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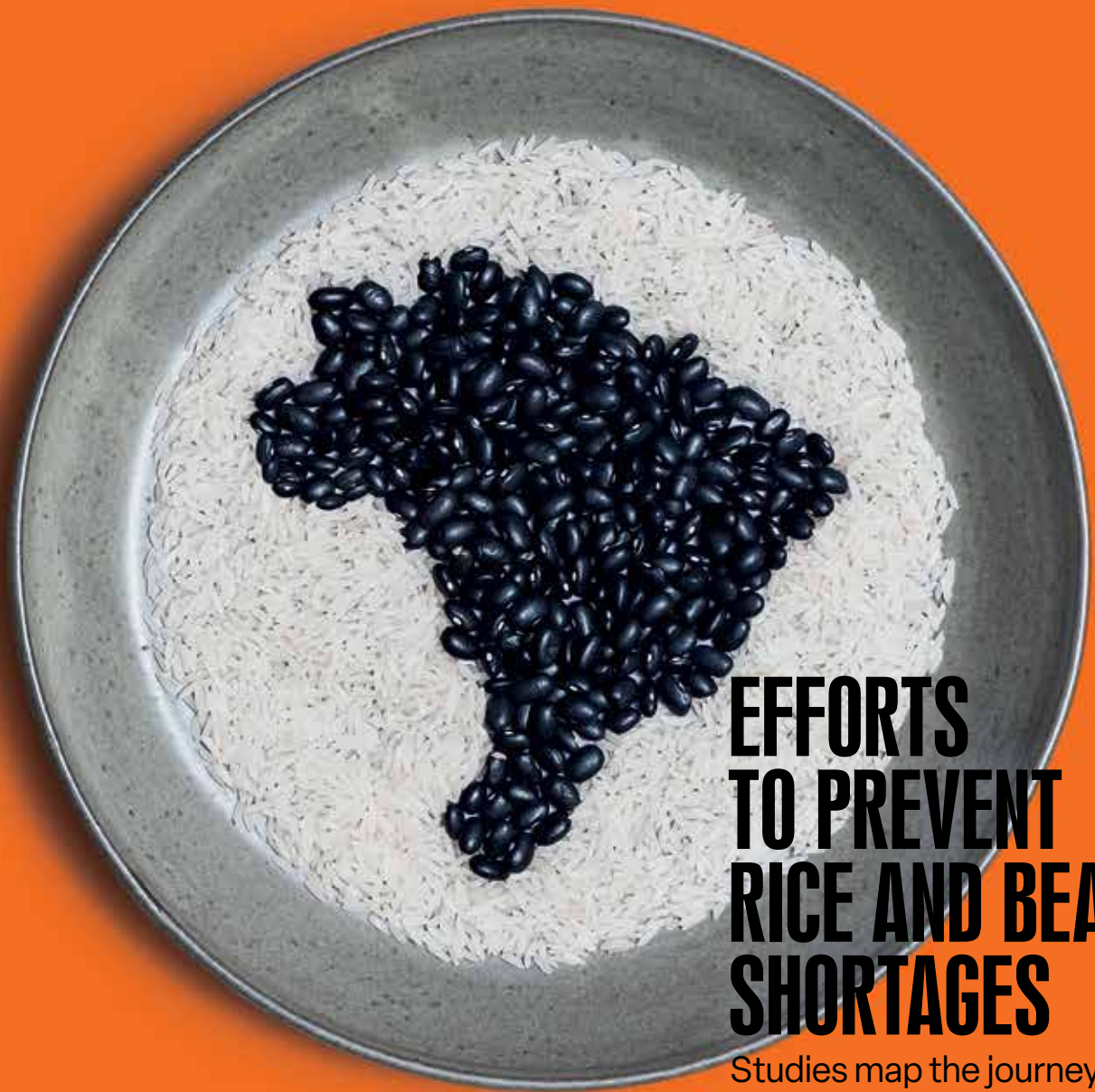

EFFORTS TO PREVENT RICE AND BEAN SHORTAGES

Studies map the journey taken by food from farm to fork with the aim of combating hunger and food insecurity

Article publication charge waivers and discounts are inaccessible to researchers in Brazil

Bioactive glass can potentially be used to treat bone cancer and induce regeneration

Company develops transgenic moth to combat maize's major pest

Ethnographic study reveals how the Yanomami interpret dreams

In its 50th year, EMBRAPA seeks a balance between productivity and environmental preservation

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Food on the table

Alexandra Ozorio de Almeida | EDITOR-IN-CHIEF

Brazil is known for its agricultural activity. The country's harvests break record after record, with growing productivity, and Brazil is a world leader in exports of various commodities. However, there is another agricultural reality that is less attractive. The area planted with rice and beans, the basis of the national diet, decreased by more than 30% from 2006 to 2022, according to IBGE, the national statistics agency.

The shift to growing more profitable export-oriented items contributes to food insecurity in the country. Food insecurity means the lack of consistent access to nourishment, both in quantity and quality. It is estimated that more than half of the Brazilian population – approximately 125 million people – today experience some degree of food insecurity.

Researchers in nutrition, economics, sociology, agronomy, and geography are focusing on hunger (cover feature, *Page 6*). In addition to understanding this complex phenomenon, they look for ways through which the country can face this apparent paradox, ensuring adequate nutrition for its population.

In 2023, EMBRAPA (Brazilian Agricultural Research Corporation) turned 50 (*Page 20*). Its mission is to provide Brazil with food security by means of a tropical model of agriculture and animal farming. The research produced at the institution, which has campuses in all federative units, is largely responsible for the country's agricultural diversity and international position as a food exporter.

However, the worrying effects of climate change and new demands from consumer markets call for greater focus on sustainable agriculture, an area of research to which Embrapa has dedicated increasing efforts.

It was in agronomic engineering that the research career of plant geneticist Marcio de Castro Silva Filho began. Castro took over as FAPESP's Scientific Director in April 2023. For several years, he has combined research on plant-insect-pathogen interactions with institutional action.

Formerly a director of CAPES, the national foundation for the improvement of higher education personnel, Castro was also a postgraduate dean at the University of Sao Paulo, an institution where he settled upon returning from a doctorate abroad. In the interview in this issue (*Page 14*), Castro talks about his career and anticipates the problems he will focus on in his new role.

A Brazilianist can be defined as a non-Brazilian national who conducts research on Brazil aimed at a foreign audience (*Page 56*). However, the term covers a historical process of both rivalry and collaboration. In the last century, these researchers focused on understanding Brazil as a whole and its historical processes. More recently, less attention has been given to a single nation, and interest has been directed toward broader themes.

Dreams are viewed by the Yanomami people as a way of seeing the invisible. From the perspective of psychoanalytical theory, dreaming is a representation of individual desire and a means of accessing the subconscious. Ethnographic research among the Yanomami points to dreams as a way of entering realities that are inaccessible while awake (*Page 62*). Experiences of their waking lives are just as important as those that occur when dreaming: they are complementary ways of existing in the world and relating to it.

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Cover
Amanda Negri, Claudia Warrak, Léo Ramos Chaves and Vitória Couto

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PHOTOS **1** CLAUDIA ANDUJAR/ COURTESY GALERIA VERMELHO **2** EDU FRAGOSO / ONÇAFARI
3 EDUARDO CESAR / PESQUISA FAPESP MAGAZINE **4** LÉO RAMOS CHAVES / PESQUISA FAPESP MAGAZINE

COVER

The food system concept emerged to encompass different stages of the food production process

In addition to poverty, research on hunger is starting to examine bottlenecks in the journey that food takes from farm to fork

Christina Queiroz

PUBLISHED IN JUNE 2023

According to the Food and Agriculture Organization (FAO) of the United Nations, Brazil is the third largest food producer in the world, and according to the Brazilian Agricultural Research Corporation (EMBRAPA), it provides food for approximately 800 million people. Such abundance, however, does not change the fact that more than half of the country's population—125.2 million people—faces some level of food insecurity. This term is defined as having not only an insufficient quantity of food to eat but also insufficient quality, according to data from the Brazilian Research Network on Sovereignty and Food Security (Rede Penssan). How can this paradox be resolved? Various fields of research have proposed that the key to addressing the problem of hunger is to analyze bottlenecks in food systems, including the journey from farm to fork, in addition to the impacts of the climate crisis.

Pioneering studies carried out in Brazil, such as the research of physician Josué de Castro (1908–1973), established direct relationships between hunger and poverty, explains Marcelo Neri, an economist and director of the Center for Social Policy at the Getulio Vargas Foundation (CPS-FGV). "In recent years, studies have begun to indicate that financial poverty must be eradicated to reduce food insecurity in Brazil, but that doing so alone is not enough," he says.

In 2021, 62.9 million Brazilians (29.6% of the country's total population) were categorized as low earners, with a household income per capita of less than R$497 per month, according to the Map of New Poverty published by FGV last year. In 2023, the number fell, returning to the 2020 level of approximately 53 million people in this income bracket. Since 2020, the federal government has tripled the amount paid out by the Bolsa Família/Auxílio Brasil welfare program and increased the number of people eligible from 14 million to 21 million. However, food insecurity only fell from 36% to 34% in the same period, a change considered very small. "It is surprising to note that during the pandemic, there was a disparity between measures to reduce monetary poverty and food insecurity," Neri highlights.

He points out that school closures during the pandemic affected one of the country's key food security policies—the National School Meals Program (PNAE), responsible for providing food to 40 million students—which may have had a greater impact on food insecurity than poverty. According to the researcher, the fact that the federal budget for school meals has not been adjusted for six years and the 2019 disbanding

PHOTOS 1 & 2 LÉO RAMOS CHAVES / PESQUISA FAPESP MAGAZINE 3 KIMIE SHIMABUKURO / GETTY IMAGES

of the National Council for Food and Nutritional Security (CONSEA), which served to advise the government on public policies related to nutrition and food security, also exacerbated the situation. "We are looking a lot at income but very little at hunger," argues the economist.

Rooted in the issue of world hunger, the concept of food security emerged after the Second World War (1939–1945) with the aim of identifying situations related to food access and based on the perception that food needed to be produced in sufficient quantity to feed a rapidly expanding global population. "Today, in addition to ensuring a sufficient calorie intake, the Brazilian concept of food security encompasses nutrition and food sustainability, expanding the notion beyond production," observes nutritionist Elisabetta Recine of the University of Brasília (UnB) and president of CONSEA, which was re-established in 2023. Nutritionist Dirce Maria Lobo Marchioni of the University of São Paulo (USP) reports that as the concept of food safety broadens, it has recently begun to include the principle of environmental preservation—the idea that diets should be healthy to help conserve the planet.

Another concept that has guided studies on food insecurity over the last five years is the food system, which encompasses the journey that food takes from farm to fork—the stages through which it is grown, caught, hunted, processed, packaged, transported, distributed, sold, purchased, prepared, eaten, and discarded. Following this approach, scientists are working to identify the bottlenecks in each link of the system—the characteristics of which differ depending on the country or city—as a basis for seeking solutions to the issue of hunger. From this perspective, one objective may be to identify whether the difficulties in accessing food are due to a lack of healthy products available in a given region or to high levels of waste. Sílvia Helena Galvão de Miranda, an agricultural engineer from USP's Luiz de Queiroz College of Agriculture (ESALQ), explains that agricultural research carried out in the 1950s and 1960s already highlighted the need to examine production chains and their environments rather than production alone. "This wider perspective made it possible to identify that sanitary standards in animal slaughter needed to be improved, for example, and that fruit transportation conditions could be improved to increase productivity and product quality," she says.

