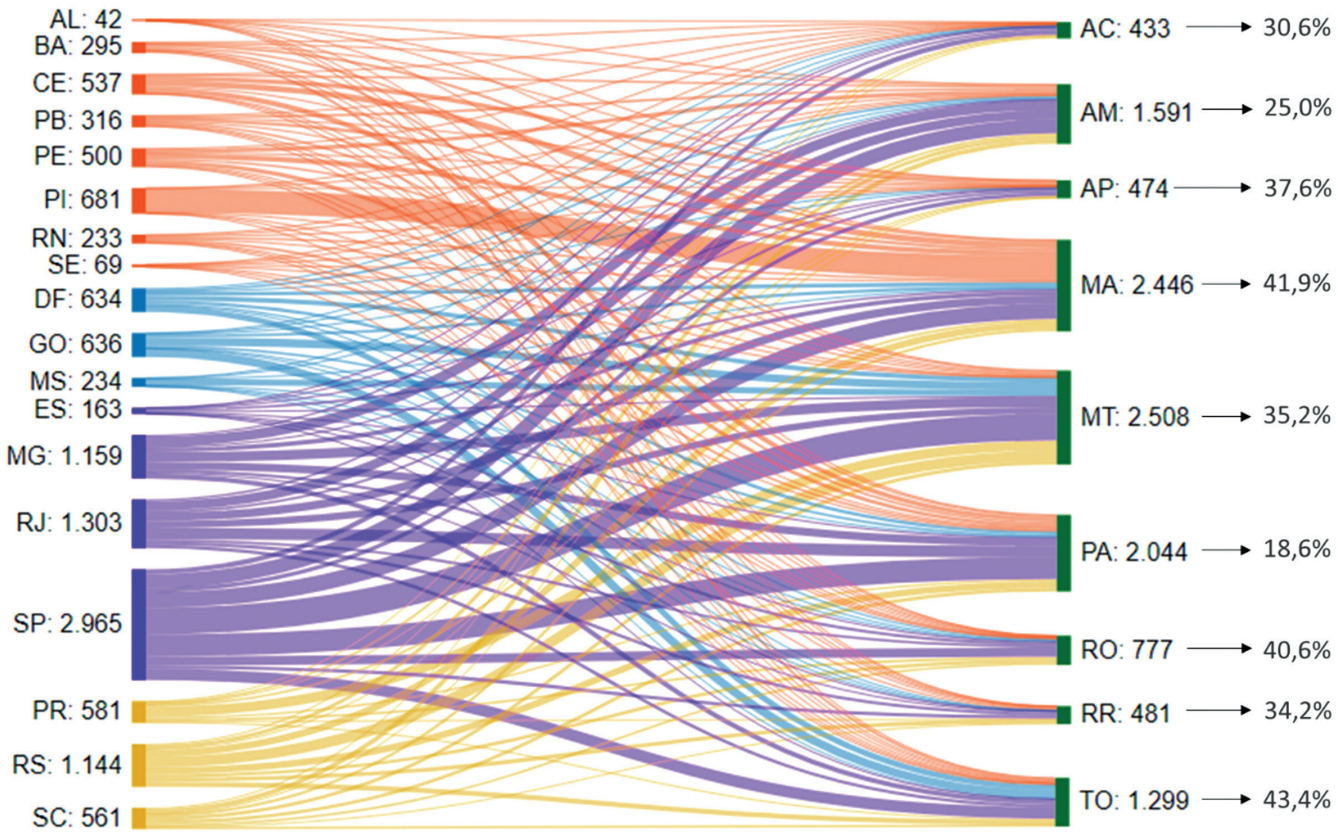


Figure 11 - Mobility of graduates (master's degree) from non-Amazon states to Amazon states

Source: Prepared by CGEE, based on data from the Sucupira Platform - Capes/MEC (1996-2021) and RAIS/MTE (2021).

Figure 12 shows the flow of masters from Amazonian states to Amazonian states, i.e., the flows within the states of the Legal Amazon. This analysis mainly aims to verify the retention/leaving rate of master's degree holders in their degree-granting states. Here, we can highlight Maranhão importing a good number of master's degree holders from other Amazonian states and Pará exporting these professionals, even though, in general, there is a strong retention of master's and doctorate holders in the state where they graduated.

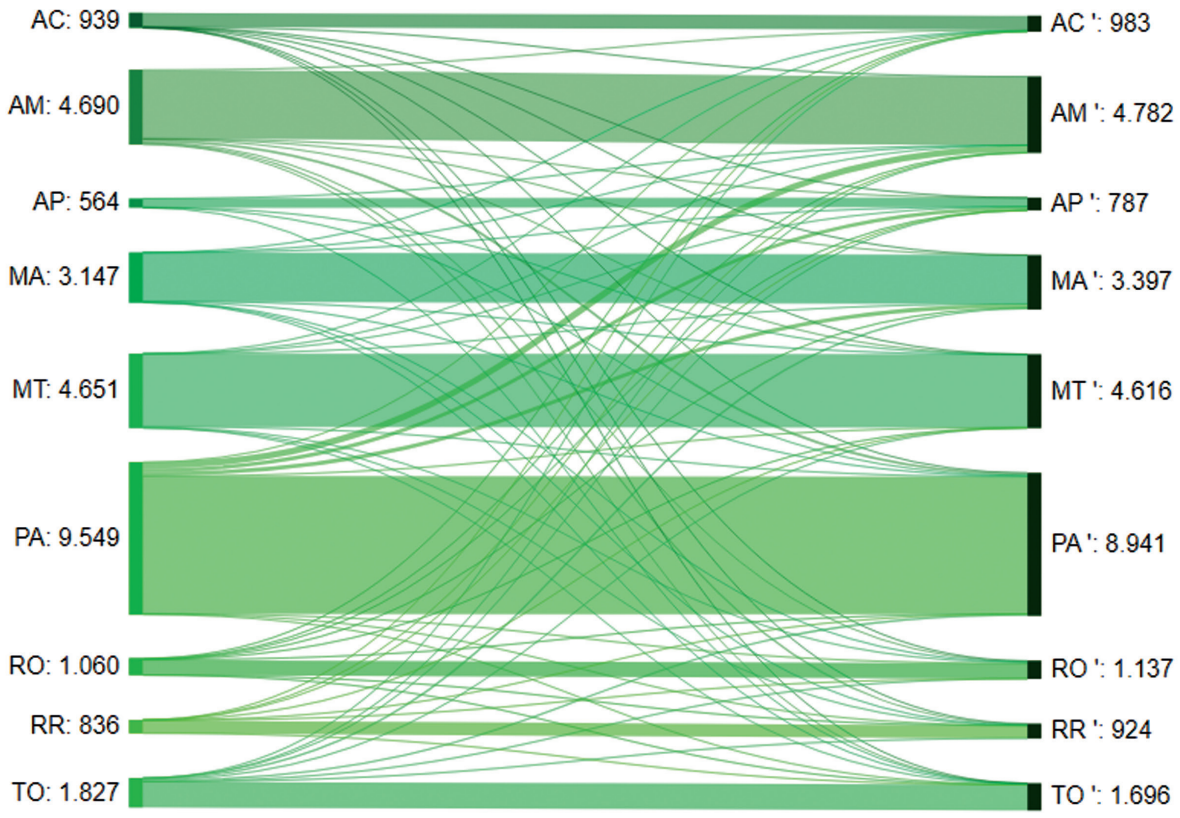


Figure 12 - Mobility/retention of graduates (master's degree) from Amazonian states to Amazonian states

Source: Prepared by CGEE, based on data from the Sucupira Platform - Capes/MEC (1996-2021) and RAIS/MTE (2021).

Figure 13 shows the flow of masters from Amazonian states to non-Amazonian states. There has been a strong migration to the Federal District and, to a lesser extent, to the state of São Paulo. A technical study carried out by the CGEE on the employment of masters and doctors had already highlighted the Federal District as having a high ratio of masters employed per thousand formal jobs (23.3), equivalent to 2.6 times the national average (CGEE, 2023).

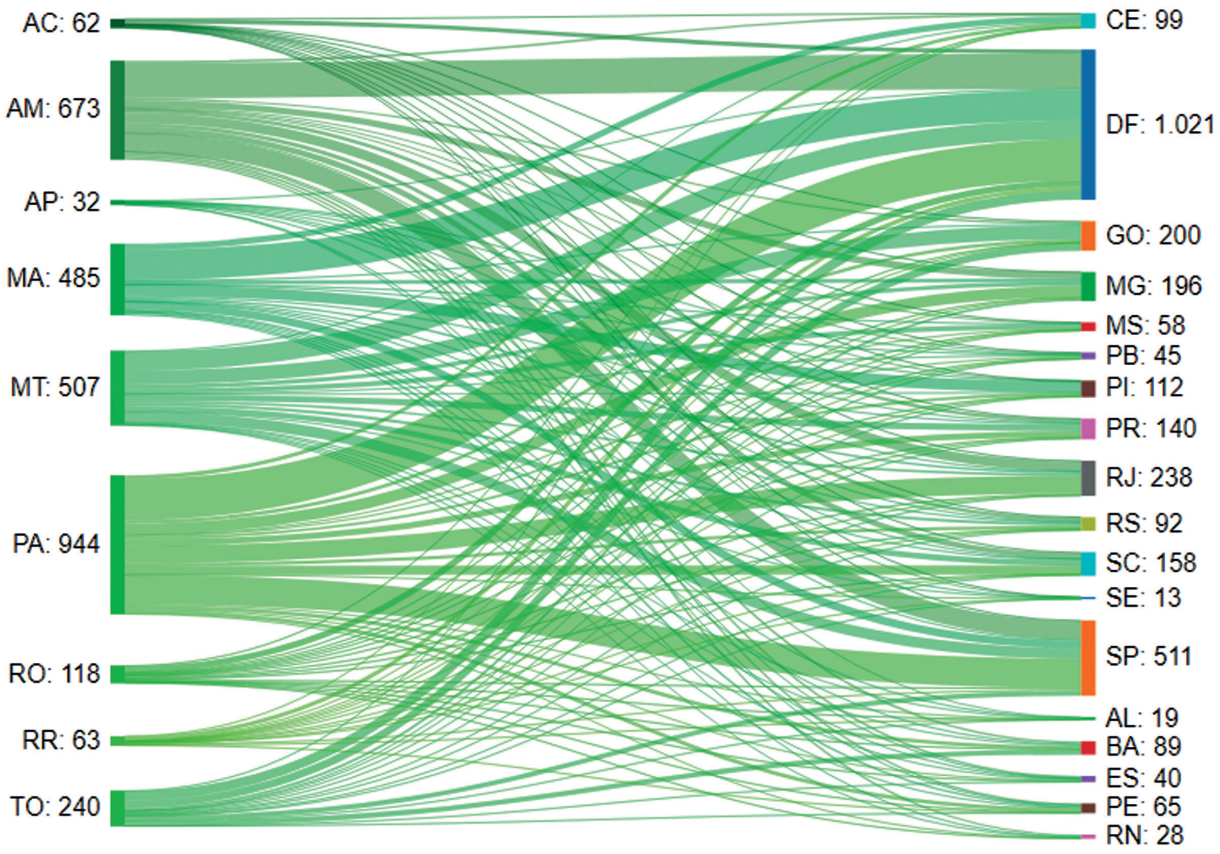


Figure 13 - Mobility of graduates (master's degree) from Amazonian states to non-Amazonian states

Source: Prepared by CGEE, based on data from the Sucupira Platform - Capes/MEC (1996-2021) and RAIS/MTE (2021).