At the World Conference of Science Journalists (WCSJ), which took place in Medellín, Colombia, at the end of March, sociologist Jenny Wiegel, regional coordinator of the International Center for Tropical Agriculture (CIAT), shared the results of her research into food systems in cities in the Global South. In a 2019 study, she

PHOTOS 1 & 3 EDUARDO CESAR / REVISTA PESQUISA FAPESP **2** LÉO RAMOS CHAVES / PESQUISA FAPESP MAGAZINE
4, 5 & 6 LÉO RAMOS CHAVES / PESQUISA FAPESP MAGAZINE **INFOGRAPHIC** ALEXANDRE AFFONSO / PESQUISA FAPESP MAGAZINE

It is mostly small businesses that produce healthy foods consumed in Brazil

Approximately 30% of food in the country is thrown out, a percentage considered high compared to other countries

SOURCE BRAZILIAN RESEARCH NETWORK ON SOVEREIGNTY AND FOOD SECURITY

A total of 19% of premature deaths worldwide are the result of hunger and obesity caused by inadequate nutrition

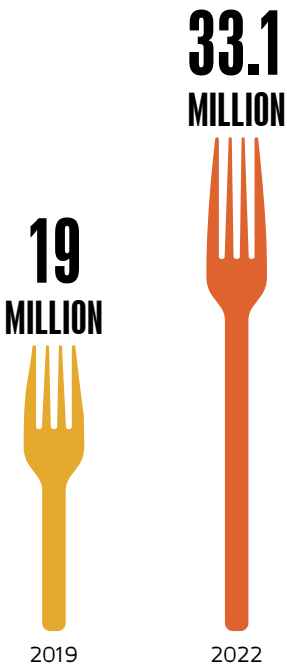
5 6

analyzed the food system in the Colombian city of Cali. The study was based on the observation that 51.3% of families were experiencing food insecurity and that children and adolescents in the municipality were on average more overweight and obese than the same age group in the Pacific region. In addition, Cali was found to have had the highest values of food waste in the entire country. "Given this situation, our hypothesis was that reducing food insecurity is inextricably linked to the search for food waste reduction strategies," said the sociologist during the conference. Wiegel also conducted research in Nairobi, Kenya. In the city of approximately 4.55 million inhabitants, 60% of people live in slums, and 65% of businesses that sell food are open-air market stalls. Her study found that 9% of the population was deficient in vitamin A, 21% was deficient in iron, and 83% was deficient in zinc. "We observed that 70% of the fruit eaten by the city's low-income population was banana, suggesting that public nutrition can be improved by increasing the variety of fruit available at street markets, in addition to creating policies to ensure they are accessible to the low-income population," proposed Wiegel.

However, what characterizes the food systems of an enormous country such as Brazil, and what are its bottlenecks? Answering this question is one of the central objectives of the Brazilian National Institute for Science and Technology (INCT) for Combating Hunger, founded at the end of last year with funding from the Brazilian National Council for Scientific and Technological Development (CNPq). Under Marchioni's leadership, the center will use the food system concept as a basis for coordinating different fields of knowledge. She explains that, in general, the agro-industrial system, which produces raw materials for foreign markets, is predominant in Brazilian agriculture. FAO data for 2022 indicate that in recent years, Brazil has remained the fourth largest grain producer in the world and the second largest exporter. As a result, Marchioni says, the country faces challenges related to the production of healthy and varied foods, such as fruits and vegetables, for the domestic market. "We need to systematize and deepen our knowledge of our bottlenecks. Brazil has multiple food systems, making the fight against hunger an even more complex challenge," she explains. The Yanomami food system, for example, is based on growing crops, hunting, and collecting fruits and insects, in stark contrast to urban populations, who usually buy their food from stores and open-air markets.

HUNGER INCREASED DURING THE PANDEMIC

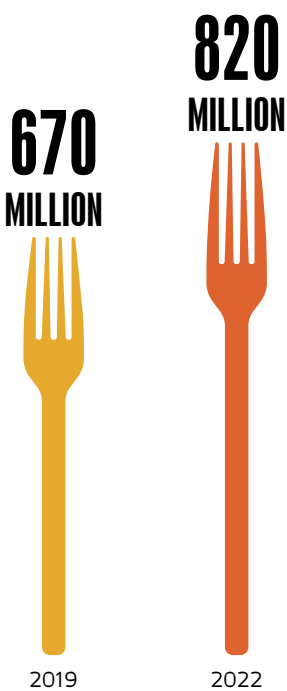
The number of Brazilians without access to food grew by 14 million as COVID-19 spread around the country



SOURCE BRAZILIAN RESEARCH NETWORK ON SOVEREIGNTY AND FOOD SECURITY

GLOBAL POPULATION

A total of 150 million people lost access to food due to the pandemic



SOURCE FOOD AND AGRICULTURE ORGANIZATION (FAO) OF THE UNITED NATIONS

The INCT was born from the Working Group on Public Policies to Combat Food Insecurity and Hunger, created by Vahan Agopyan, who was at the time dean of USP and is now the São Paulo State Secretary of Science, Technology, and Innovation. "The working group combined the experience of more than a dozen research groups at the university that studied food, food security, economics, and public policy," says Agopyan. The group, coordinated by Miranda from ESALQ-USP, drafted 39 recommendations for the formulation of public policies, including the creation of minimum income and food and nutrition education programs, the development of online platforms to coordinate civil initiatives related to food security, and the strengthening of the federal policy for basic food stocks. "One of the surprising things about the report is that most of the recommendations do not require huge investments," says Agopyan. Some of the guidelines recommend the development of integrated measures across public institutions in the state of São Paulo, such as state schools and universities, to search for answers to society's biggest hunger-related questions and to create mechanisms to formalize the work of family farmers and help them join the food commercialization and distribution system. The secretary points out that universities and researchers are striving to translate scientific information into practical proposals for public policies. "Transforming research findings into recommendations for public managers is a complex process. Without this work, legislators would find it difficult to understand the results and incorporate them into legislation," he points out.

In addition to the concept of food systems, another element that has guided recent studies on hunger is the climate crisis. Marchioni highlights that in *Geografia da fome* (The geography of hunger; 1946), Josué de Castro (*see* Pesquisa FAPESP *issue no. 324*) reflects on the relationship between hunger and ecology, but global climate change has led to new and challenging factors for academics.

These new investigative approaches were punctuated by two dossiers published by the medical journal *The Lancet* in 2019, systematizing the argument that science needs to seek coordinated solutions to three major challenges that have been addressed only individually until recently: malnutrition, obesity, and the climate crisis. The reports showed that malnutrition in all its forms, including obesity and undernutrition, causes 19% of premature deaths worldwide. The term syndemic, coined by American anthropologist and physician Merrill Singer in the 1990s, is

The climate crisis and extensive cultivation of products for the foreign market, such as soy, have exacerbated food insecurity

1
2

BRAZIL PLACED 5TH IN RESEARCH RANKING

A survey conducted by the publishing house Elsevier on global scientific output related to the Sustainable Development Goals (SDGs) set by the United Nations (UN) ranked Brazil fifth in the world for studies into hunger and sustainable agriculture between 2019 and 2022. With 10,000 articles published in that period, the country's scientific output was 110% above the world average.

The Brazilian National Council for Scientific and Technological Development (CNPq) and the Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES) ranked 3rd and 4th, respectively, among funding agencies that invested the most in research related to SDG 2, which aims to eradicate hunger. The survey data came from the SciVal platform, which provides research results from more than 20,000 institutions in 230 countriess.

PHOTOS 1 BLOOMBERG / GETTY IMAGES **2** PAULO FRIDMAN / CORBIS VIA GETTY IMAGES **INFOGRAPHIC** ALEXANDRE AFFONSO / PESQUISA FAPESP MAGAZINE

used to describe a situation where two or more diseases interact in such a way that they cause greater harm than they would separately. In recent years, the meaning has evolved, and the term has been adopted by researchers investigating the complexity of global hunger. Malnutrition, obesity, and the climate crisis have thus come to be considered syndemics that share a common determinant: food systems. "These systems are the main drivers of poor health and environmental degradation. Urgent global efforts are needed to collectively transform diets and food production," urge the authors of one of the reports.

The Lancet dossiers recommend developing policies with the potential to reduce the global consumption of foods such as red meat and sugar by 50% and to increase the intake of foods considered healthy—such as nuts, fruits, vegetables, and legumes—by 100%, arguing that doing so could prevent 10.8 to 11.6 million deaths per year. They also stress that agriculture needs to be reoriented toward the cultivation of food for domestic consumption while incorporating practices to preserve biodiversity and to reduce water consumption and carbon dioxide emissions. Halving food losses across the entire supply chain, from production to consumption, is another recommendation. Andréa Rossi Scalco of São Paulo State University (UNESP), Tupã campus, whose research on food waste reduction strategies was funded by FAPESP, explains that it is estimated that 30% of the food produced in Brazil is thrown away—a percentage considered high. Specific legislation is therefore needed to regulate the disposal of products that cannot be sold but that are suitable for consumption. "Argentina, Colombia, and Mexico, for example, have laws that oblige commercial establishments to donate this food, stipulating the necessary conditions," she explains.

Despite the lack of specific legislation, technological advances can contribute to improved food use. Nutritionist Eliana Bistriche Giuntini of the Food Research Center (FORC), one of the Research, Innovation, and Dissemination Centers (RIDCs) funded by FAPESP, gives an example of a technique developed to produce green banana flour. "Banana is a sensitive fruit, and producers record significant losses throughout the supply chain. Selling the product while it is still green, to be used to make flour, offers a potential way of mitigating this waste," she points out. A patent for the methodology has been filed by FORC. The secret is to maintain

the resistance of the starch during production of the flour, avoiding the nutritional losses caused by inadequate processing.

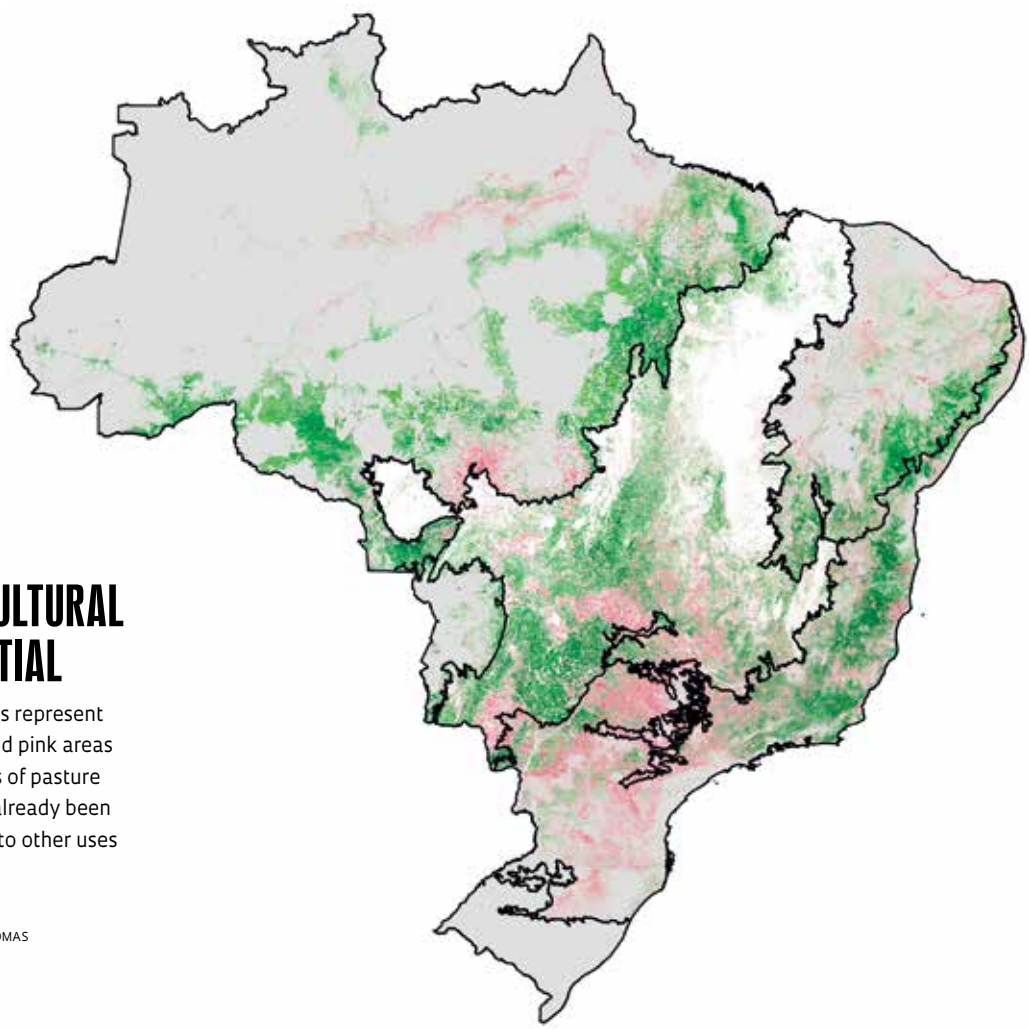
Artificial intelligence (AI) resources offer other alternatives in the search for solutions to the problem of world hunger. A group of researchers from MapBiomas, a collaborative network of nongovernmental organizations (NGOs), universities, and technology startups, has been using AI to analyze satellite images of cattle pastures across Brazil since 2008. Remote sensing expert Laerte Guimaraes Ferreira of the Federal University of Goiás (UFG), current director of programs and scholarships at the Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES), says that pasture areas, which currently occupy approximately 20% of Brazil's national territory, could be used to double food production in the country without increasing deforestation. To do so, she says investment is needed in the recovery of degraded pastures and intensification of livestock farming, which would free up pasture areas for other uses.

Antonio Mauro Saraiva of USP and the Combating Hunger INCT conducts research into how AI can contribute to the development of small-scale farmers who sell products for local consumption. Considering the complexity of food systems, Saraiva maintains that AI is essential in research and the formulation of public policies since information on food is spread across different databases, such as EMBRAPA, the Agronomic Institute (IAC), the Brazilian Institute of Geography and Statistics (IBGE), and state and municipal departments. In response to the *Lancet* recommendations, many researchers have suggested that food security measures need to impact two or three links in a food system simultaneously. "We cannot solve hunger by changing just one factor, and AI is crucial to integrating all of the dimensions involved," concludes the engineer, who is also part of the Center for Artificial Intelligence funded by FAPESP through an agreement with IBM. ■

Projects

1. FORC – Food Research Center (no. 13/07914-8); **Grant Mechanism** Research, Innovation, and Dissemination Centers (RIDCs); **Principal Investigator** Bernadette Dora Gombossy de Melo Franco (USP); **Investment** R$47,236,474.87.
2. Artificial Intelligence Center (no. 19/07665-4); **Grant Mechanism** Engineering Research Centers; **Principal Investigator** Fabio Gagliardi Cozman (USP); **Investment** R$7,050,377.09.

Other projects, scientific articles, books, and reports consulted for this article are listed in the online version.



AGRICULTURAL POTENTIAL

Green areas represent pasture, and pink areas show areas of pasture that have already been converted to other uses

SOURCE MAPBIOMAS

MAP MAPBIOMAS/UNIVERSIDADE FEDERAL DE GOIÁS (UFG)

IMPACT ON FOOD PRODUCTION

The way basic Brazilian ingredients are cultivated needs to be adapted to withstand the effectsof the climate crisis

Researchers are investigating how climate change affects crops such as rice and cassava

The cultivation of rice and beans, two central ingredients in the Brazilian diet, faces challenges related to rising global temperatures, higher levels of carbon dioxide in the atmosphere, and declining water availability for irrigating crops. Confronted with the worsening climate crisis, the country needs to invest in the research and development of technologies capable of improving the adaptability of its food production processes.

Coffee, beans, and rice are the most consumed daily items per capita in Brazil, according to a 2020 survey by the Brazilian Institute of Geography and Statistics (IBGE). Domestic production is not sufficient to meet the demand for beans, which is supplemented by imports. To meet local demand by 2050, EMBRAPA found that bean production will have to expand by 44%, equivalent to an increase of 1.5 million tons. The research, carried out in partnership with the Luiz de Queiroz College of Agriculture at the University of São Paulo (ESALQ-USP), was published in the journal *Agricultural Systems* in 2022. "This expansion will have to take place in a scenario marked by the adverse effects of climate change," warns Alexandre Bryan Heinemann, an agronomist from the Rice and Beans Unit of the Brazilian Agricultural Research Corporation (EMBRAPA) in Goiás.

The total area in Brazil used to grow rice and beans decreased by more than 30% between 2006 and 2022, according to the IBGE's Systematic Survey of Agricultural Production. In the same period, the cultivation of soybean and corn—two of the country's largest agricultural exports—increased by 86% and 66%, respectively. "Growing products for export is more profitable, but it does not help improve food security in the country," notes Heinemann. Another study led by the researcher, published in *Frontiers in Sustainable Food Systems* in 2022, found that by 2050, the effects of the climate crisis could lead to a reduction of up to 60% in the amount of water needed to produce upland rice in Goiás, Rondônia, Mato Grosso, and Tocantins.

In 2018, concerned about the impacts of droughts and rising temperatures on the production of basic foodstuffs, the Agronomic Institute (IAC) of São Paulo's Department of Agriculture and Food Supply launched its first bean cultivar designed to cope with water shortages. The research identified that bean plants with more aggressive roots are able to absorb more nutrients and water from deeper in the soil. Another finding was that precocious plants with short growing cycles are more tolerant to climatic stresses. "Improving the adaptability of our crops is one of our greatest challenges," says IAC agronomist Alisson Fernando Chiorato.

Cassava, named the food of the twenty-first century by the Food and Agriculture Organization of the United Nations (FAO) in 2018, is one of the crops that can best adapt to the effects of climate change, according to other studies by EMBRAPA. Research carried out since 2017 by agronomist Jailson Lopes Cruz concluded that high atmospheric concentrations of CO_2 alleviate the inhibitory effects of drought on the physiology and growth of cassava plants. This means that new areas can be incorporated into the cassava production process, especially in semiarid regions, improving the supply of this product. "This crop is also highly versatile. It can be eaten directly, but its derivatives, such as starch flour, can also be used as ingredients for other products, generating income for producers," concludes Carlos Estevão Leite Cardoso, an agronomist from EMBRAPA Cassava and Fruit Crops. ■ **Christina Queiroz**

PHOTOS 1 EDUARDO CESAR / PESQUISA FAPESP MAGAZINE **2** LÉO RAMOS CHAVES / PESQUISA FAPESP MAGAZINE

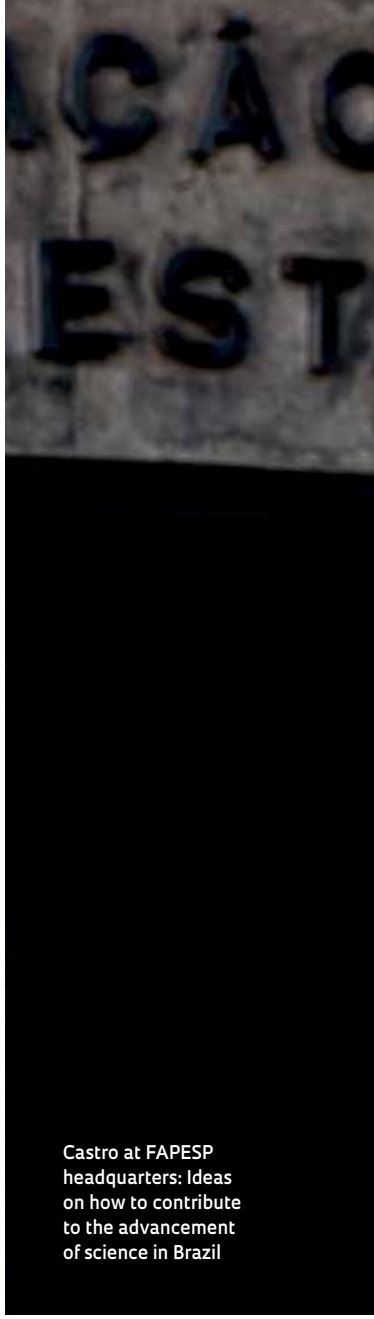
A BOOST FOR BOLD RESEARCH

New scientific director shares his vision for science and the future of FAPESP and reflects on his career as a plant geneticist

Alexandra Ozorio de Almeida, Fabrício Marques and Neldson Marcolin

PORTRAIT **Léo Ramos Chaves**

PUBLISHED IN JUNE 2023



Castro at FAPESP headquarters: Ideas on how to contribute to the advancement of science in Brazil

Marcio de Castro Silva Filho, a geneticist from the state of Minas Gerais, has been familiar with FAPESP since the beginning of his scientific career, when he was invited to join the Young Talents program at the University of São Paulo (USP) in 1994. The aim of the initiative was to attract researchers who had recently graduated and had studied abroad to work at the institution. With Castro, this goal was achieved. Within just a few years, he built a strong scientific career at the Luiz de Queiroz College of Agriculture (ESALQ-USP), including his own laboratory and research projects funded by the foundation.

Almost 30 years later, Castro went from a FAPESP beneficiary to the agency's director. On April 27, he was appointed scientific director, replacing neuroscientist Luiz Eugênio Mello. The move will provide an opportunity to improve processes that, as a user, he felt could be more effective.

Marcio de Castro was born in Belo Horizonte and studied agronomic engineering at the Lavras College of Agriculture, now known as the Federal University of Lavras (UFLA). During an internship at EMBRAPA Maize and Sorghum, he began to specialize in plant genetics, which he studied further during his PhD work in Belgium and later in research carried out at ESALQ. One of the topics he studies is interactions between sugarcane plants and insects. As part of a collaboration with a group from the University of Campinas (UNICAMP), he showed that biological information and digital information have the same mathematical structure.

At the turn of the century, Castro began helping the Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES) in the evaluation of graduate programs and went on to become director of the agency between 2011 and 2016. When he was named scientific director at FAPESP, he was working as dean of graduate studies at USP. In the interview below, conducted in person at the foundation's headquarters in São Paulo, the new director talks about his most important scientific work and lays out some ideas about how he intends to contribute to the advancement of science in Brazil.

AGE 62

FIELD OF EXPERTISE
Plant genetics, science and technology management

INSTITUTION
University of São Paulo (USP)

EDUCATION
Undergraduate and master's degrees from UFLA, PhD from the Catholic University of Louvain, Belgium

SCIENTIFIC OUTPUT
80 articles and 4 patents

You graduated as an agronomist and became a geneticist. Why the change?
First, we need to go back a step. I am the son of Marcio de Castro Silva [1931–2015], a respected angiologist and vascular surgeon from Belo Horizonte. My intention, ever since I was a child, was to study medicine. But when the time came to apply, I asked myself, "Will I even have the chance to work in the same field as my father?" I loved nature and the farms where I spent my childhood vacations. When it was time to sign up for the enrollment exam, I decided on agronomy instead. Soon after, I went to talk to my grandmother on my father's side, who often used to say that he was the pride of the family. She greeted me by saying, "So we're going to have another doctor in the family." When I told her that no, I was going to study agronomy, she responded, "No, don't do that! Everyone knows how to work in the garden." The funny thing is that if I had studied medicine, I think I still would have ended up in genetics research.

Agronomy is a broad field, isn't it?
Yes. I often joke with people that if you don't know what to do, study agronomy. It covers human sciences, health, biology, agriculture, agricultural economics, rural economics, sociology... You will find something that suits you. You will find your path. That's how it was for me. I did the degree but not the undergraduate research project. As a fresh new graduate, still very young and not really knowing where to go, I received a fellowship from EMBRAPA. I went to Brasília to see where I could work, because they have units all over Brazil. Someone there asked me, "What field do you want to work in?" I didn't know what to choose. The person I was talking to looked at me and said, "You look like a geneticist."

Is that true?
It is. I didn't even like genetics when I studied it as an undergraduate, but I started working in the area and realized that it was my thing. I went to EMBRAPA Maize and Sorghum in Sete Lagoas,

Minas Gerais, where I met a fantastic researcher called Ricardo Magnavacca. I always listened to him closely, and when he told me about his experience of doing a PhD in the USA, I realized that I wanted to study abroad. Ricardo advised me to do a master's degree in Brazil and a doctorate abroad. He said it would be good to do a master's degree here while I matured and saw if this was really the path I wanted to take.

Did you follow his advice?
I did. I studied my master's degree at Lavras College of Agriculture, which is now the Federal University of Lavras. I was one of the last to do a full doctorate abroad with a scholarship from the CNPq [Brazilian National Council for Scientific and Technological Development]. In the 1990s, they started doing sandwich courses, through which doctorates are studied in Brazil but with part of the research done abroad. That makes things a lot cheaper. Instead of sending one person overseas, they can send four or five. When I went, almost everyone who applied for an agronomy fellowship from the CNPq was given one and did their PhD at an institution in another country.