The next three figures (14, 15, and 16) show the flow of professionals with doctorates into formal jobs "from" and "to" different Brazilian states. In the case of doctors, the graph in Figure 14 shows the high percentage—often over 80%—of doctors coming from programs in non-Amazon states. This is because some Amazonian states have few or no options for programs offering doctoral degrees.

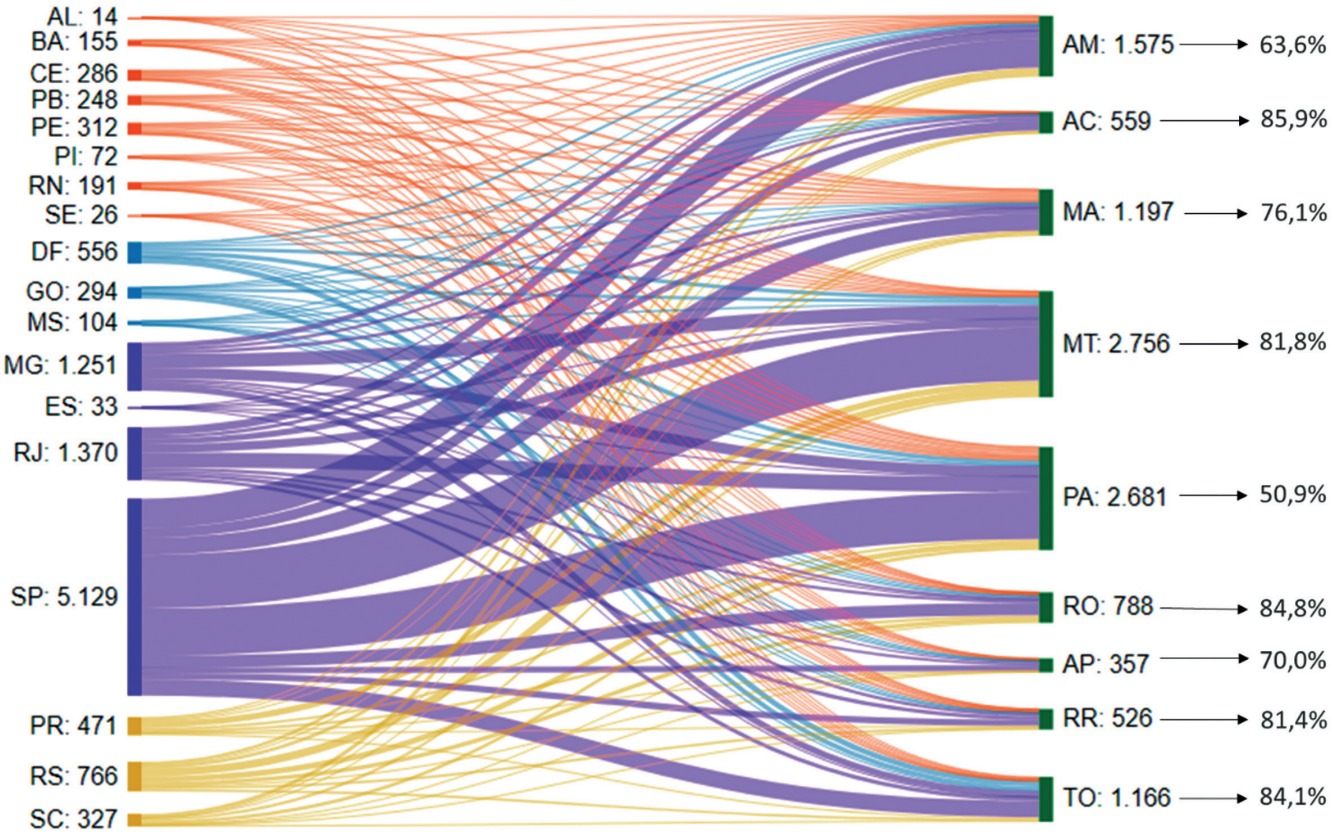


Figure 14 - Mobility of graduates (doctorate) from non-Amazon states to Amazon states

Source: Prepared by CGEE, based on data from the Sucupira Platform - Capes/MEC (1996-2021) and RAIS/MTE (2021).

Figure 15 shows a similar result to Figure 12, highlighting the level of doctor retention in the states of their degree programs. Pará and Amazonas are states that export doctors to formal jobs in other states in the Amazon region.

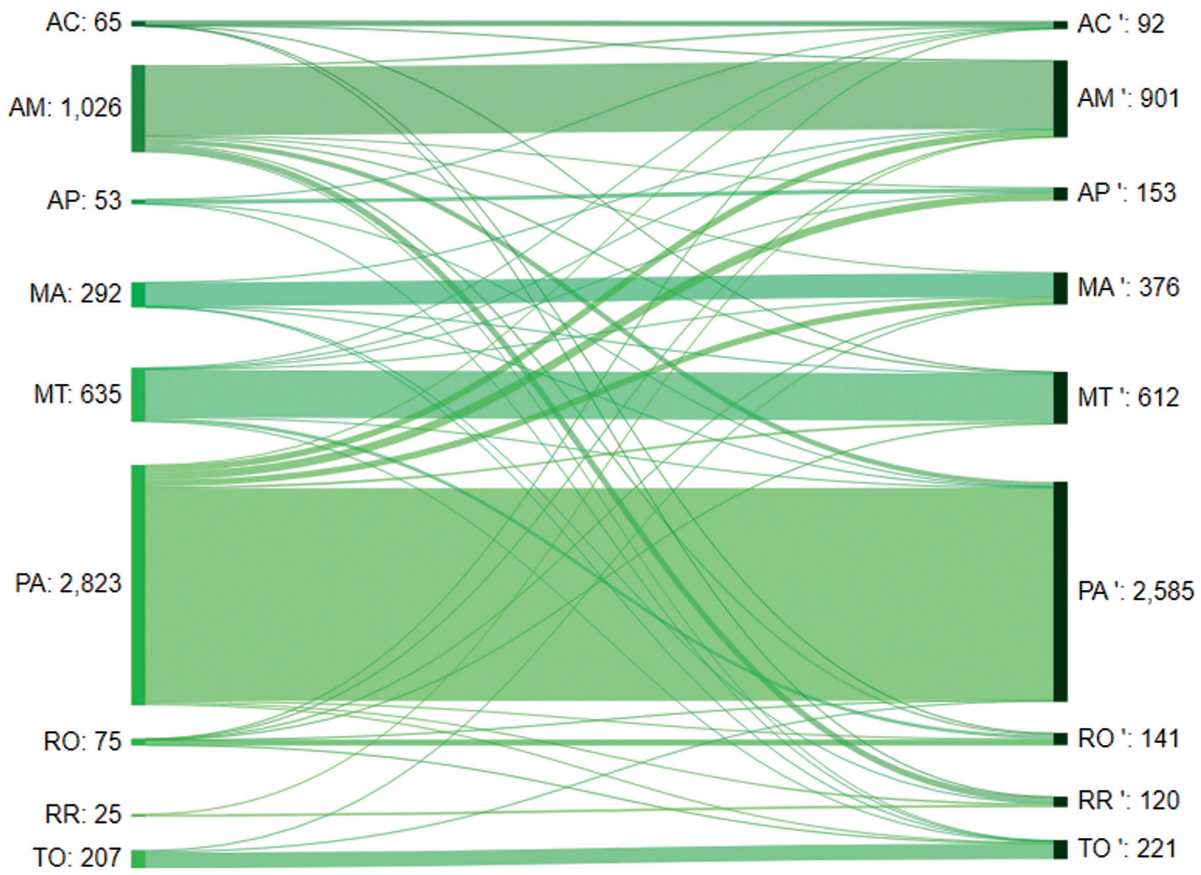


Figure 15 - Mobility/retention of graduates (doctorate) from Amazonian states to Amazonian states

Source: Prepared by CGEE, based on data from the Sucupira Platform - Capes/MEC (1996-2021) and RAIS/MTE (2021).

Figure 16 shows doctors with degrees from Amazonian states with formal jobs in non-Amazonian states. Once again, the Federal District and São Paulo receive the largest numbers of formal professionals with degrees in the Amazon region.

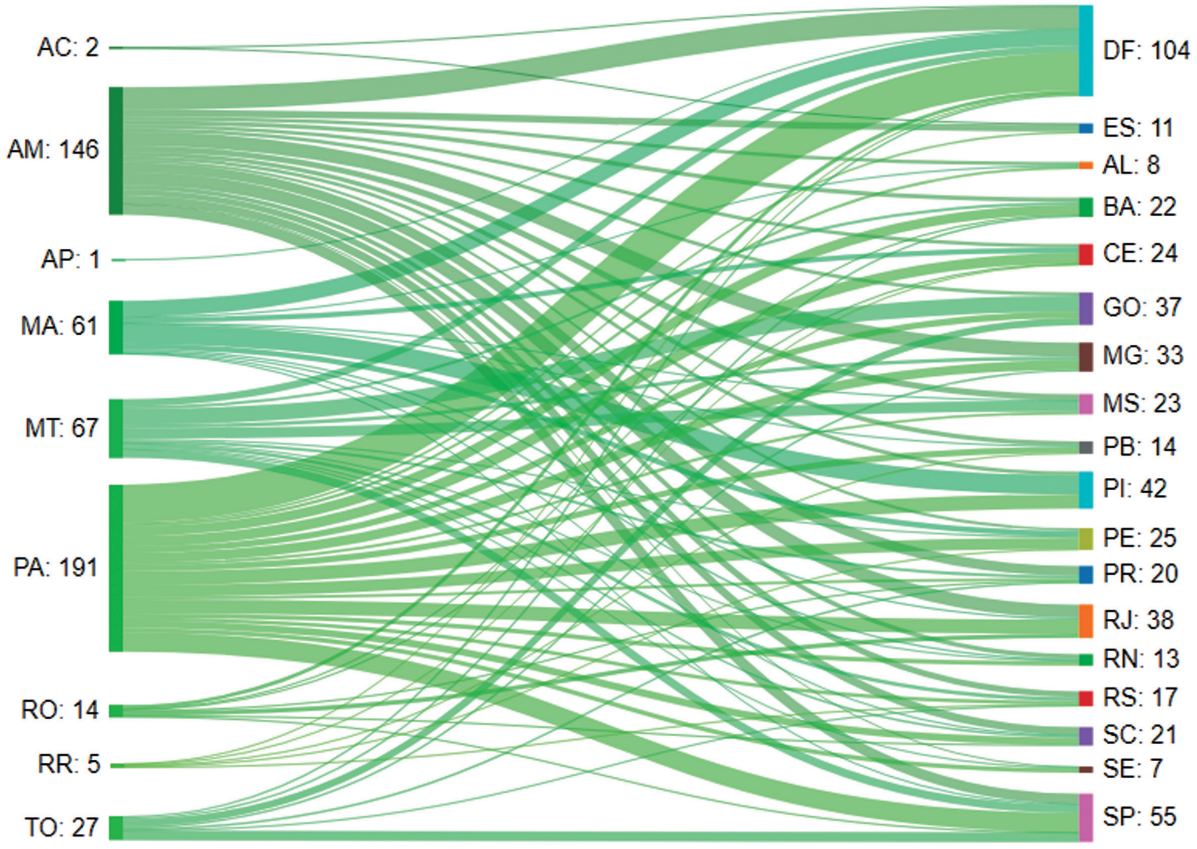


Figure 16 - Mobility of graduates (doctorate) from Amazonian states to non-Amazonian states

Source: Prepared by CGEE, based on data from the Sucupira Platform - Capes/MEC (1996-2021) and RAIS/MTE (2021).

In Brazil, women have held the majority of master's degrees since 2000 and doctorates since 2003 (CGEE, 2023). This study aimed to see how the number of women with master's and doctoral degrees has evolved in the Amazon region.

Figure 17 shows the evolution of the number of masters and doctors in Brazil (left axis) and the same evolution only for the Amazon states (right axis). There was a more marked acceleration for the masters in the Amazon region. The evolution in the number of female doctors is similar to the national average.

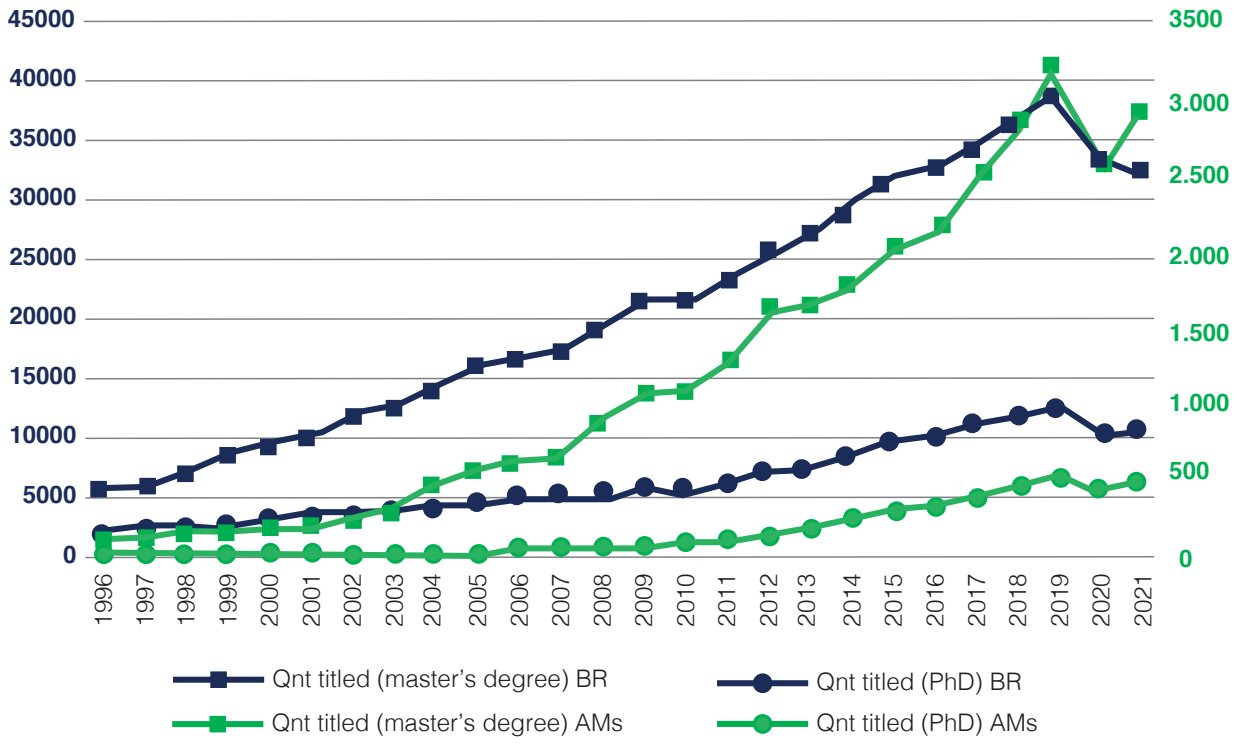


Figure 17 - Evolution of master's and doctoral graduates in Brazil and the Amazon states

Source: Prepared by CGEE, based on data from the Sucupira Platform - Capes/MEC (1996-2021).

When discussing gender balance in any area and at any level of qualification, we have to look at one of the biggest problems women face: the pay *gap* between men and women for the same job. Figure 18 shows the average remuneration of female masters as a percentage of the average male remuneration for the Amazonian states and the national average. Figure 19 shows the same analysis for female doctors.

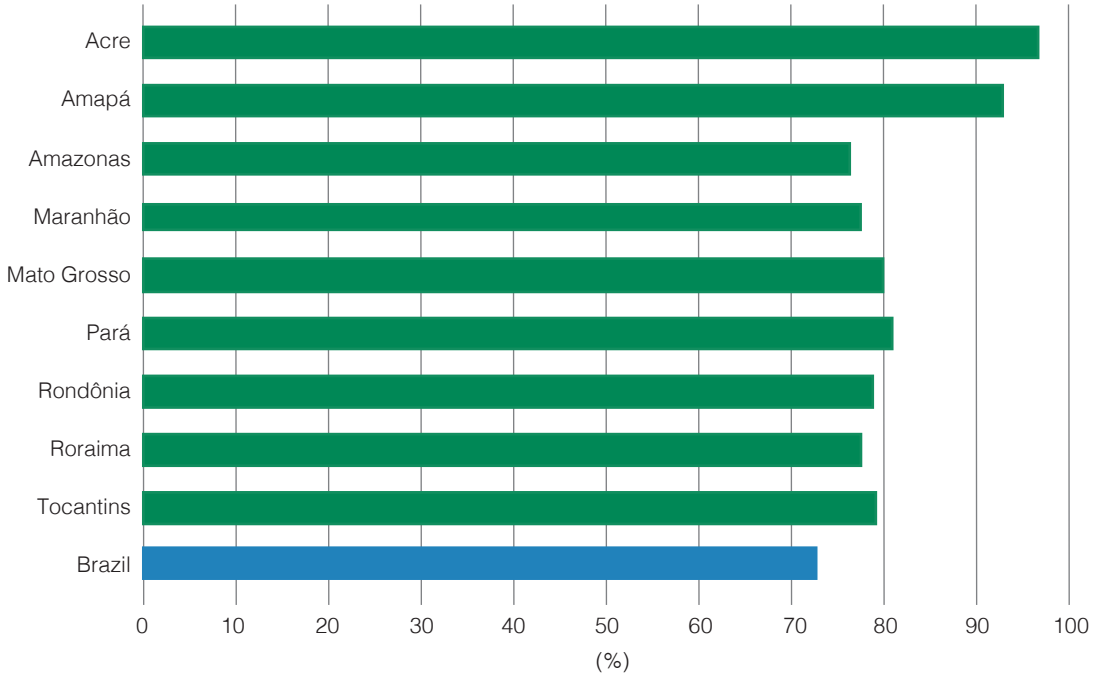


Figure 18 - Masters: Average monthly remuneration of women as a percentage of that of men

Source: Prepared by CGEE, based on data from the Sucupira Platform - Capes/MEC (1996-2021) and RAIS/MTE (2021).

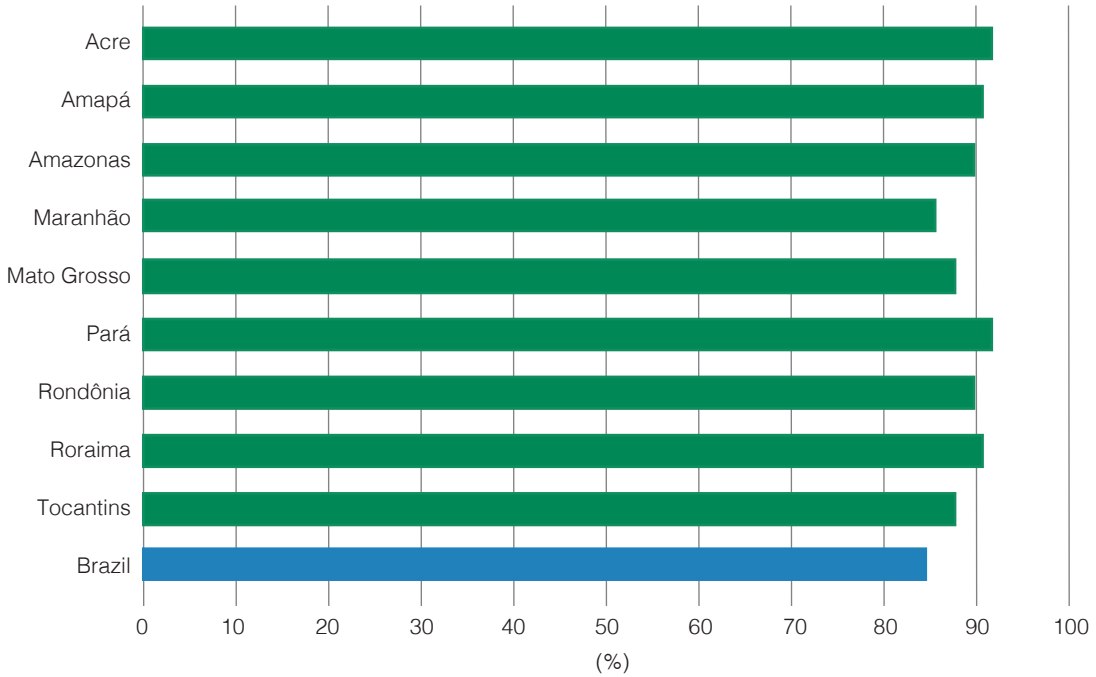


Figure 19 - Doctors: Average monthly remuneration of women as a percentage of that of men

Source: Prepared by CGEE, based on data from the Sucupira Platform - Capes/MEC (1996-2021) and RAIS/MTE (2021).

At first glance, the fact that the salary *gaps* are smaller than the Brazilian average in both cases could be seen as very positive. However, a more in-depth analysis may indicate that this reflects the hiring profile of masters and doctors in the Amazon region. Figure 20 shows the distribution of the legal nature of the institutions that hire masters and doctors for Brazil and for a cross-section of Amazonian states. This analysis shows that, for the Amazon region, these professionals are mainly present in public institutions, which require, for example, a selection process via public tender, which leads to less disparity between men's and women's salaries.