Why did you choose Belgium?
I wanted to work with the Belgian scientist Marc Van Montagu. He and Jozef Schell [1935–2003] won an important prize in Japan for their contributions to science, including the discovery of the mechanism behind horizontal gene transfer between *Agrobacterium tumefaciens* and plants. But his group was full, since geneticists from all over the world wanted to work with him. I ended up in another laboratory at the Catholic University of Louvain. My advisor, Marc Boutry, was also a brilliant scientist.

And how did you end up at ESALQ?
During the last year of my PhD, I saw an ad for USP in Nature. It was an announcement by Erney Plessmann de Camargo [1935–2023], who was dean of research at the time, saying something along the lines of "Brazilians abroad: Don't you want to work at USP?" He had created an initiative called the Young Talent program. I had always studied in Minas Gerais and never in São Paulo. At that time, USP seemed like it was out of my reach. I submitted my résumé, and

> "I didn't even like genetics as an undergraduate, but I started working in the area and realized that it was my thing

one day, I received a fax from the director of ESALQ at the time, João Lúcio de Azevedo. It said, "This is a formal invitation to work at the Luiz de Queiroz College of Agriculture of the University of São Paulo." I was practically jumping for joy. I defended my thesis as soon as I could and then started working at the Genetics Department in Piracicaba. And that's where I built my career.

After arriving in São Paulo, how long was it before you became a recipient of funding from FAPESP?
The foundation was essential to me. Even before I arrived, I already had a research project in mind. My advisor said, "When you return to Brazil, avoid administrative positions. Work on developing your scientific career. That will make you invulnerable. Focus on your career." So I came back to Brazil and submitted my research proposal, and it was rejected. I got in touch with Rogério Meneghini, who was on the scientific board's advisory panel, to defend my project and appeal the decision. In the end, it was approved. Three years later, I submitted a thematic project, and this time, it was approved without any problems. Once I started working at ESALQ and managing my projects, I needed more physical space and more people to work with me. My workbench was attached to my desk, with little room to move. It was difficult. I used FAPESP's infrastructure program to improve and expand my lab. The new space was incredible and allowed me to progress with many collaborations. I made a great career of it and started receiving requests from CAPES to help with graduate course evaluations in the early 2000s.

Let's go back a little bit to the 1990s. What were your early studies like at ESALQ?
I wanted to understand how proteins inside a cell are directed to their respective addresses. Plant cells, like any other eukaryotic cell, are divided into organelles: the nucleus, mitochondria, chloroplast, endoplasmic reticulum, etc. There is intense protein traffic inside the cell, with every protein traveling in a certain direction. A protein that goes to the mitochondria does not go to the nucleus, for example. Nucleus proteins do not stay in the cytosol [the liquid that fills the cytoplasm] because they need to perform their function in the right place inside the cell. When I arrived at ESALQ, I tried to find a more practical application for this knowledge. My first project was to introduce a protein called leghemoglobin into a cellular organelle (the chloroplast in tobacco and potato plants in this case) to promote carboxylation of the RuBisCO enzyme, increasing photosynthesis. During my PhD, I had studied an unusual targeting sequence, and I invested in a collaboration with USP professor Carlos Menck. It was the first study showing that a protein could be simultaneously directed to two distinct locations within a cell, to the mitochondria and chloroplasts.

When did your research on plant-insect interactions begin?
At the end of my PhD, a Canadian postdoc friend of mine suggested that I could work with plant-insect interactions, which is a more applied field. When I arrived at ESALQ, I met Professor [José Roberto Postali] Parra, who is really knowledgeable in this area. And there was also Walter Terra, a biochemistry professor at USP's Chemistry Institute. I thought it seemed like a really good path, so I started studying plant-insect

interactions in sugarcane. That's how I later got involved in Bioen [FAPESP's Bioenergy Research Program]. I dedicated myself to understanding how plants produce defense mechanisms to prevent insects from using them as food or hosts. I studied several mechanisms, including how insects break down barriers to start using a plant as a host.

Soon after that, you made other discoveries related to this complex plant-insect interaction. Can you tell us more about them?

In a study that started more than 10 years ago, we investigated the complex interaction between sugarcane, its biggest pest, the sugarcane borer (*Diatraea saccharalis*), and fungi that were considered opportunistic—but we showed that they are not. We published papers emphasizing that the fungi control the plant and the insect as a means of propagating through the production of molecules that we call volatile compounds. When the plant is infected by the fungus, it produces volatile compounds that attract uninfected insect females. The females lay eggs on the plant, and when the caterpillars hatch, they bore into the plant and become infected. When the insects become adults, they are attracted to healthy plants. Thus, the fungus controls both the plant and the insect.

In the late 1990s, you were part of the Organization for Nucleotide Sequencing and Analysis (ONSA), a consortium of laboratories that sequenced the genome of the bacterium* Xylella fastidiosa *and then several other organisms. What was your role?

José Fernando Perez, then scientific director of FAPESP, and Fernando Reinach, one of the ONSA coordinators, called me right at the beginning because they knew I had been working with André Goffeau [1935–2018] of the Catholic University of Louvain, leader of the group that first sequenced an entire eukaryotic organism, a yeast species called *Saccharomyces cerevisiae*. They also called on Marcos Machado of the Agronomic Institute, João Carlos Setúbal from USP, and UNICAMP's João Meidanis, as well as Paulo Arruda, also from UNICAMP, for the bioinformatics parts. I participated in several meetings. People ask me why I didn't coordinate one of the *Xylella* groups. I considered doing so because the role included a public call for proposals with the prospect of major funding. But at around the same time, my first thematic project was approved. I sought advice from Walter Terra, who said, "Marcio, take care of your own area of expertise. It's more important that you develop your line of research. You'll become a point of reference in the field." I chose to go with the thematic project, but it pained me greatly that I couldn't do both.

Do you still think you made the right decision?

It would have been easier if I had joined the Genome Program. It received funding that allowed it to set up larger labs than ever before, but I think I made the right choice. The formation of the ONSA network was a daring and risky initiative that ended up turning out really well and generating great results. Developing a methodology capable of delivering a genome sequence was extremely important, and many people were trained in this area. Nowadays, it is possible to sequence dozens of bacteria in one day, and the new challenge is to ask scientific questions based on this information, build hypotheses, design experiments that explain natural phenomena, and transform it into knowledge that can be applied. There were lots of important scientific questions to be asked, but not every group was able to do so. The researchers who really stood out and established a guiding thread for their careers were those who had a good scientific question to follow, such as Parra, Menck, or Terra, to name a few.

> "The ONSA researchers who developed a guiding thread for their careers were able to do so because they had a good scientific question to follow

During your managerial career, you chose not to leave the lab. Do you plan to continue like this?

In the interview for the scientific director position, they asked me, "This role is going to take up a lot of your time; how are you going to deal with that? And your research?" I didn't want to say too much, but I don't plan on giving it up. I started at CAPES in 2011, then I was an associate dean at USP, and I supervise five doctoral students, a postdoc, and an undergraduate. I go to the laboratory pretty frequently to speak to them. "How are you? How are things going? Tell me about everything." I've changed a little bit in terms of the need to be by the students' side every day. We know what needs to be done; we have regular meetings. Almost all of them are also doing exchanges abroad, so they come and go. I'm a CNPq 1A researcher, and I still have my fellowship, with high-quality work now appearing in important journals. Curiously, I don't have any students from ESALQ, just one undergraduate student. All the rest are from other institutions, who see our work at conferences or in publications and seek me out. It's a fantastic group, and I can keep my eye on them from afar. They see the opportunities and have a strong interest in everything moving forward—they want to do more; they want to discover more things.

What is your opinion on the importance of encouraging researchers with different backgrounds to work together?

Interdisciplinary research is crucial to the advancement of knowledge, for science to move beyond an incremental level. The big leaps arise from interdisciplinary work. All over the world, the organizational structure in closed, monothematic departments is being left behind. When I was researching protein transportation, I was approached by two PhD students who worked with Reginaldo Palazzo Jr.

in the UNICAMP electrical engineering department. They had already been in touch with several researchers, but none were interested in collaborating with them. I went to talk to Palazzo, who is a brilliant researcher, and we decided to work together on mathematical explanations for biological phenomena. To put it simply, we showed that every DNA sequence has a mathematical structure behind it based on error-correcting codes, which are similar to the codes used in digital communication. Biological information and digital information have the same mathematical structure. We thought the work would have a great impact, but there was a lot of mathematics in the paper and it was published in an electrical engineering journal. However, it was only possible for us to achieve what we did by stimulating dialogue between different fields, with a group of electrical engineers talking to a geneticist.

How can we encourage interdisciplinarity?

Before I answer, let me point out that the two places most resistant to change are cemeteries and universities, by free choice of the people who reside there, okay? It is very difficult to encourage interdisciplinarity in an environment where people are so comfortably settled within their areas of expertise. One approach is to robustly fund transversal topics that require different expertise to generate answers. If you look at funding from the National Science Foundation, you'll see that it is directed toward transversal subjects. Two years ago, I was in London at a Research Councils UK event, and two colleagues invited me to dinner at the organization's restaurant. Dinner cost £80–100, but if you sat at a table near the entrance, which could seat about 12 people, you only had to pay £10. The goal was to encourage academics from different fields to sit next to each other and talk. Researchers from the humanities and applied social sciences also need to be involved. Isolation leads nowhere. Many of the answers to scientific questions will come from this type of collaboration.

Interest in graduate courses is on the decline. How can we deal with this problem?

The value of fellowships is one of the important variables, but not the only one. There is less interest because our graduate courses date back to the second half of last century. Students don't feel encouraged to continue in research. There are hardly any physicians doing graduate studies anymore. At USP and many other universities, students are starting their PhDs at the age of 33. They finish at 37 or 38 and start working aged almost 40. In Europe, the USA, and Canada, people finish their PhDs at 27 or 28 years old. Instead of wasting time talking about subjects, they have to interact, develop skills, gain international experience—at USP, 15% of doctoral students do fellowships abroad. That's fantastic. But there are other factors involved in the problem, and they do not only occur in Brazil. A recent editorial in *Nature* described the graduate education crisis as a global phenomenon. I spoke at an event in Egypt last year with the associate dean of the Technical University of Munich, and he said that 90% of the PhD graduates from the institution leave academia to work for private companies, government agencies, or NGOs or to set up their own business. At USP, we created a graduate course called Entrepreneur Scientist. It teaches basic concepts, and at the end, there is a workshop in which students have to solve a problem faced by society through an interdisciplinary approach.

> “The two places most resistant to change are cemeteries and universities, by free choice of the people who reside there

How can an agency like FAPESP help induce or promote this type of change?

One example would be for graduate fellowships to include social security contributions. I came back from doing my doctorate at the age of 33, and my father gave me good news. He told me he had paid my social security contributions during my studies. That will help me out in my retirement. If these students start contributing only when they graduate at age 38, they will have a very different professional life than they would have had in other careers. We could also establish new graduate study models. The master's degree has become a professional program. Only a third of master's graduates go on to do PhDs, but we continue to insist on demanding a master's degree as part of a researcher's training. Wouldn't it be better to reinforce doctoral and postdoctoral studies? While fewer people are looking for research-focused graduate courses, enrollment in MBA programs is exploding, reflecting the current demands of society. We need to create an environment of interaction with society through which researchers are taught to solve problems, participate in interdisciplinary projects, and work as part of a team in contact with diversity. If we don't stimulate these changes, there will be no jobs for PhD graduates.

Compared to developed countries, Brazil has proportionally fewer researchers in general and far fewer working for private companies. What is your perception of this?

The academic environment is not favorable to interactions with the private sector. There are certain initiatives that have been successful—EMBRAPII, for example, which unites support from universities, federal funding, and business resources, with companies defining what they want. There are many interesting projects bringing new knowledge into the company. At FAPESP, we have Engineering Research Centers/Applied Research Centers [CPEs/CPAs], but they involve partnerships between universities and what is still a restricted group of companies. It is not part of a development policy, which is what Brazil needs. There were people who said that this doesn't matter and that it's easier to just import from China. Then, the pan-

demic came, and we ran out of microchips, syringes, and drugs, almost all of which came from India.

Does your experience as a researcher funded by FAPESP give you any ideas on what to do as scientific director?
Of course. I have benefited greatly from FAPESP over the years. I'm receiving an ongoing grant at the moment, and I submitted two other proposals before taking on my new position. One example is that I think we can simplify our processes because we still get lost in the rules sometimes. Not just at FAPESP but in graduate studies as well, we have this habit of maintaining structures that were established a long time ago and never stopping to wonder whether they still make sense. We want to give researchers more autonomy and reduce bureaucracy.

Could you give an example?
Sure; I'll talk about my own case. My thematic project was for five advisors. Nowhere in the world does that. Three approved it the way it was, one asked for further details on the methodology, and the other wanted to reduce the budget by 10%. What response did I receive? Denied. To appeal the decision, I had to ask the whole group to come in and reconfirm their interest and then fill out a huge number of forms all over again. They were allowed to ask for more information about the materials and methods or to reduce the budget. Then, FAPESP would see if it was acceptable or not and would forward it for a comparative analysis. There is a huge firewall blocking the entrance to FAPESP and only a small one at the exit. Is your work incremental or disruptive? Was it used to formulate public policy, a new law, a change in understanding, or to open a new branch of knowledge? That's what we want to know.

So the idea is to avoid micromanagement and the need to monitor day-to-day activities, instead giving the community more space and trust—within certain limits—to do what it considers best for the development of the research. And the other side of the coin is demanding more from the results.
That's right. In the end, I can say that the result was disruptive, but whoever is evaluating it might say, "No, your findings didn't change anything. You described something that had already been discovered by A, B, and C. When your next application is submitted, we will compare it to this." Of course, my approach comes with risk. Those who dare cannot always achieve their aims, but we need to encourage people to become more daring anyway. Boldness can yield results in the future, at the end of the project or when submitting the next proposal. I have always been in favor of giving autonomy with responsibility because in the end, everyone's work is evaluated. If you give people autonomy but without evaluation, then there is a risk. But autonomy with the right oversight, particularly in terms of results, then yes. We need to slightly deconstruct the system that has developed in Brazil, where the means is gaining more relevance than the end. This should never be the case. The end result is what we must be focused on. The means must serve as the way of achieving the end, not the other way around.

> "I have always been in favor of giving autonomy with responsibility because in the end, everyone's work is evaluated

FAPESP has some special programs, such as Biota and Climate Change. Is there a chance of any new programs?
This is a role that FAPESP must continue to fulfill. Our understanding of the knowledge we have in certain fields should show us which challenges are most important. But this cannot be done alone. The foundation needs to increase its interactions with other agencies. FAPESP serves a lot of individuals—very few of its beneficiaries are companies. The foundation could also cooperate more with scientists from other states and other countries. It has already been doing this very well abroad. We need to reach out across the entire country because there is room to advance in partnerships with other research-funding agencies.

How do you see the future of the RIDC program?
The RIDC [Research, Innovation, and Dissemination Center] is a FAPESP trademark used to fund long-term projects. The approach, within the current structure, is interesting because it stimulates actions that are a little more interdisciplinary than thematic projects, which are more focused on a specific area. In the best RIDCs, there is a little more complexity and greater opportunity for more comprehensive research. I'm only just starting in my role here, but I think this is an aspect that should be thought about, to assess what things were like before this long-term investment and what changes it has caused in the knowledge of a given field. This kind of assessment is really important and needs to be done. The structure of an RIDC should encourage interdisciplinarity and more transversal research because there is a kind of permanence that allows people to be bolder.

In your inaugural speech, you mentioned scientific integrity and good research practices, among other things. Are there going to be any new guidelines?
FAPESP was the first agency in Brazil to create rules, guidelines, and regulations for the system. Universities followed suit—some more than others. It is an area that is well structured here. But now there is the challenge of artificial intelligence, which did not exist two years ago. We're going to have to adapt to that. That's the way the world is now. If you want to write a proposal about any research field today, just ask ChatGPT, and it writes it for you. We're going to have to think a little bit about the dynamics of AI and how to deal with it. ■

THE SEEDS OF MODERNITY

Now reaching its 50-year mark, EMBRAPA seeks to reconcile different models of agricultural production and promote environmental preservation

Carlos Fioravanti

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PHOTOS 1, 3 AND 5 EMBRAPA **2 AND 6** LÉO RAMOS CHAVES / PESQUISA FAPESP MAGAZINE **4** SERGIO DUTTI / PESQUISA FAPESP MAGAZINE

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Agricultural diversity: (*top*) greenhouse tomatoes in the mountainous region of Rio de Janeiro, cattle raising in the forests of São Carlos, São Paulo; (*bottom, from left to right*) Gala apple farming in Bento Gonçalves, Rio Grande do Sul; a bee wears a tracking device in Belém, Pará; arrowroot grown in the region of Santa Luzia do Pará, Pará; *Vanilla pompona*, a native species of vanilla, in Brasília, Federal District

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Agricultural engineer Tatiana de Sá, from the Eastern Amazon branch of EMBRAPA (the Brazilian Agricultural Research Corporation), in Belém, makes a four-hour trip nearly every month, usually by bus or car, to work with farmers in Santa Luzia do Pará, in eastern Pará State. Together, they select the best ways to grow and use three root plants—arrowroot and purple and white yams—and three fruit crops—banana, tucumã (*Astrocaryum aculeatum* palm), and peach palm. Their goal is to eliminate an old problem: losing root crop and fruit harvests due to the difficulty of selling and storing them.

Farmers from the Santa Luzia region also go to the EMBRAPA unit in Belém to talk to the Agribusiness Lab team about ways to prepare flour, pasta, bread, and biscuits with the root and fruit crops they grow. "The techniques for growing and using arrowroot were being forgotten because of the dominance of wheat, the major enemy of food sovereignty in the Amazon," comments Sá, who was hired in 1972 by the Northern Brazil Agricultural Research Institute (IPEAN), which was later incorporated into EMBRAPA. "The residents of the Santa Luzia region were interested in planting native roots, which were being lost."

Recognizing local knowledge and organizing production through associations and small farmer unions are precepts of agroecology, an approach that advocates agricultural diversification and the preservation of natural resources. Valued as a response to international pressure on Brazil and its rural producers, who are increasingly being asked to prevent environmental damage caused by the practice of monoculture and the intensive use of pesticides, this approach is gradually gaining ground at EMBRAPA, an institution that will have been in operation for exactly 50 years on April 26.

"Organic agriculture—an area of agroecology—was seen as a utopia 30 years ago, but today it is recognized worldwide and taught in university courses," says agronomist Jose Antonio Azevedo Espindola, a researcher at EMBRAPA Agrobiologia, in Seropédica, Rio de Janeiro, and chairperson of the management committee for its ecologically based production systems portfolio.

The environmentally friendly agriculture proposed by the agroecology movement follows principles that are quite different from the model that has previously given direction to EMBRAPA and other agricultural research institutions in Brazil. These institutions have been guided by a high-production paradigm based on mechanization, intensive use of fertilizers and pesticides, and mass crop cultivation on extensive properties, which has greatly increased national agricultural production.

"Soybean, which previously was not found north of Paraná, today is grown in the Legal Amazon. Brazilian sparkling wines win international awards. Apples used to only come from Argentina because there were no national varieties. We went from being food importers to exporters, and today Brazil is the third largest food exporter in the world," observes physicist Silvio Crestana, a former director and researcher at EMBRAPA Instrumentação, one of five units that FAPESP has supported in the state of São Paulo since 1991, through 927 research projects and grants totaling R$97.9 million.

Crestana, who was the director of EMBRAPA from 2005 to 2009, believes these achievements should not overshadow the future: "We now have to think about the social and environmental impacts of agriculture, because the world and the majority of producers and consumers want it that way. It's fundamental to rebuild EMBRAPA so that it can rise to these new challenges."

Agronomist Irene Cardoso, from Federal University of Viçosa (UFV), in Minas Gerais, points out that "Agricultural research institutions, not just EMBRAPA, need to pay more attention to other forms of agriculture, such as family and traditional agriculture, without chemical fertilizers and without pesticides." A former president of the Brazilian Association of Agroecology (ABA), Cardoso adds that agribusiness, to which the history of EMBRAPA is closely linked, "is not environmentally sustainable, as it causes a reduction in biodiversity and extreme emissions of greenhouse gases because of deforestation and fires." Tatiana de Sá adds, "EMBRAPA cannot be homogeneous, because its public isn't."

Agronomist Celso Moretti, who has served as the president of EMBRAPA since 2019, told Pesquisa FAPESP that the country's largest agricul-

tural research institution is already quite eclectic. "Our studies are developed to serve all farmers of every profile, without biases, with a focus on increasing productivity, adding value to the product, and sustainability," he says. "We carry out research both for improving products for export—like commodities—and for domestic consumption, which pertains to most small farmers and organic and agroecological agriculture."

Moretti observes that EMBRAPA has a practical problem, a failure to replace employees who have left or retired over recent years: "The last time we hired new researchers was in 2014, through a 2010 civil service exam." Agronomist Heitor Cantarella, director of the Agronomic Institute of Campinas (IAC), voices a similar complaint. "To refresh our lines of research and plan agriculture for the next 20 years, we need to rejuvenate EMBRAPA's research team. During the last 15 years, we lost 40% of our employees, who were not replaced because there are no civil service exams being conducted," he says.

Cantarella recognizes the social pressure in favor of food production methods with fewer environmental impacts and lower greenhouse gas emissions. He argues that the most recent research—even if based on a conventional approach—seeks to reduce the use of pesticides, for example, by selecting varieties of plants that are naturally more resistant to pests and diseases and promoting so-called agricultural intensification, which entails producing more food with the same area of land.

However, are these concrete signs of renewal? "The technological paths of the conventional paradigm, which I call the mechanical-chemical model, are reacting to the problems of the ecological crisis through a solution that remains within the paradigm: an attempt at "greening" the path with biological solutions that, in general, are at the service of mechanics and chemistry," says economist Francisco de Assis Costa from Federal University of Pará (*see* Pesquisa FAPESP *issue no. 277*). Cantarella observes: "Ecological agriculture will continue to increase, but it will have to coexist with some version of 'mechanical-chemical' agriculture, because of the pressure to produce abundant, low-cost food and raw materials."

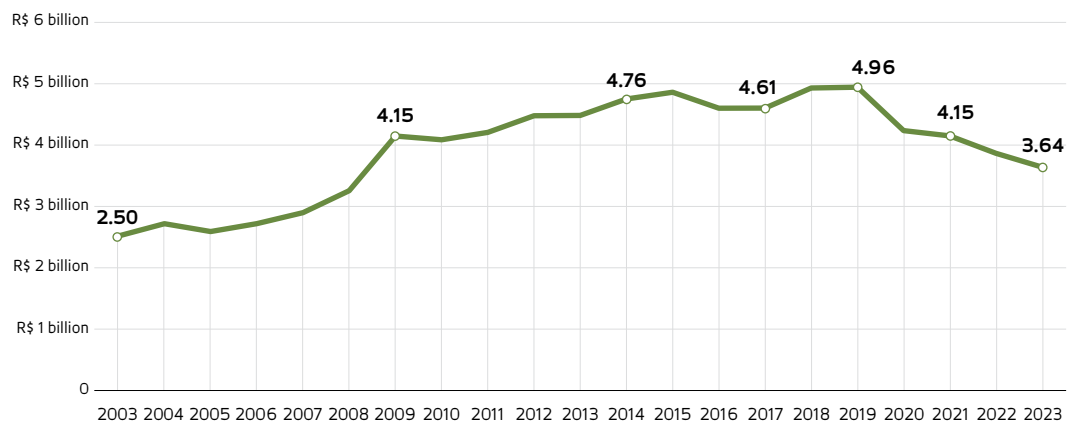
The disproportion between the size of teams allocated to the two differing approaches to research and agricultural production is another challenge. "At EMBRAPA," says Espindola, "the percentage of researchers involved in generating technological solutions adapted for conventional agriculture is still much higher than the number dedicated to agroecology and organic production, but we're making progress." For Moretti, the number of researchers is not a good indicator of a research area's relevance: "With focus and work capacity, it's possible to deliver what's necessary to meet the differing demands." After doing an intensive study on grains, such as soybean, corn, or cotton, most researchers focus on other crops but also with a high-production bias.