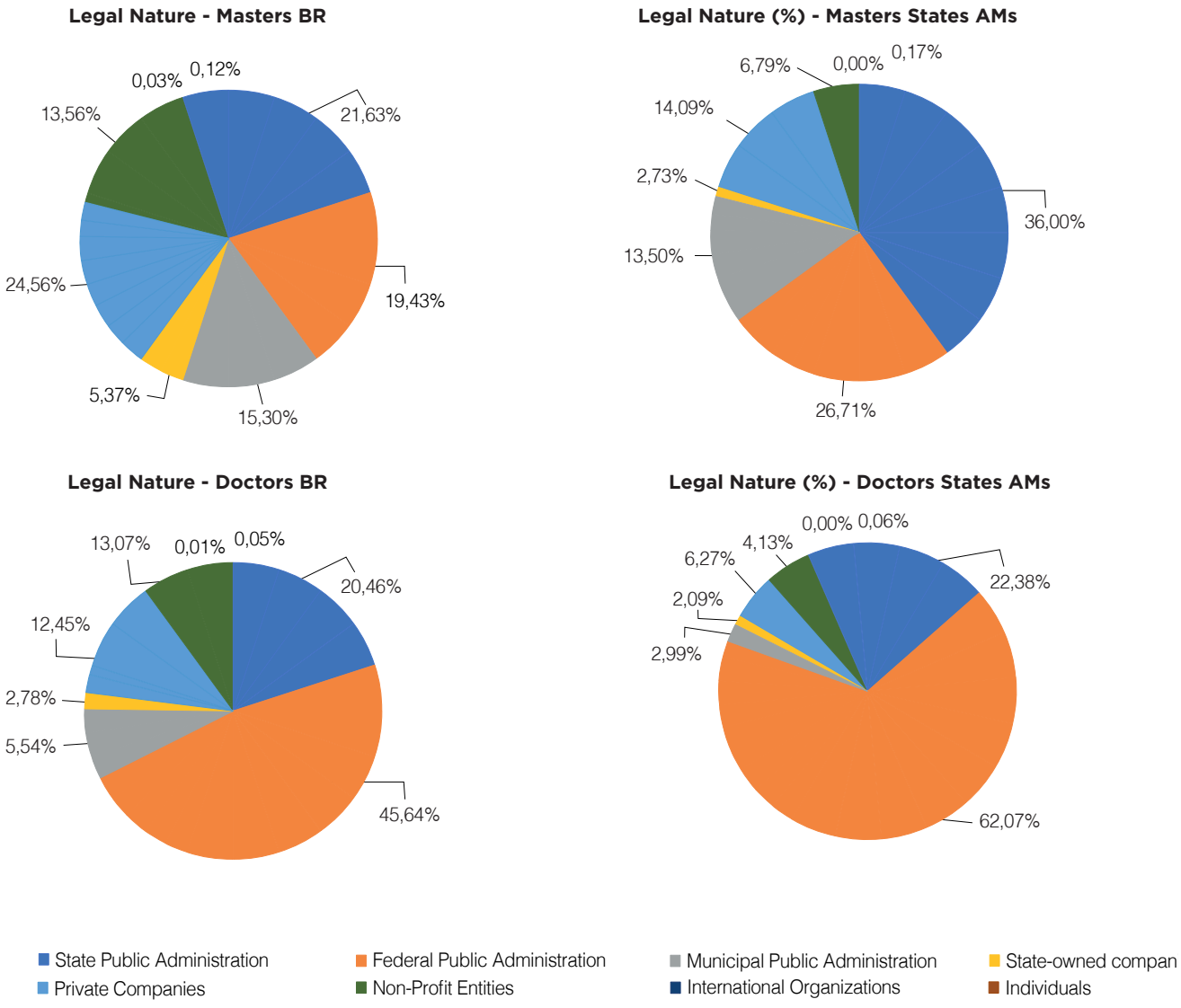


Figure 20 - Legal nature of formal jobs for masters and doctors in Brazil and the Amazon region

Source: Prepared by CGEE, based on data from the Sucupira Platform - Capes/MEC (1996-2021) and RAIS/MTE (2021).

2.1 Results' overview of the education and performance of human resources for STI analysis in the Amazon region

The data presented in this section provides an overview of one type of innovation capacity: human resources for STI. The results show some asymmetries to the national average, reflecting the region's smaller variety of postgraduate programs. However, the accelerating trends in the national average for the creation of such master's programs, as well as the increase in the number of masters and doctors, can be seen with optimism and are, above all, necessary.

The analysis of the areas of knowledge surveyed in the Amazon region showed a different profile from the national average. To assess the scientific and technical capacities available in the region, a more precise investigation into priority technologies is recommended.

The analysis of the flow of masters and doctors from the states in which they hold degrees and to the states in which they are formally employed made it possible to deepen the analysis of the number of professionals available in each state and their transition profiles between Amazonian and non-Amazonian states and within the Amazon region itself.

Finally, this section also aimed to address the important issue of gender parity in this group of highly qualified professionals and to raise hypotheses about the different salary *gaps* between men and women.

This section is the result of a collaboration between the teams of the Bioeconomy Observatory and the HR Observatory for STI, both from the Center for Management and Strategic Studies. This partnership made it possible to carry out analyses employing a personalized extraction of a broader set of data available in the studies of masters and doctors, accessible on the CGEE website.

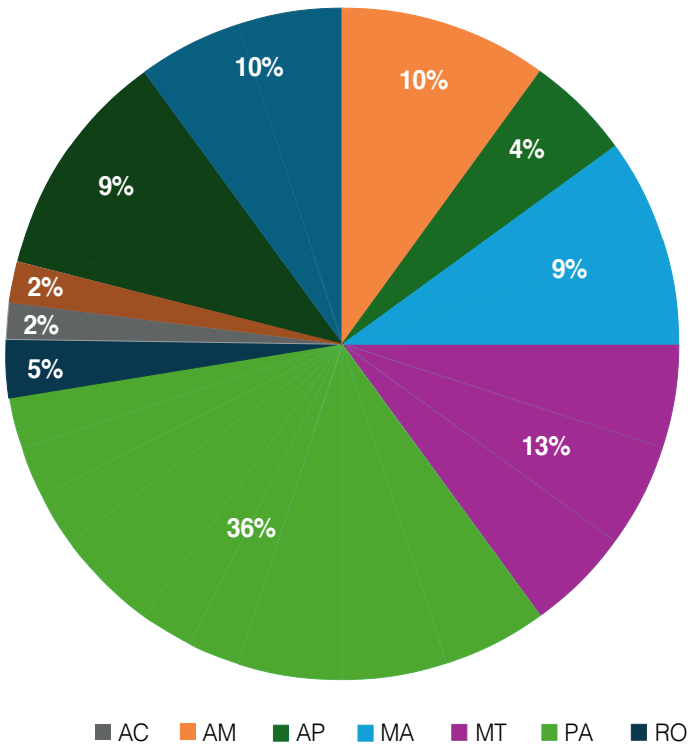
3. Scientific production by institutions in the Legal Amazon

In addition to examining the Amazon in terms of national and international scientific publications (Amazonian Bioeconomy Bulletin), it is necessary to focus on the scientific production generated by the STI institutions established in the region. CGEE's Science, Technology, and Innovation Observatory (OCTI) collected data on scientific articles available on the *Web of Science* (WoS) database from the main institutions in each state of the Legal Amazon between 2018 and 2023.[2] National, federal, and state institutions in each state were considered, and a separate section was made for the National Institute for Amazonian Research (INPA).

2 For more information on the data collected by the Science, Technology, and Innovation Observatory (OCTI), visit the latest thematic bulletin here and the Observatory's website here.

The information on scientific production in the states of the Legal Amazon allows us to assess the distribution of scientific strength among the Amazonian states and how this production has behaved over the last few years. It also provides an overview of the areas of knowledge these institutions are most studying. Identifying the most recently researched areas points to a profile of scientific and technological expertise that could form the basis of a bioeconomy in the region. This approach allows the identification of potential and bottlenecks for the development of new bioproducts and bioprocesses based on biodiversity.

Figure 21 shows the distribution of scientific production over the last five years by state in the Legal Amazon. Pará has the greatest distribution, accounting for 36% of publications, followed by Mato Grosso with 13%.



State	Amount
AC	242
AM	1.054
AP	426
MA	988
MT	1.441
PA	3.815
RO	499
RR	228
TO	969
INPA	1.080

Figure 21 - Distribution of scientific publications in the states of the Legal Amazon

Source: Prepared by CGEE, based on Web of Science data collected by OCTI.

Figure 22 shows the evolution of scientific production in the states over the last five years.[3] The numbers are stable, with a slight downward trend from 2021 to 2022, which may still reflect the COVID-19 pandemic announced by the World Health Organization (WHO) on May 5, 2023, and the Brazilian government on April 22, 2022.

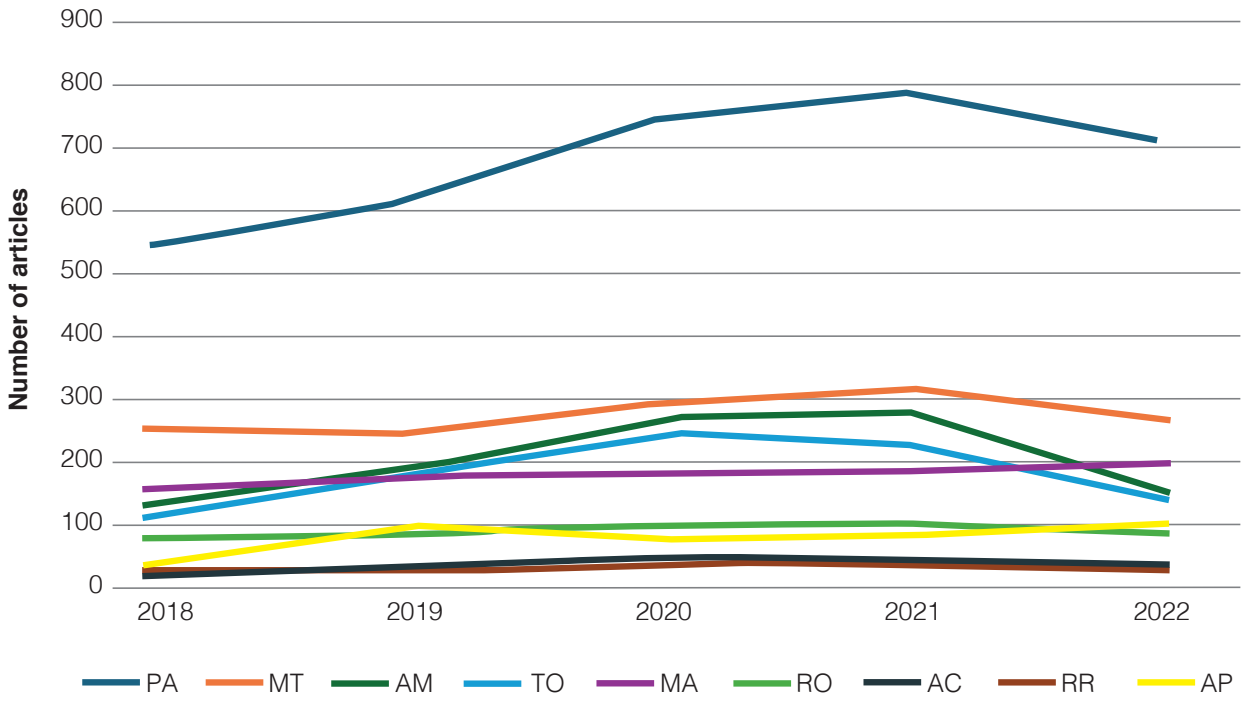


Figure 22 - Scientific production by state and year

Source: Prepared by CGEE, based on Web of Science data collected by OCTI.

3 We chose to present the graph in Figure 22 up to 2022 since the data for 2023 is partial and could lead to a hasty analysis of a drop in publication numbers.

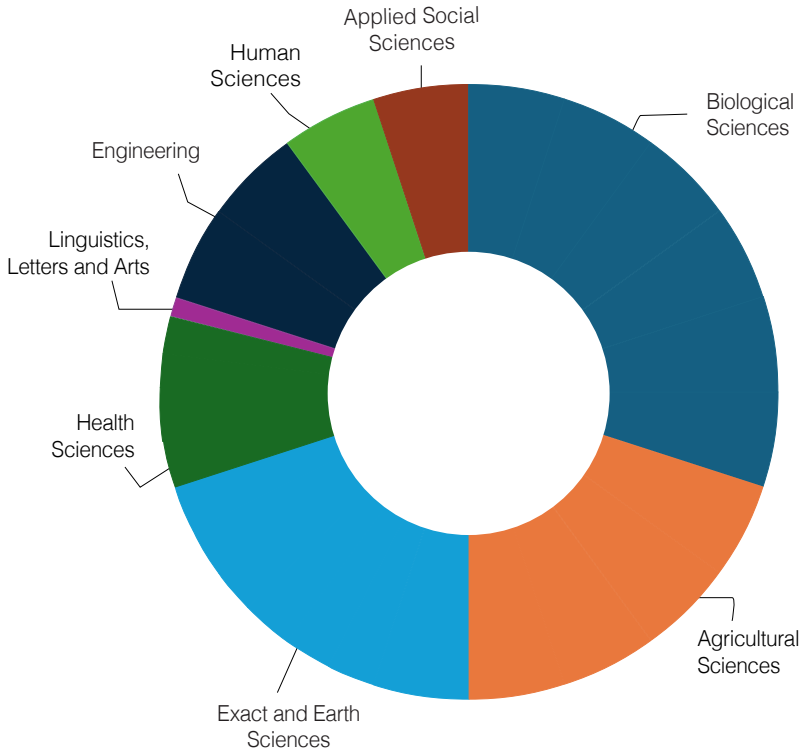
Figures 23 and 24 show an overview of the areas of knowledge in the set of publications from the institutions in the states of the Legal Amazon. Figure 23 shows the 30 most frequent areas of knowledge, classified by the major areas of knowledge of the Coordination for the Improvement of Higher Education Personnel (Capes).[4] The three most frequent areas are environmental sciences and ecology, zoology, and plant science, which reflect the region's biodiversity as the main focus of research.

Figure 23 - Thirty most frequent areas of knowledge in the complete set of publications from the states of the Legal Amazon

Source: Prepared by CGEE, based on Web of Science data collected by OCTI.

4 The major areas of knowledge were classified according to the Coordination for the Improvement of Higher Education Personnel (Capes). The areas of knowledge are classifications from the *Web of Science* (WoS).

Figure 24 shows the profile of the major areas of knowledge of the complete set of publications. The biological and agricultural sciences dominate, but the exact sciences and engineering participate less. This profile differs from the national average, where engineering—an area with a wide range of sub-areas in this domain, such as Electrical, Chemical, Mechanical, and Civil Engineering—has the largest share of national production (CGEE, 2023).



Large area	Count
Biological Sciences	4.856
Agricultural Sciences	2.254
Exact and Earth Sciences	1.720
Health Sciences	1.171
Engineering	1.044
Human Sciences	721
Applied Social Sciences	404
Linguistics, Literature and Arts	168

Figure 24 - Characterization of the major areas of knowledge of the complete set of publications

Source: Prepared by CGEE, based on Web of Science data collected by OCTI.

The discreet presence of engineering areas could be a concern for developing an Amazon bioeconomy. In addition to the relevance of research specific to this area of knowledge, many disciplines are essential for the prototyping, development, scaling, and optimization phases of innovations from other areas of knowledge.

Figure 25 shows the profile of the major areas of knowledge for the individual states. This separation makes it possible to identify local vocations in STI. Most states have a similar profile, with Biological Sciences and Agricultural Sciences as the most frequent areas. It is worth highlighting Maranhão, which has the Health Sciences as the second most frequent area, and especially Tocantins' different profile, in which of the 969 articles, 540 are from the Human Sciences.

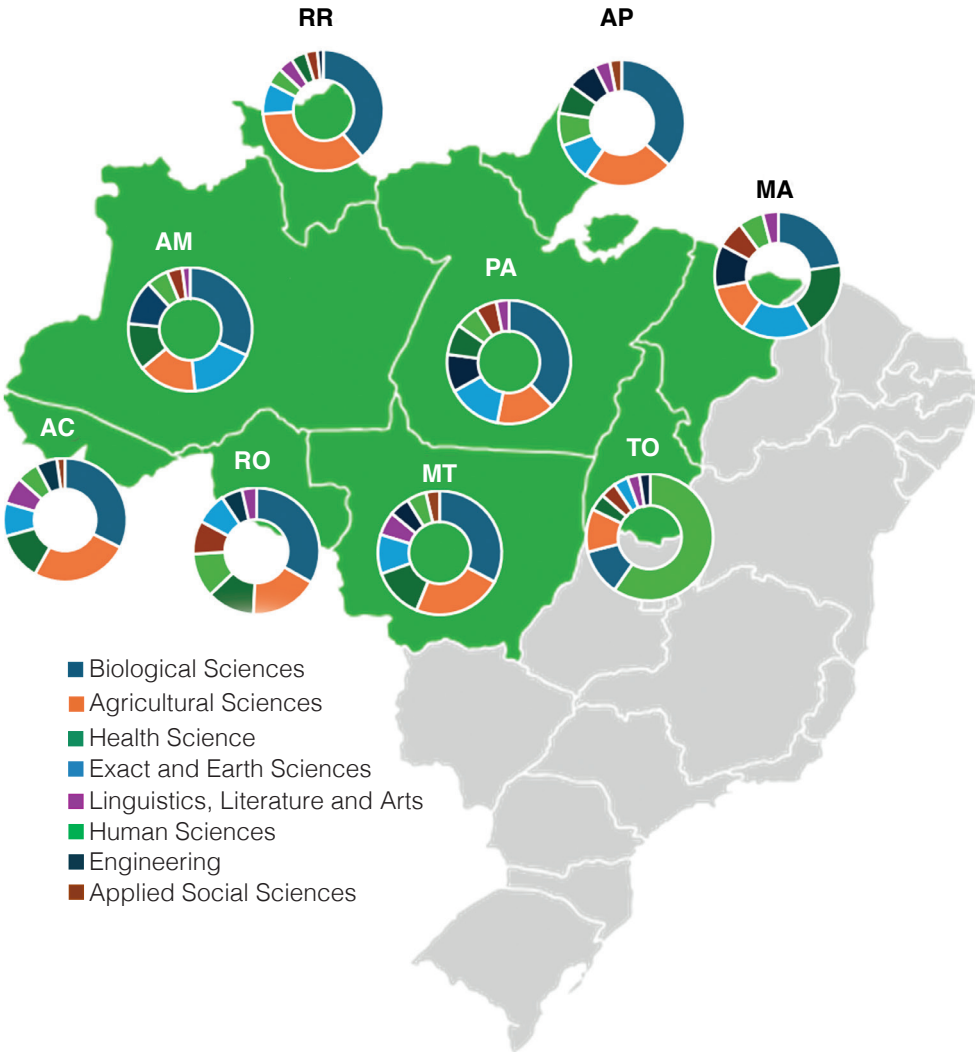


Figure 25 - Profile of the major areas of knowledge of publications from the states of the Legal Amazon

Source: Prepared by CGEE, based on Web of Science data collected by OCTI.

3.1 Results' overview of examining the scientific production of STI institutions in the Legal Amazon

An analysis of the scientific output of institutions in the Legal Amazon shows that its vast biodiversity of fauna, flora, and micro-organisms seems to influence the thematic profile of the research in the region. The focus on the biological sciences, which differs from the national average, is a key element in developing a biodiversity bioeconomy, but it is not the only one. The absolute values of scientific publications in other areas, such as exact sciences and engineering, are lower than the national average, but they are necessary knowledge for such development.

Another element that needs to be highlighted is an expectation of growth in the number of scientific productions, given the increasing recognition of the region's bioeconomy potential. This increase has not yet been identified, possibly due to the pandemic. However, developing the scientific and technological capacities that the advanced bioeconomy will require is expected and necessary.

This section is the result of close collaboration between the teams of the Bioeconomy Observatory and the Science, Technology, and Innovation Observatory, both of the Center for Management and Strategic Studies. This partnership allowed for a focused analysis in the context of the bioeconomy of a broader set of data available at the OCTI.

4. Genetic heritage and associated traditional knowledge

Completing the proposal to diagnose STI for developing socio-bioeconomics in the Amazon, this bulletin also provides data on access to patimônio genético [genetic heritage] (PG) and associated traditional knowledge (ATK) in the Amazon biome. This data results from an analysis of the records made in the National System for the Management of Genetic Heritage and Associated Traditional Knowledge (SisGen) - an electronic system created by Decree No. 8.772 of May 11, 2016, which regulates Law No. 13,123, of May 20, 2015, as an instrument to assist the Genetic Heritage Management Council (CGen).

The Biodiversity Law (Law No. 13,123 of May 20, 2015) was a structured response to a 2001 provisional measure aligned with the Convention on Biological Diversity. Its goal was to regularize access to PG and ATK and guarantee fair and equitable benefit sharing to prevent biopiracy.

As of November 6, 2017, it became mandatory to register all access to genetic heritage and associated traditional knowledge in SisGen. In addition to registering the activity, other procedures—such as notifying finished products and reproductive material—must be carried out in the system.

Although the law faces some challenges, such as high transaction costs, users' lack of knowledge, the supervisory body's lack of training, and some barriers in the case of non-commercial research (CGEE, 2020; FIOCRUZ, 2024), the procedures are constantly being improved. In this sense, researchers must collaborate to bring criticisms and suggestions to the Câmara Setorial da Academia [Academia Sector Chamber] (CSA), the appropriate and legitimate space for discussions and proposals on Biodiversity Law. Brazil has pioneered registering such accesses and respective results from PG and ATK and guaranteeing the sharing of benefits.

Benefit sharing can be non-monetary or monetary. The percentage set is 1%, or up to 0.1% by sector agreement. The Federal Government benefits from benefit sharing regarding access to genetic heritage. This resource goes to the National Fund for Benefit Sharing (FNRB), which in 2022 was estimated at approximately R$4 million (SENADO NOTÍCIAS, 2022).

In the case of ATK, the beneficiaries are indigenous peoples, traditional communities, and traditional farmers. Micro-enterprises, small businesses, individual micro-entrepreneurs, traditional farmers, and their cooperatives with annual gross revenue equal to or less than that established in the relevant legislation are excluded from the obligation to share benefits. The intermediate product - which is the one used in the production chain, which will add it to its production process as an input, excipient, and raw material for the development of another intermediate product or finished product - is also exempt from the obligation to share benefits (BRASIL, 2015).

For this bulletin, activity data and finished product notifications for the Amazon biome were analyzed. Determining the biome means focusing the analysis on accesses to PG, PG and ATK, since accesses to ATK alone do not need to be linked to a specific biome. Intermediate products, like ATK, are not linked to a specific biome and are another element not included in the analyzed data. Data on access to PG, PG, and ATK was therefore collected for research and development activities.

On the national scene, the Amazon biome is the third with the most access requests registered since 2017, after the Atlantic Forest, which has 45% of the accesses, and the Cerrado, which has 21% (Figure 26).

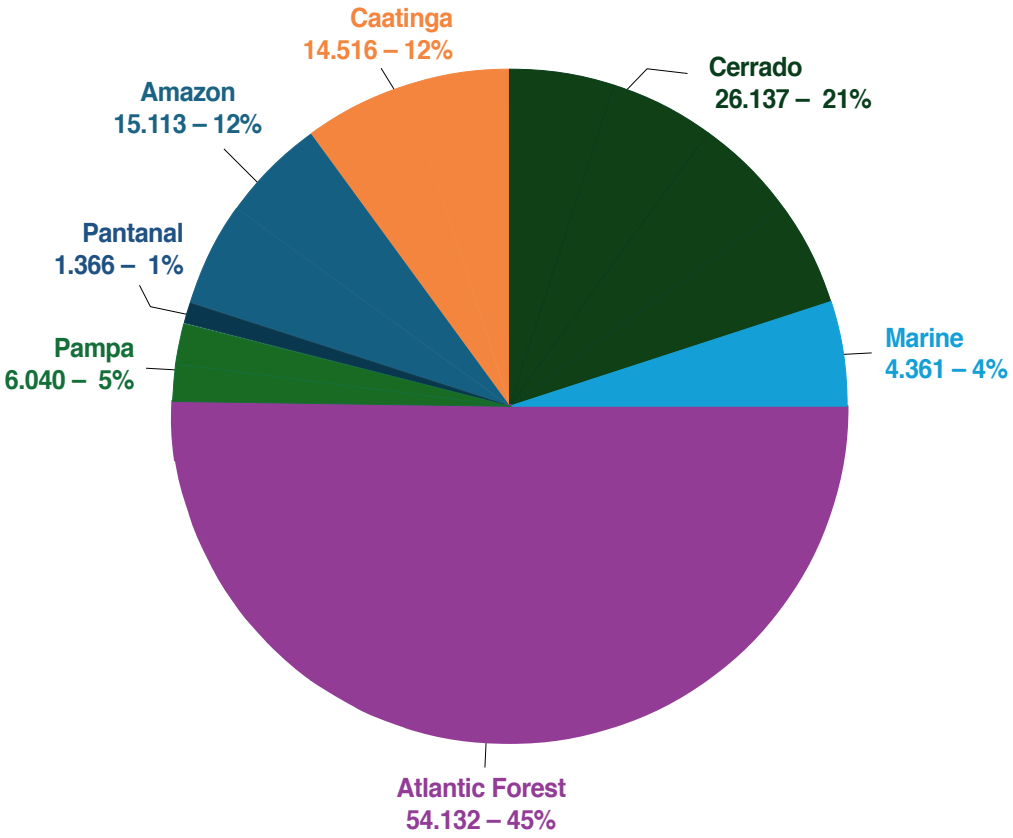


Figure 26 - Registrations of access to genetic heritage (PG) and associated traditional knowledge (CTA) by biome since 2017

Source: Prepared by the author based on data from SisGen (2023).