The EMBRAPA president further observes that the teams dedicated to research on carrot and tomato production, although small, have achieved important results. In 2020, the institution launched a carrot cultivar (variety) for organic production, which is recommended for planting

PHOTO EMBRAPA INFOGRAPHICS ALEXANDRE AFFONSO / PESQUISA FAPESP MAGAZINE

A FLUCTUATING BUDGET

The last five years have reversed the upward trend that began two decades ago (values in R$ billion, adjusted to the IPCA [Brazilian consumer price index])



SOURCE EMBRAPA

Sorghum production in a crop-livestock-forest integration system in the Cerrado region of Maranhão

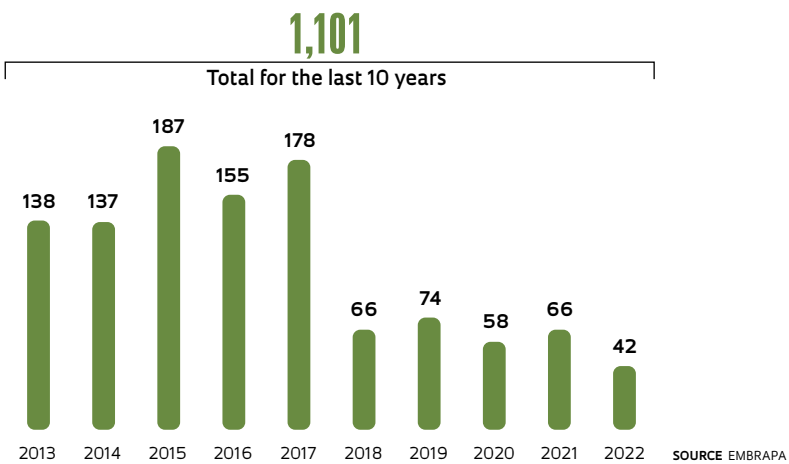
during the off-season of conventional cultivars. In turn, Tomatec is a growing system launched in 2005 that uses drip irrigation and integrated pest management.

Forestry engineer Édson Luis Bolfe, the former coordinator of Agropensa, a research division created to help EMBRAPA and its partner institutions formulate research strategies, sees a gradual improvement in agricultural production systems. "In the same way that direct planting was a novelty in the 1970s, integrated crop, livestock, and forest systems will evolve and consolidate in the coming years with greater food production and less pressure on natural resources."

As a researcher at EMBRAPA Agricultura Digital in Campinas, São Paulo, Bolfe worked with colleagues from other institutions to develop methods for accurately mapping the boundaries, diversification, expansion, contraction, or conversion of various agricultural crops by combining a variety of satellite images. Tested in municipalities in Goiás, Bahia, Maranhão, Mato Grosso, Mato Grosso do Sul, and São Paulo, the new approach maps native vegetation and differentiates plantations such as soybean, corn, cotton, and sugarcane plantations, as detailed in articles published in the journal *Remote Sensing* in 2022 and this year in the journal *Land*.

INNOVATION IN THE FIELD

As of 2018, the count includes only market-ready technologies



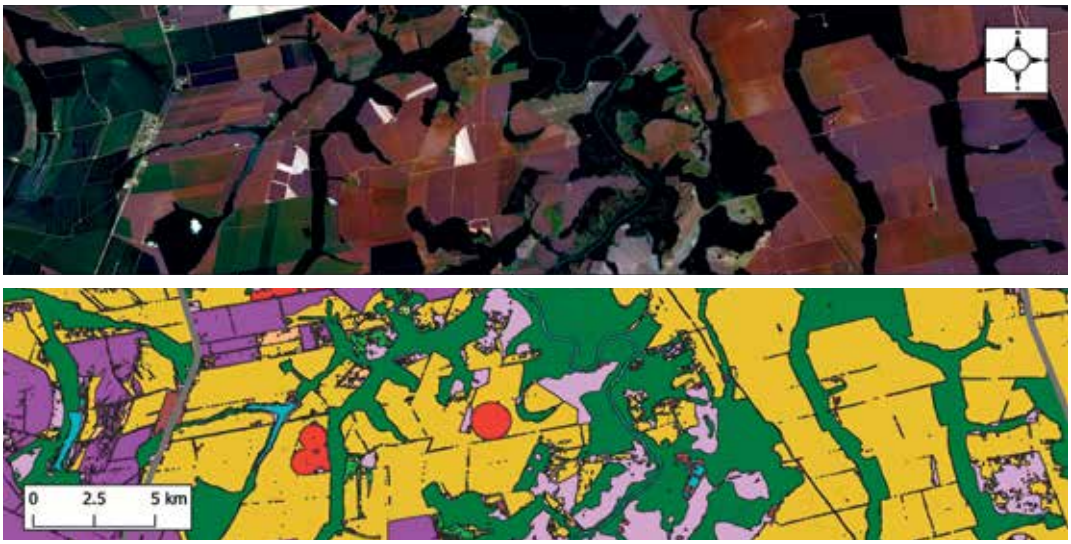
SOURCE EMBRAPA

Currently employing 2,201 researchers (there were 2,437 in 2013), with a budget of R$3.6 billion for the most recent fiscal year (in current values, the budget was R$2.5 billion in 2003), EMBRAPA is a relatively recent addition to the oldest group of national agricultural research institutions. The Instituto Agronômico de Campinas (IAC) was created in 1887; the Luiz de Queiroz College of Agriculture (ESALQ) was launched in 1901 and later incorporated into the University of São Paulo (USP); the Agricultural School of Lavras, in Minas Gerais, began in 1908; and the Escola Superior de Agricultura e Veterinária de Viçosa, later integrated into UFV, dates back to 1920. However, no other agency has as many branches—there are seven central units, located in the Federal District, and 43 spread throughout the Brazilian states.

"EMBRAPA is one of the big projects of the past military government, and had a strong influence from the United States," says historian Jefferson Sanches, a basic education and college entrance exam teacher in the public and private school systems of Vinhedo and Jundiaí, in the state of São Paulo. He observes that for the military government, the production model based on monoculture on large properties and bank loans with interest below inflation was a way of occupying

PLANTATIONS WITH PRECISE BOUNDARIES

Method using satellite image analysis facilitates the mapping of rural areas



Landsat images and maps from MapBiomas and the Department of National Transportation Infrastructure (DNIT) show the distribution of native vegetation, agriculture, and livestock in Sorriso, Mato Grosso

- Highways
- Urban areas
- Water bodies
- Native vegetation
- Cotton
- Bean
- Corn
- Other rainfed crops
- Cultivated pastures
- Sugarcane
- Irrigated crops

the Midwest, undermining the concept that agrarian concentration was an obstacle to economic development and a way to put off agrarian reform.

In a November 2022 article in *Revista de História*, Sanches describes how EMBRAPA was formed through connections between the Brazilian government and American philanthropic organizations, including the Rockefeller and Ford foundations, which turned to promoting increased food production after their contributions to funding research on global health issues. He writes that EMBRAPA's creation was inspired by prior efforts funded by US institutions, such as expanding the production of rice in the Philippines, wheat in Mexico, and potatoes in Peru. In this way, the Green Revolution, a strategy to increase productivity in the agricultural field that began in the US in the 1960s, went global, encouraging the consumption of seeds, fertilizers, and equipment produced by American companies.

EMBRAPA assumed the functions of the Agricultural Research Department of the Ministry of Agriculture, with the mission of consolidating scientific investigations and coordinating between state-owned companies, many of which had been deactivated over the previous years. One of its initial priorities was to implement commercial agriculture in the central region of Brazil, which at that time was mostly untouched Cerrado (wooded savanna). Sanches explains that the development of new techniques gave science-based reinforcement to the occupation being led by shrewd farmers in the states of Rio Grande do Sul and Santa Catarina, who had purchased land at low prices. Methods of correcting soil acidity with limestone, directly planting the soil (without tilling, to avoid loss of nutrients), and the use of nitrogen-fixing bacteria became common. Sanches notes that the initial research that led to expanded agricultural production in this region was a doctoral thesis by Serbian scholar Nikolai Pulchritudoff, presented in 1971 at the University of California at Davis in the United States. His study described the mineral deficiencies of the Cerrado and the ways they could be successfully ameliorated.

Sanches characterizes the creation of EMBRAPA as a sign of what he calls the "modernization of permanence," an expression based on the concept of conservative modernization, created by the American sociologist Barrington Moore Jr. (1913–2005). "It was a reorganization of agricultural production without changing the land base, drawing on a narrative based on science and technology, according to which modernization would be the only path, and naturally beneficial," he comments. In the book *A modernização dolorosa* (The painful modernization) (Zahar, 1982),

PHOTOS 1 LÉO RAMOS CHAVES/ PESQUISA FAPESP MAGAZINE 2 EMBRAPA MAP EMBRAPA

1

ENCOURAGING THE USE OF DIGITAL TECHNOLOGIES IN THE FIELD

Connectivity projects promote the use of apps among small and medium-sized rural producers

EMBRAPA Digital Agriculture's climate monitoring system in Campinas

2

FAPESP is set to make a public announcement this month regarding a multidisciplinary research and innovation project named Science Center for Development in Digital Agriculture (CCD/AD/SemeAR), headquartered at EMBRAPA Digital Agriculture, in Campinas. Its purpose will be to expand the use of digital technologies and internet connectivity among small and medium-sized rural producers throughout Brazil.

"Complex projects like SemeAR often require adjustments in funding models," said FAPESP Science Director Luiz Eugênio Mello. "In this case, we requested that the project include something similar to a PMO (project management officer) and we dedicated several months to planning and structuring the project to increase its chances of success," he explained.

"One of our goals is to put rural producers in direct contact with the market, without intermediaries," adds Carlos Américo Pacheco, director-president of FAPESP's Technical-Administrative Board. "This project should have a big impact on improving rural incomes."

Five pilot areas will be monitored in the state of São Paulo, one in Minas Gerais State, and one in each of the other four regions of the country (North, Northeast, Midwest, and South). Work has already begun in two municipalities in cooperation with the association of producers, city halls, and businesses. The first is Caconde, a key coffee-producing municipality in São Paulo with approximately 20,000 residents on the east side of the state; the other is São Miguel Arcanjo, to the south, a major supplier of fruits and vegetables with approximately 33,000 inhabitants .

"Digital technology is already on the minds of many producers," observes Silvia Massruhá, CCD-AR/SemeAR coordinator. She says researchers will find companies, or develop apps, to solve the demands of farmers and expand the connectivity of small and medium-sized rural producers. A 2021 survey by the Ministry of Agriculture and ESALQ/USP indicated that only 23% of the country's rural area has internet access. "Every modern production chain demands digital technology tools," she says. The project has the participation of approximately 40 researchers, including other EMBRAPA units, the Center for Telecommunications Research and Development (CPQD), the IAC, the Institute of Agricultural Economics, the National Institute of Telecommunications, ESALQ, and UFV

agronomist José Graziano da Silva emphasizes that this process increased wealth concentration, income disparities, the rural exodus, and the exploitation of the agricultural workforce.

The Cerrado has become one of Brazil's principal agricultural granaries, currently responsible for providing 86% the country's cotton production, 50% of its soybean, 43% of its bean, and 34% of its beef production. Agriculture has grown stronger. However, as a negative consequence of employing the high-production paradigm, it is estimated that 45% of the area previously covered by native vegetation has been occupied by agriculture, with losses to biodiversity and possibly worse: the risk that rivers with headwaters in the Midwest—and that flow to other regions of the country—will run dry (*see interview with Mercedes Bustamante* in Pesquisa FAPESP *issue no. 324*).

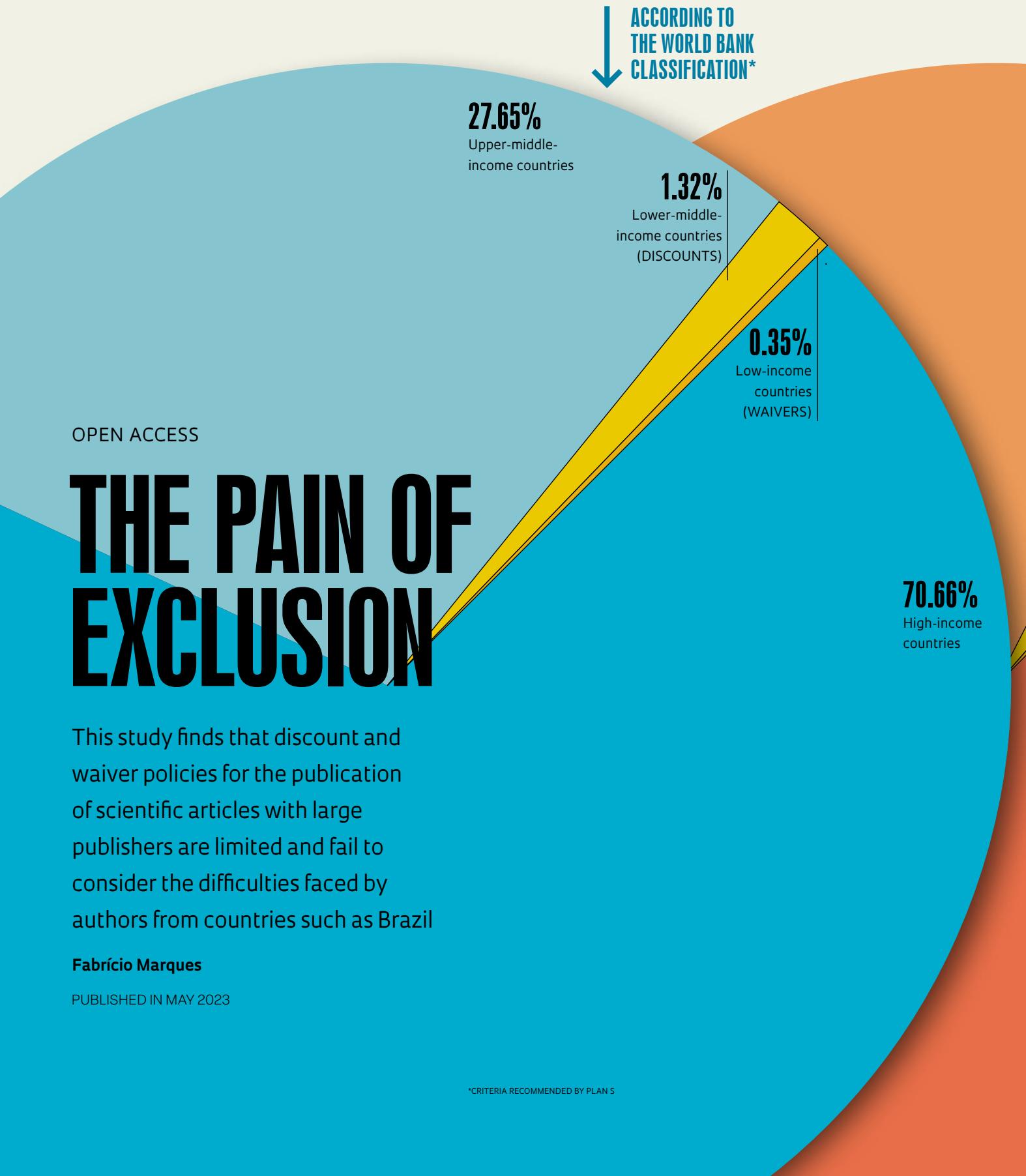
In 1996, EMBRAPA launched "light pork," with less fat, already in its third generation, and has since introduced grapes and other fruit varieties to be grown along the banks of the São Francisco River. It participated, together with other research institutions, in the development of most of Brazil's 140 coffee cultivars and created methods for cultivation amid forests in Rondônia State. The company's institutional website portfolio lists 1,106 products or technologies, including beef production with lower carbon dioxide and methane emissions, the gases principally responsible for global warming.

During its 50 years, EMBRAPA has developed 72 cultivars of orange, 53 of peach, 44 varieties of grape, 24 of cupuaçu, 22 types of banana and passion fruit, and 10 cultivars of pineapple and melon. Including other fruit types, a total of 419 new varieties have been developed by EMBRAPA. One of its most recent innovations, announced in October, is a new variety of a typical Cerrado fruit, the pequi, without inconvenient thorns.

As a basis for future research, EMBRAPA's gene banks contain approximately 300,000 samples of 1,096 species of cereals, fruits, root plants, palm trees, and others, in addition to 115,000 samples of animal semen and 70,000 microorganisms. ■

Genetically modified, herbicide-tolerant sugarcane seedlings

The full *Pesquisa FAPESP* dossier on EMBRAPA and the projects and articles consulted for this article are listed in the online version.



OPEN ACCESS

THE PAIN OF EXCLUSION

This study finds that discount and waiver policies for the publication of scientific articles with large publishers are limited and fail to consider the difficulties faced by authors from countries such as Brazil

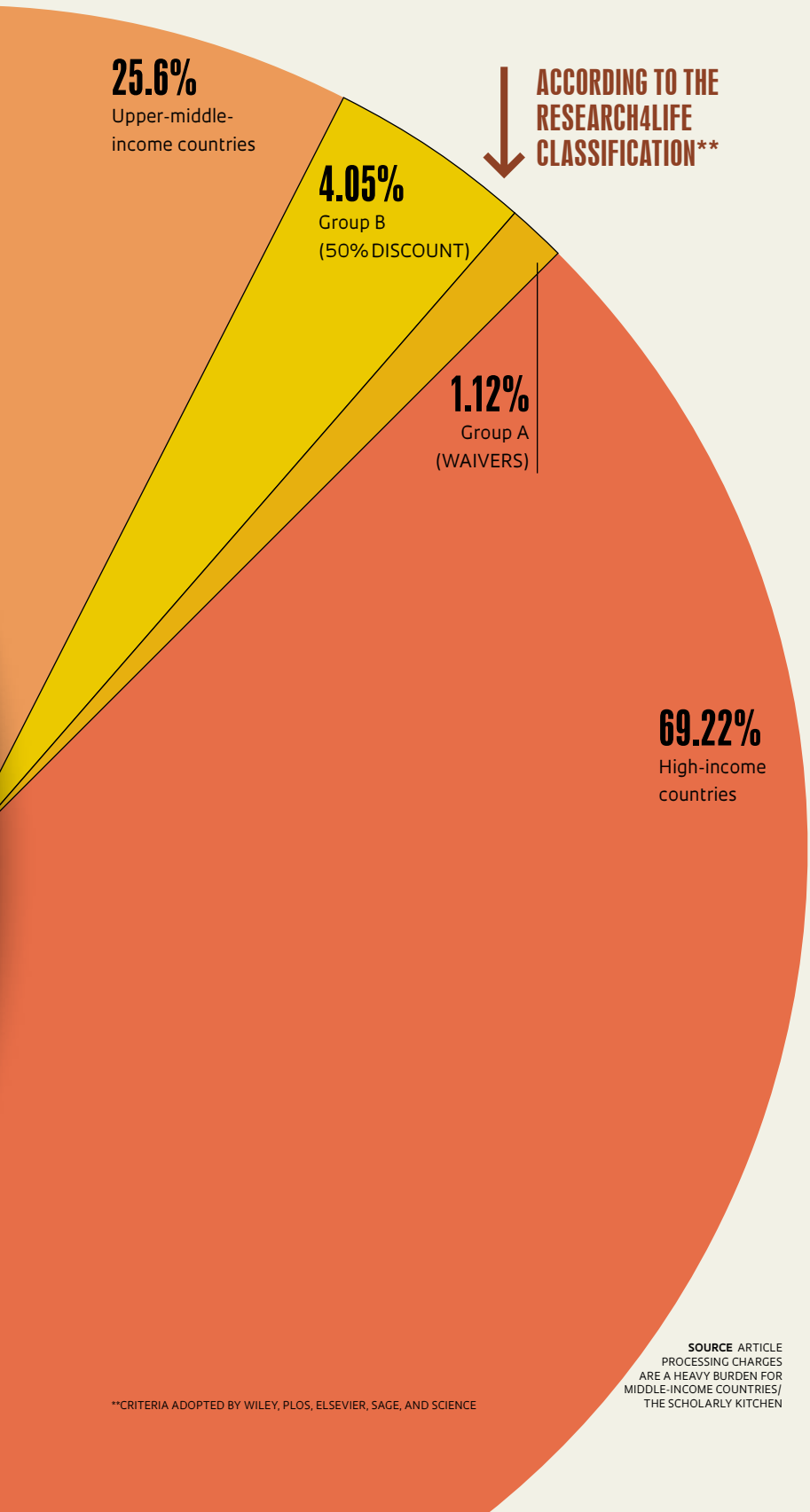
Fabrício Marques

PUBLISHED IN MAY 2023

*CRITERIA RECOMMENDED BY PLAN S

LIMITED BENEVOLENCE

Percentage of scientific articles from countries/territories eligible for discounts or waivers from open-access article publication charges – Scopus database



SOURCE ARTICLE PROCESSING CHARGES ARE A HEAVY BURDEN FOR MIDDLE-INCOME COUNTRIES/ THE SCHOLARLY KITCHEN

**CRITERIA ADOPTED BY WILEY, PLOS, ELSEVIER, SAGE, AND SCIENCE

A study by researchers from the University of São Paulo (USP) and the University of Campinas (UNICAMP) highlighted an obstacle faced by scientists from developing countries seeking to publish articles in prestigious international journals. With the increasing adoption of the open-access model, through which readers are given free access to articles online without having to subscribe to journals, the costs of publication have begun to fall on the authors, their institutions and funding agencies, which have to pay often prohibitively expensive publication fees. Scientific publishers have acknowledged this problem and implemented discount and waiver policies for authors from countries with a lower average income. However, a Brazilian study published on the academic blog The Scholarly Kitchen in March demonstrates that these solutions are ineffective—these policies are highly restrictive and inaccessible to researchers from middle-income countries such as Brazil.

The study found that according to the criteria adopted by Research4Life—a coalition of publishers including Wiley, PLOS, Elsevier, Sage, and Science—only 1.12% of articles in the Scopus database published between 2012 and 2021 would have been eligible for waivers, which are granted to authors who live in low-income nations, mostly in Africa but also in conflict zones such as Yemen, Syria, and Afghanistan. Another 4.05% would have been offered discounts of up to 50% off article-processing charges (APCs) because they originated from lower-middle-income economies, including countries in North Africa, Latin America, and South Asia. Based on the criteria established by Plan S, an open-access publishing initiative implemented in 2021 by a group of major European funding agencies and organizations such as the Bill & Melinda Gates Foundation, the limitations are even greater. Only 0.35% of articles would have been eligible for waivers and 1.32% for discounts. Under Plan S, national incomes are classified according to the World Bank's criteria. This system is currently being used by publishers such as Springer *Nature* and Taylor & Francis.

"In my specialty, scientific journals charge between US$3,000 and US$5,000 to publish an article, but there are extreme cases, such as journals in the Nature collection, where the cost exceeds US$11,000," explains biochemist Alicia Kowaltowski of USP's Institute of Chemistry, lead author of the study, which was coauthored

by physicist Paulo Nussenzveig and biologist Ariel Silber from USP, and mechanical engineer José Roberto Arruda of UNICAMP.