Figure 27 shows the evolution of access requests from 2019 to 2023, highlighting the Atlantic Forest as the biome with the highest number of accesses per year. This result reflects, albeit without an in-depth analysis, the influence of the STI infrastructure established in the coastal region of the country's center-south and the lesser magnitude of this infrastructure in the north. The Amazon - despite representing 43% of Brazil's area, with more than 4 million km² (IBGE, 2022), responsible for what is estimated to be more than 15% of the planet's biodiversity (HUBBELL *et al.*, 2008) and almost 200 indigenous ethnic groups (NOBRE *et al.*, 2023) - it still does not have a significant number of registrations for access to genetic heritage and associated traditional knowledge, when compared to the Atlantic Forest and the Cerrado.

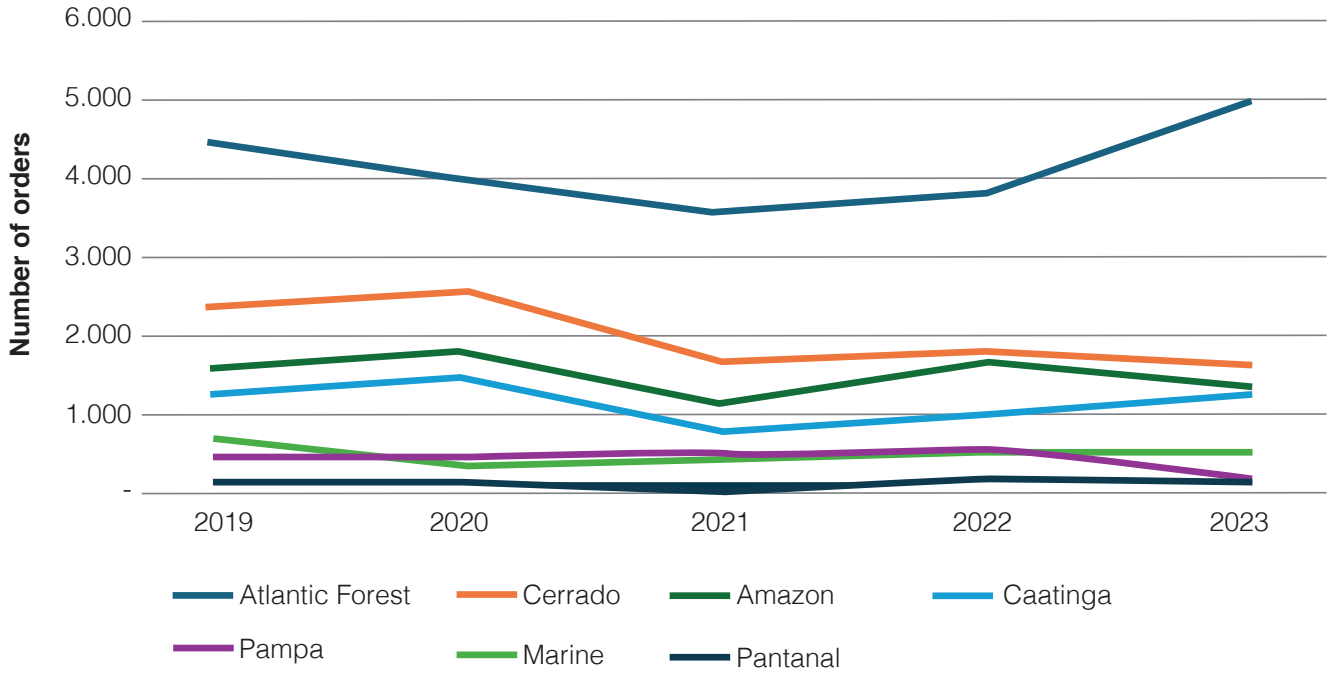


Figure 27 - Number of activity registrations in the last five years

Source: Prepared by the author based on data from SisGen.

Focusing on data from the Amazon biome allowed us to explore specific aspects, such as the need for secrecy, the type of access object, PG or PG and ATK, and the purpose of access, whether research, research, and development or just development. These three results can be seen in Figure 28.

In the case of "Purpose of access," the relevant proportion of 35% is in the "Not identified" situation since this data may be in the process of being regularized, for example, in the case of the access activity not having started (and not having obtained access authorization) before November 17, 2015, but had an access authorization request in process during the validity of Provisional Measure (MP) Num. 2.186-16, of August 23, 2001 - or it refers to bioprospecting (CGen, 2017).

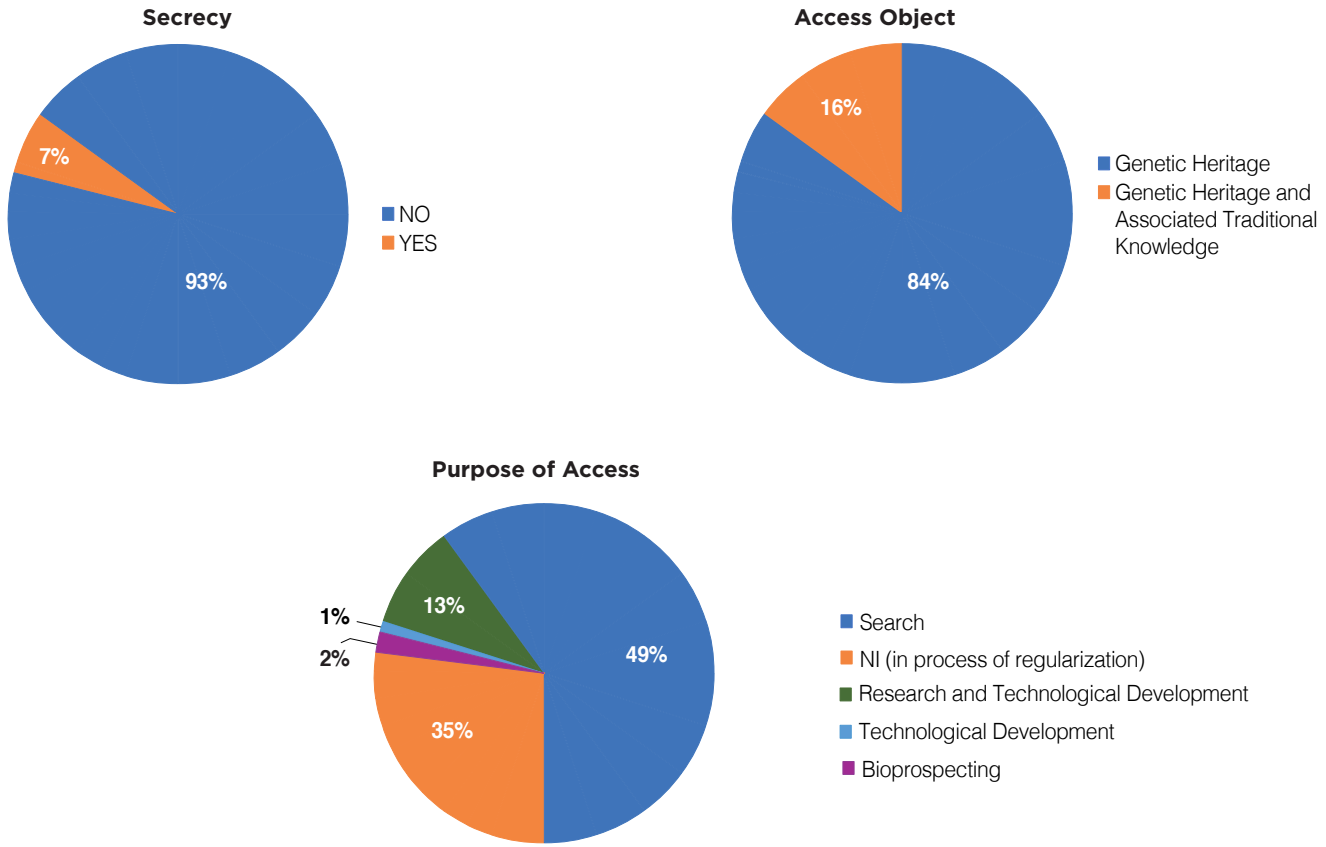


Figure 28 – General information on activity data: confidentiality, object of access, and purpose of access

Source: Prepared by the author based on data from SisGen.

The graph in Figure 29 shows each state's participation in the Legal Amazon in requests for access to the PG and ATK exclusively in the Amazon biome. As seen in the scientific publication data, Pará has the highest participation. However, unlike what was seen in the chapter on scientific publications, the state of Mato Grosso has a much smaller share. Part of this is because the state also has the Cerrado and Pantanal biomes and the Amazon biome in the north.

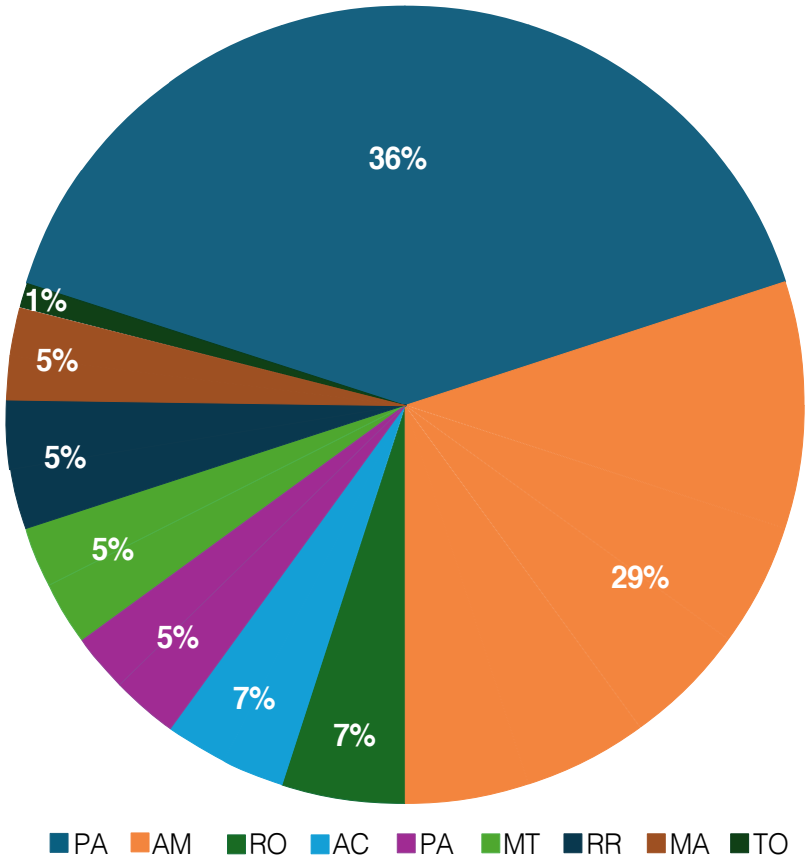


Figure 29 - Distribution of requests by state

Source: Prepared by the author based on data from SisGen.

Figures 30 and 31 show what the applicants for access to the PG and the ATK are investigating. Figure 30 shows the types of genetic heritage components accessed. It can be seen that almost half of the accesses refer to the use of Amazonian flora, with significant participation from fauna, fungi, and microorganisms.

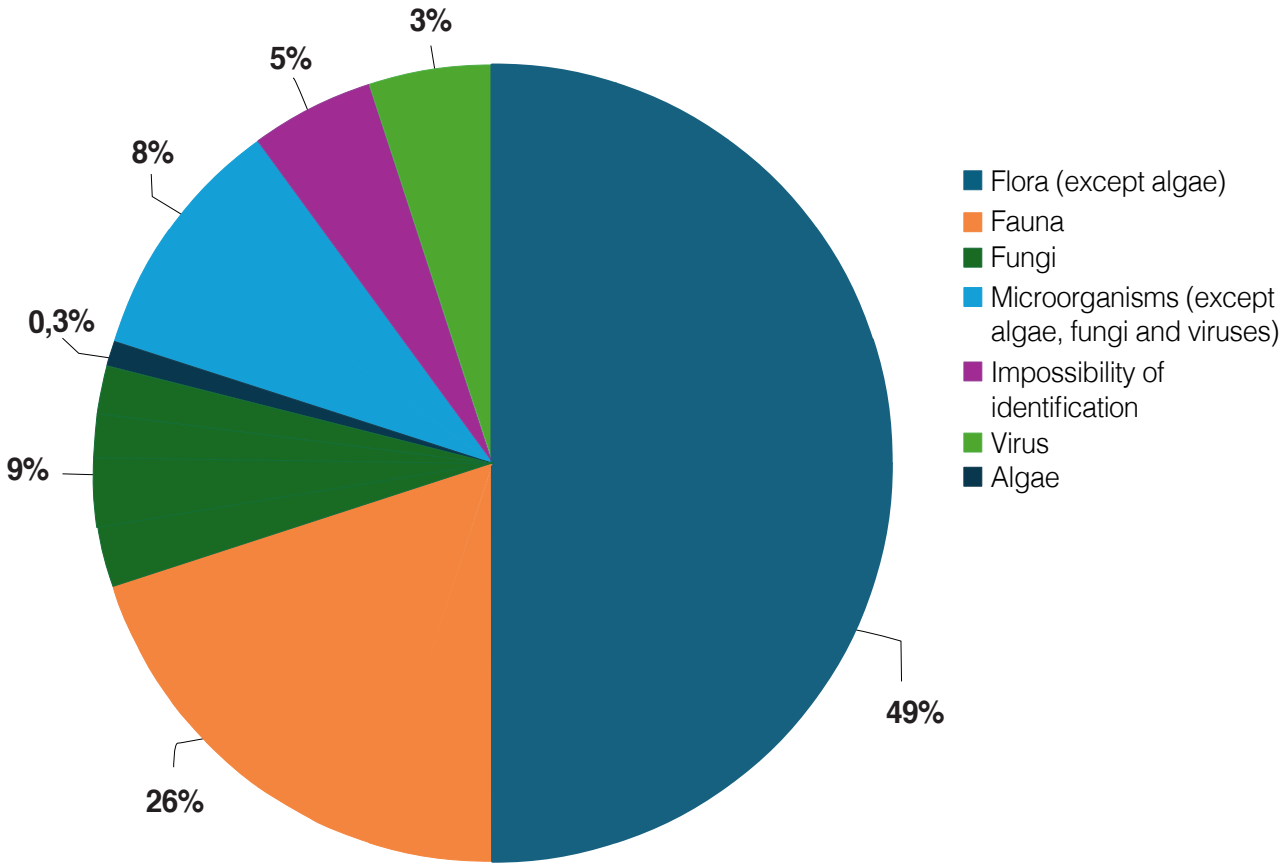


Figure 30 - Distribution by type of genetic heritage component

Source: Prepared by the author based on data from SisGen.

Figure 31 shows a word cloud of the project titles. Many activities involve the study of oils and extracts from the Amazon and efforts to identify and characterize genetic heritage.

Figure 31 - Word cloud of project titles

Source: Prepared by the author based on data from SisGen.

To register access with PG and/or ATK, the user can represent a company or institution or be a Brazilian citizen. Whether you are an independent researcher or a representative, registering as an individual is allowed. However, in the latter case, the CNPJ associated with the representative's CFP must also be registered, which has not been done in many cases.

Figure 32 shows the user's profile requesting PG and/or ATK access. Most activities are registered by federal universities and institutes (46%) and ICT [Institute of Science and Technology] (22%). Companies account for 5% of accesses. It can be seen that 27% of the registrations are not associated with a company or institution and are only registered in the name of individuals.

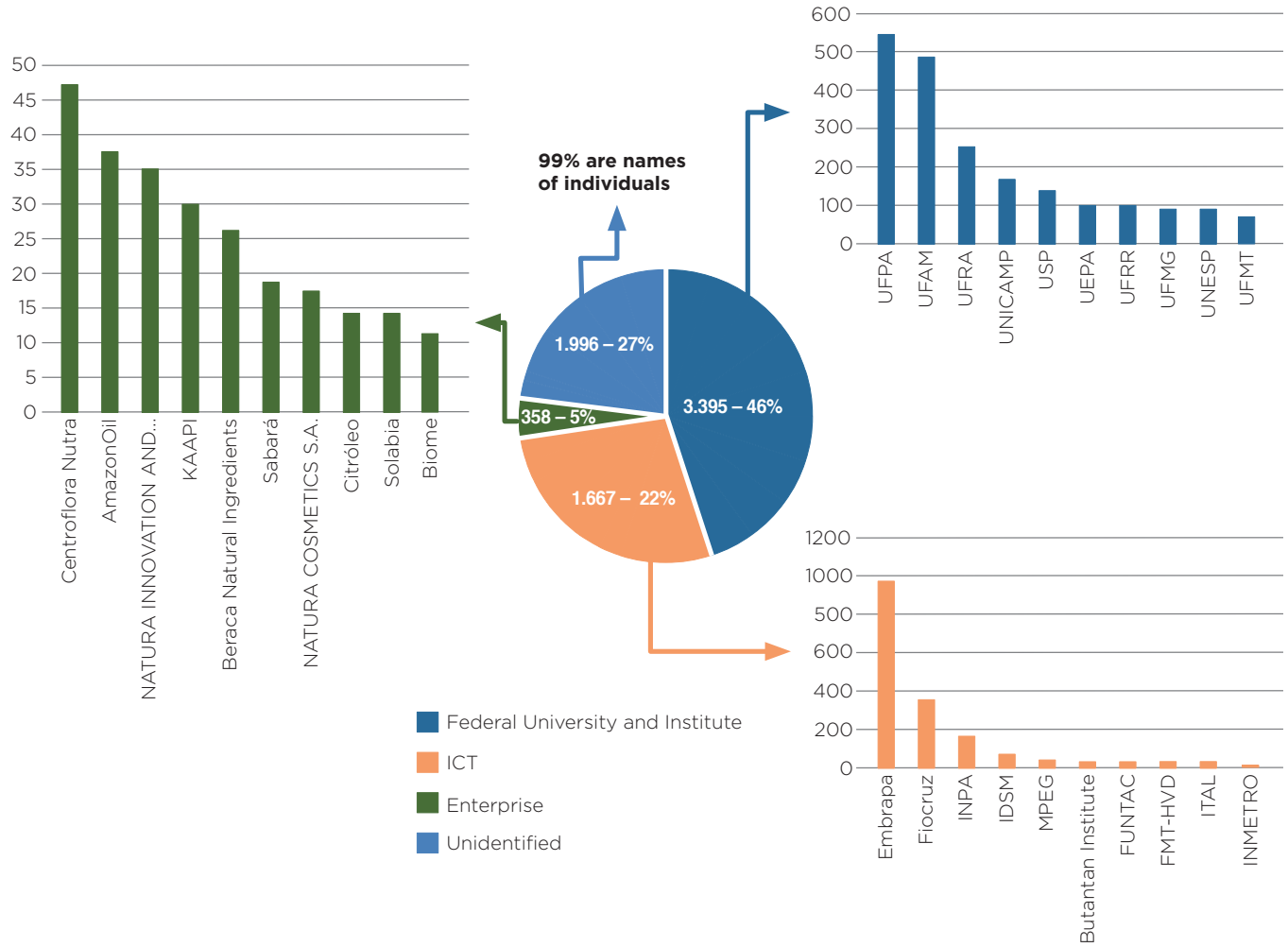


Figure 32 - User profile (activities)

Source: Prepared by the author based on data from SisGen.

The PG and ATK access data allow one to analyze the field based on the results obtained by the access. Considering that access is the first step in a research and/or development activity, it is understandable that many of these results have not yet been obtained and registered in SisGen. Figure 33 also shows that most results are described as "dissemination of results in scientific or communication media."

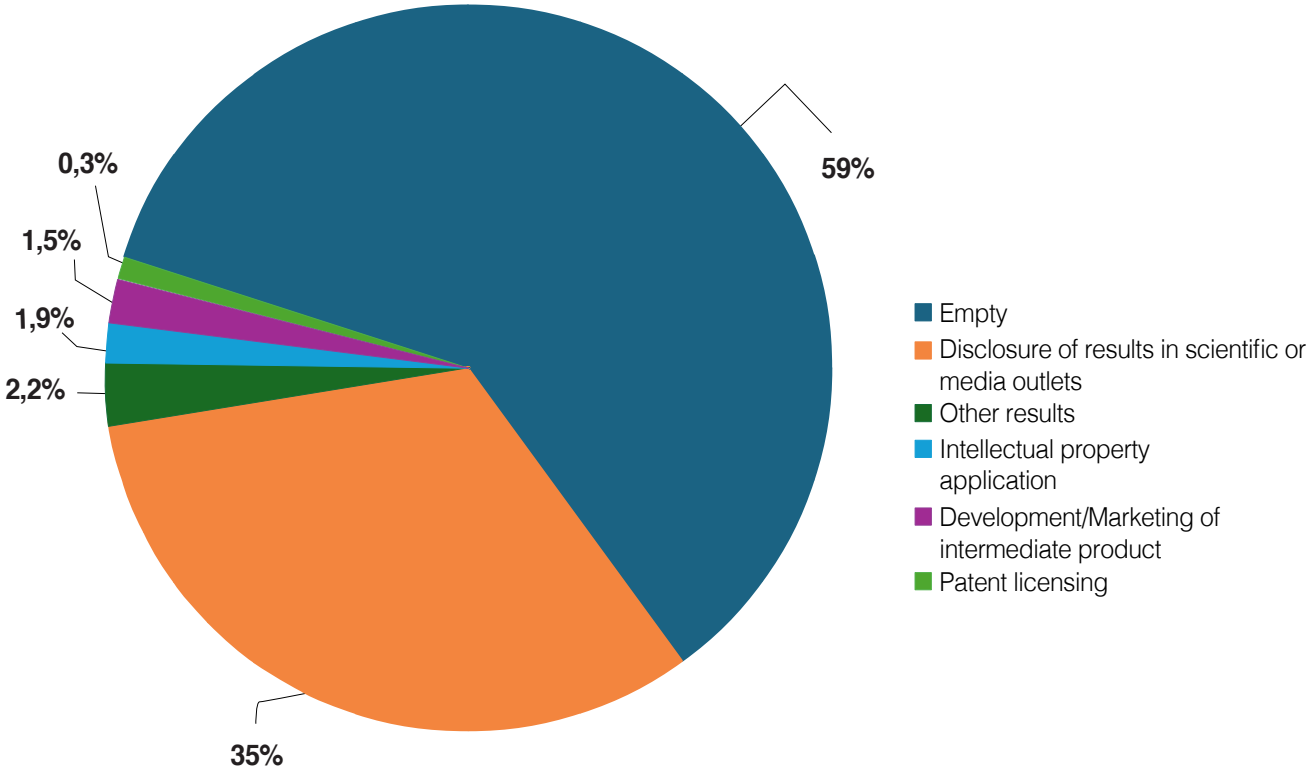


Figure 33 - Results registered in SisGen from access to the PG and ATK for the Amazon biome

Source: Prepared by the author based on data from SisGen.

A more tangible way of analyzing the results of access to the PG and ATK is to look at the notification data for finished products or reproductive material. SisGen makes this data available, and the evolution of these two types of records can be analyzed*(check* Figure 34). Considering the entire historical series since 2017, more than 17% of activities resulted in notifications of finished products (99.7%) and reproductive material (0.3%0 %).

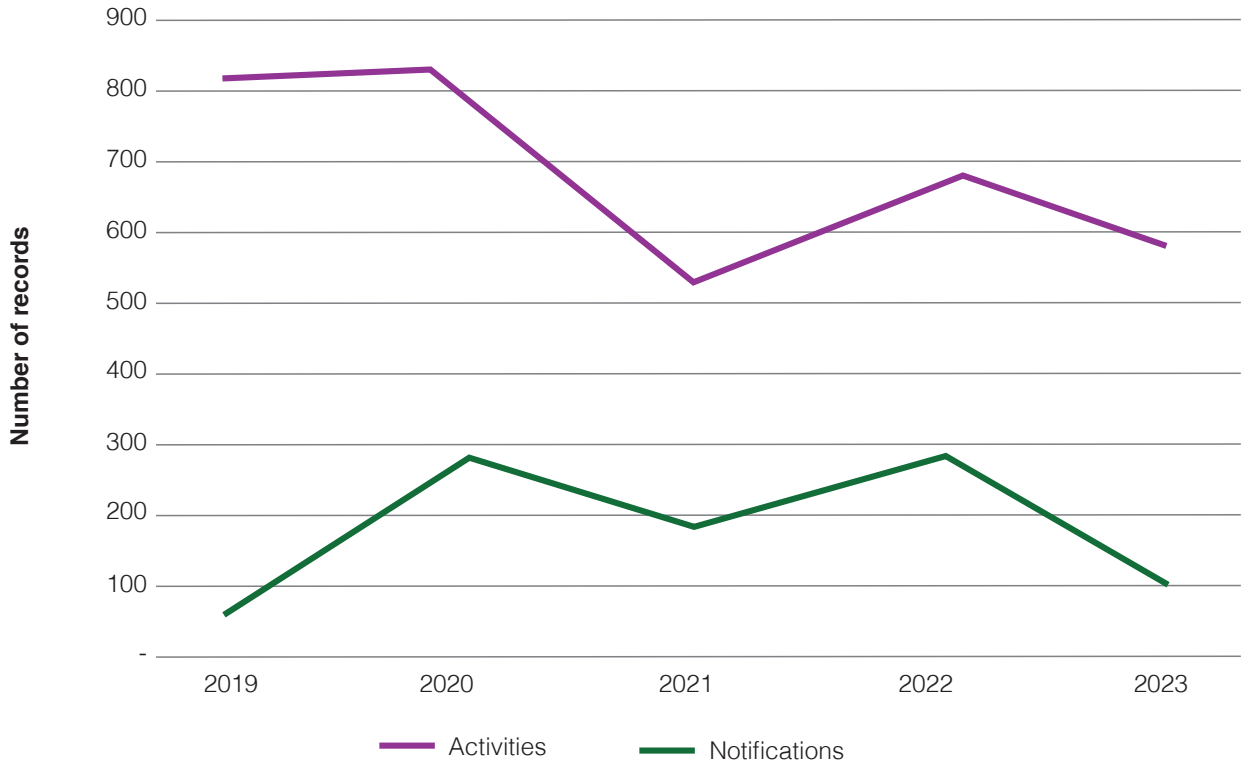


Figure 34 - Evolution of activity records and notifications for the Amazon biome over the last five years

Source: Prepared by the author based on data from SisGen.

Figure 35 shows that companies make 95% of registrations for users who register product notifications. The cosmetics industry has been extremely important in developing the Amazon bioeconomy based on PG and ATK. Nevertheless, this result also indicates that much of the potential of the Amazon's biodiversity is still not being investigated and developed. The potential compatible with the socio-biodiversity of the Amazon biome, as well as that of the other Brazilian biomes, can be seen in a much broader spectrum of sectors and companies, including cosmetics, pharmaceuticals, food, new materials, and chemicals in general, which are still completely absent from the use of the region's genetic resources.

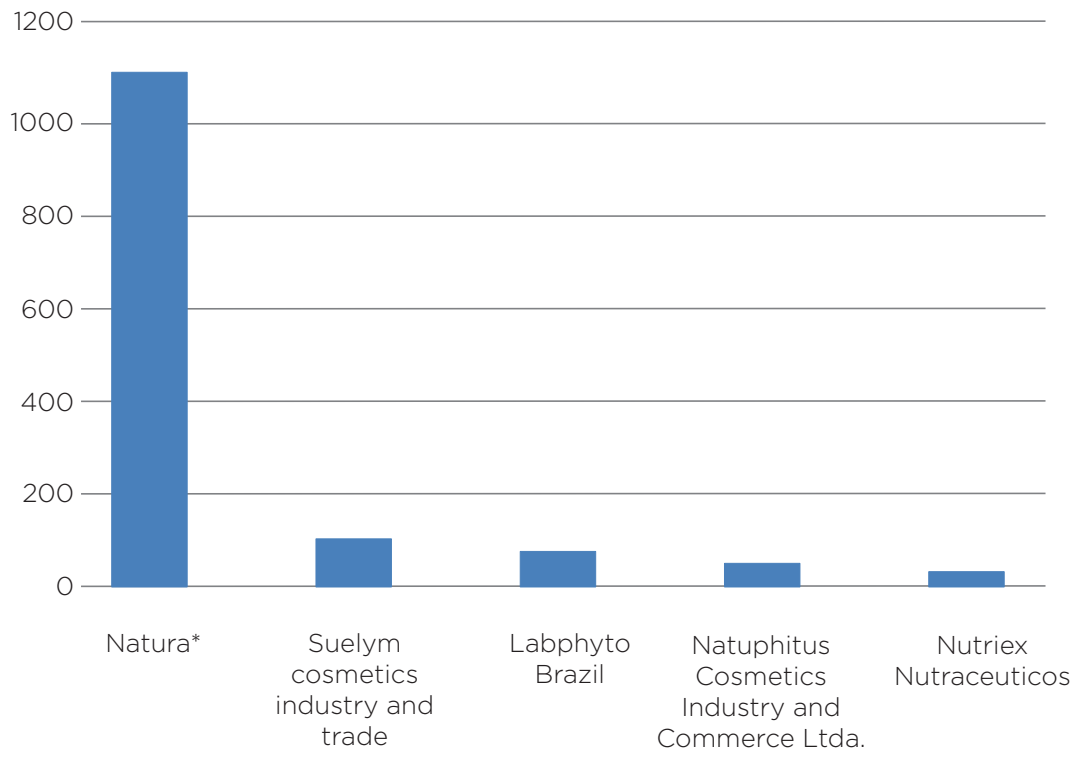


Figure 35 - Main companies notifying finished products from PG and ATK for the Amazon biome

Note: *Includes Natura Cosméticos S.A., Natura Inovação e Tecnologia de Produtos Ltda. and Indústria e Comercio de Cosméticos Natura Ltda.

Source: Prepared by the author based on data from SisGen.

4.1 Overview of the data analysis results on access to genetic heritage and associated traditional knowledge in the Amazon biome

This pioneering analytical overview of the data available in SisGen for the Amazon biome provided an overview of how genetic heritage and associated traditional knowledge are being used, and how much of these activities are being converted into finished products.

Through this exercise, it was possible to compare the activities related to the Amazon biome with those of other national biomes to see the relevance of flora, especially its extracts, in the activities registered, as well as more specific elements, such as requests for secrecy and objects and purpose of access.

As a result of the research and development (R&D) activities registered, it was also possible to verify that more than 17% of the accesses made to genetic heritage and associated traditional knowledge are converted into finished products. However, these products belong almost exclusively to just one sector, cosmetics, among the many that the bioeconomy can cover. The existing barriers need to be investigated in greater depth and how they can be overcome so that other economic sectors - such as pharmaceuticals, food, new materials, and chemicals in general - can also become part of the mix of bio-businesses and bio-products from Amazonian biodiversity.

Finally, it is worth noting that the recent nature of this type of data poses inherent challenges for its in-depth analysis. Methodologies, systems, and definitions are being developed to improve accessing, recording, and reporting such activities.

5. Conclusions

In recent years, Brazil has sought to expand its bioeconomic potential through the sustainable use of biodiversity resources, particularly in the Amazon biome. Initiatives such as the preparation of the National Bioeconomy Plan via an inter-ministerial committee, the resumption of external and internal funding for the Amazon, and the determination of the bioeconomy as one of the missions in the new neo-industrialization policy, among many others[5] - make clear the coordinated national intention to develop the national bioeconomy. However, the Amazon region must have scientific and technological capacities and skills to address this potential.

These capacities and competencies combine various elements, such as teaching and research infrastructure, qualified human

5 For a mapping of initiatives in the Amazon bioeconomy, access the *3rd OBio Bulletin - Amazon Bioeconomy* here.

resources, and an active regulatory regime compatible with the local reality. Brazil has laid the foundations for the emergence and development of this sophisticated and rich socio-bioeconomy, such as the Biodiversity Law and the instruments for the fair and equitable sharing of benefits, but there is still a need to improve existing policies and measures; complete the regulatory and incentive mechanisms, to have appropriate institutional arrangements and business models, as well as improve the STI, energy, mobility and connectivity infrastructures; guarantee permanent control of actions that threaten the biome, such as deforestation and illegal mining; and consolidate instruments to ensure the rights of traditional peoples.

Information about this precious biome and all the spheres that influence its dynamics must be demystified and understood. Evidence about the current situation of the Amazon and the people who inhabit it needs to be measured and analyzed so that efforts and resources can be used efficiently. This is an important part of the Bioeconomy Observatory's mission.

This bulletin discusses some of the elements that make up an STI assessment for the Amazon region: training of human resources in STI with a focus on programs, training, and performance of masters and doctors in the region; scientific production of the main teaching and research institutions established in the Brazilian Legal Amazon; and data on access, use and generation of products from the genetic heritage and associated traditional knowledge of the Amazon biome. As well as providing information, these overviews aim to provoke a discussion on how much still needs to be developed to achieve this desired bioeconomy based on the Amazon's extraordinary biodiversity.

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