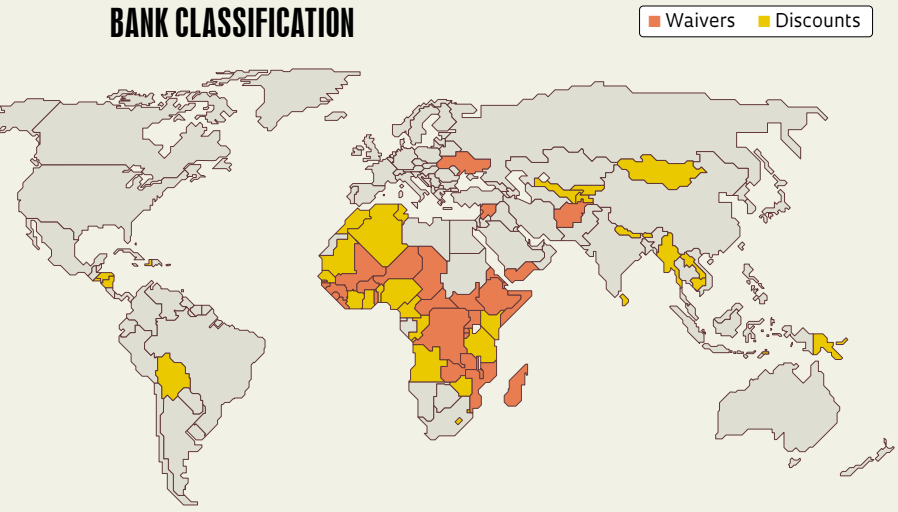
The analysis shows that the prohibitive cost of publication hurts researchers from middle-income countries. In very poor nations that qualify for waivers and discounts under Research4Life's criteria, 52% of articles are available via open access. Among high-income countries, the percentage is 45%. However, in middle-income countries such as Brazil, which do not benefit from waivers or discounts, the proportion of open-access articles drops to 32%. "These countries have much smaller research budgets than high-income economies, but they are expected to pay full APCs. The data show that due to high costs, they are being excluded from this publication model," says Kowaltowski.

The study proposes the expansion of waiver policies to include authors from low- and lower-middle-income countries and the application of 50% discounts to all authors from upper-middle-income economies. "In practice, this would result in full waivers for approximately 2% of authors and discounts for approximately 25%. This could easily be absorbed by most publishers—the sector is known for its high profit margins of over 30%," says Kowaltowski. She acknowledges that many publishers say they are willing to negotiate individual requests for waivers and discounts. "But personal requests have disadvantages, such as reduced bargaining power. FAPESP covers APCs for articles by researchers they are funding, but to a maximum limit of R$12,000, an amount that is more than generous. I use this limit to ask publishers for discounts, but it usually takes five or six emails before anyone starts listening," says the researcher.

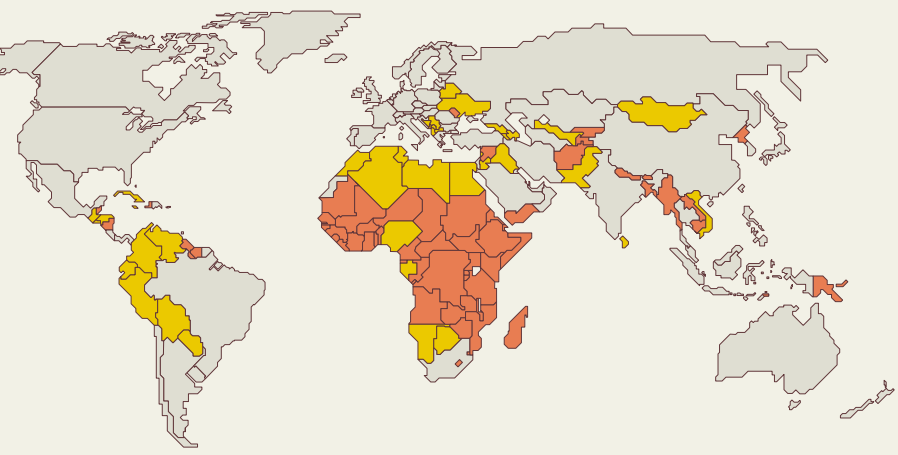
ELIGIBLE TERRITORIES

Countries that qualify for discounts or waivers on open-access article publication charges

ACCORDING TO THE WORLD BANK CLASSIFICATION



ACCORDING TO THE RESEARCH4LIFE CLASSIFICATION



SOURCE ARTICLE PROCESSING CHARGES ARE A HEAVY BURDEN FOR MIDDLE-INCOME COUNTRIES/THE SCHOLARLY KITCHEN

The study's proposal provoked some strong reactions. American information scientist and consultant Phil Davis criticized the idea of expanding waiver and discount policies, arguing that the move would financially suffocate small regional publishers that predominantly serve authors from low- and middle-income countries. "Those who are quick to blame commercial publishers for their monopoly-like grip on the market and their 'unusually high profit margins' may be surprised to find that their policy, if adopted, would only lead to strengthening commercial publishing," he wrote in the blog post's comment section.

Abel Packer, head of the SciELO Brasil scientific journal library, believes the article by Kowaltowski and colleagues succeeds at highlighting the problem of the cost of APCs to researchers in developing countries, which is a key issue in the advancement of open-access science. "A more equitable approach is needed. A Brazilian researcher cannot pay the same amount as a researcher from Sweden. The purchasing power here does not reach the same level; it is simply a matter of equity," he says.

He notes, however, that the study addressed only one aspect of the problem. "We also need to question the system as a whole and remember that scientists only feel they need to publish in journals with high APCs due to the requirements of current assessment systems for career

IN MIDDLE-INCOME COUNTRIES, THE PROPORTION OF ARTICLES PUBLISHED VIA OPEN ACCESS IS SMALLER THAN IN LOW-INCOME COUNTRIES THAT BENEFIT FROM APC DISCOUNTS AND WAIVERS

progression." He points out that the mission of SciELO, funded by FAPESP over the last 25 years, has been to promote more than 300 open-access journals in Brazil, many of which do not even require APCs for Brazilian scientific articles, even though these titles lack the impact and reputation of elite journals. "We have high-quality national journals that are willing to publish good articles by Brazilian authors," he says.

José Roberto Arruda, coauthor of the paper, says the team did not underestimate the importance of open-access initiatives such as SciELO, but the aim was to demand more effective waiver policies from major commercial publishers. "This is vital to allow researchers from upper-middle-income countries to continue to publish in prestigious scientific journals while APC-based open-access models continue to be used," he said. In response to Phil Davis's criticism, Arruda says that it is not necessarily a question of reducing publisher revenues but of better distributing costs among researchers from countries with different income levels and different research-funding circumstances.

In theory, the APC-based open-access model should soon change. In its original conception, Plan S stated that all articles resulting from research funded by signatory agencies and countries should be published exclusively in open-access journals from 2020 onwards. That start date was eventually pushed back to 2021, and the rules relaxed, allowing hybrid publication models to be used until 2024, through which authors can pay to publish open-access articles in journals that also sell subscriptions. From 2025 onward, this intermediate format will no longer be accepted, with publishers expected to start publishing articles in only open-access formats by entering into comprehensive agreements with national governments, funding agencies, or institutional libraries, which redirect the money currently spent on journal subscriptions to the payment of APCs, making articles freely available online.

The prospect of that happening, explains Kowaltowski, is still uncertain. "It is not clear what will happen. Plan S was mostly adopted in Europe and not elsewhere." China, which has surpassed the USA in the volume of scientific articles, is not part of the arrangement. The US government, meanwhile, belatedly decided at the end of last year that its federal agencies must create policies by 2025 to ensure that all publications provided federal funds are freely available to the public via open access. The plan of attack is yet to be determined and may include the use of preprints. When that happens, the speed of any changes in the international scientific communication landscape will become clearer.

Until now, Brazil has stayed away from the debate, although in 2020, it invested R$380 million in contracts with scientific publishers to make the content of their journals available to Brazilian researchers. These journals are accessible through a platform created by CAPES (Brazilian Federal Agency for Support and Evaluation of Graduate Education), an agency run by Brazil's Ministry of Education that assesses and funds graduate programs. Views on open-access publishing in the country are starting to change. In a statement given to *Pesquisa FAPESP*, CAPES said that "it is committed to reaching transformative agreements that allow the academic community to publish articles in open access, in addition to subscriptions to scientific publications." According to the agency, it is working in partnership with institutions such as the Brazilian Society for the Advancement of Science and the Brazilian National Council for Scientific and Technological Development to lead a movement demanding researchers in Brazil be able to publish at prices that reflect the country's socioeconomic situation.

The agency recently began consulting with the scientific community on the topic, and a collaborative workshop is set to be held in May to discuss open-access publication. "One of the subjects we address will be the payment of article-processing charges within the scope of our Journal Platform contracts," says the statement from CAPES. The topic was also on the agency's agenda last November, at the fifth edition of the Journal Platform Seminar. "With the upcoming workshop, the objective is to continue the theme and deepen discussions in the academic community." ■

INFOGRAPHIC ALEXANDRE AFFONSO / PESQUISA FAPESP MAGAZINE

From left to right, cupuaçu flower, guaraná, copaíba, tucuma, and passion fruit flower

SUSTAINABILITY, FEMALE SUBJECT

Entrepreneurs from the Amazon use innovation and traditional knowledge to create new cosmetics and foods

Sarah Schmidt

PUBLISHED IN JANUARY 2023

A group of entrepreneurial women from the Amazon have developed a collection of innovative products, including cosmetics and foods, that demonstrate potential for driving sustainable development in the region. Biologist Andrea Waichman, a researcher from the Federal University of Amazonas (UFAM) and partner at the cosmetics startup Darvore, has developed an oil reducing balm made from copaíba (*Copaifera langsdorffii*) and tucuma (*Astrocaryum aculeatum*), working with inputs from extractivists from the Uatamã Sustainable Development Reserve in the state of Amazonas. She explains, "We have created nanometric capsules made with Amazonian bioactives, instead of synthetic materials. This way, we are able to have 100% natural products". Darvore has headquarters in Manaus (Amazonas) and a branch in Ribeirão Preto (São Paulo).

This businesswoman, who was born in Argentina and based in Amazonas for over 25 years, was one of those interviewed in the e-book *Potência amazônica* (Amazon

power), which was released in October and brought together some local leaders from the region's innovation ecosystem. In addition to the copaíba balm nanoencapsulated in tucuma butter, Darvore, at which economist João Tezza is also a partner, has developed a facial moisturizer made from copaíba but encapsulated in cupuaçu (*Theobroma grandiflorum*) butter. Both of these products were released in June 2022. The nanoencapsulation process was subject to a patent application filed in 2019 with the National Institute of Industrial Property (INPI). The product was developed in partnership with the São Paulo State Institute for Technological Research (IPT) and is manufactured by Yosen, a startup with a focus on nanotechnology that is located in Supera, the business park for innovative companies of Ribeirão Preto, in the state of São Paulo.

The ancestral knowledge and culture of indigenous peoples have also inspired fledgling companies in the Amazon. Biologist and farmer Raquel Tupinambá, who is pursuing a PhD in social anthropology at the University of Brasília (UnB), is trying to set up a processing house within the Tupinambá territory in the Tapajós-Arapiuns Extractive Reserve (RESEX) in Pará, where she was born, grew up, and lives. Alongside her sister, agroecologist Mariane Chaves, the researcher has developed products inspired by Tupinambá gastronomy and culture. The most famous product is an orange–red cassava wine called Mani-Oara, with an alcohol content of 8%. The fermentation uses fungi from another cassava-based drink consumed by the indigenous people from the region, called tarubá.

The idea of creating products that valued the work of women from the indigenous territory matured between 2014 and 2016, while the biologist was studying for her master's degree in botany at the National Institute of Amazonian Research (INPA) and her sister was taking a master's in ecology at the Federal University of Viçosa (UFV) in Minas Gerais. She kept herself informed of public notices, organizations, and acceleration programs that could help her start her own business. She and her sister decided to give new life to the Association of Agroextractivist and Indigenous Residents of Tapajós (AMPRAVAT), which organizes and distributes the production of approximately 30 families. They were considered in a public bid by the nongovernmental organization Sáude e Alegria (meaning health and happiness), with funding through the L'Oréal Fund for Women, for the construction of the processing house in the Indigenous territory. They successfully obtained funding in 2019, but the pandemic delayed the start of the work until 2022. The objective is to achieve artisanal certification from the Pará Agricultural Defense Agency (ADEPARÁ), which would permit the sale of its products in supermarkets and malls within the state. In addition to the wine, they produce a black tucupi sauce, jams, and other products that are only sold in stores and markets in Santarém and Alter do Chão.

The initiatives of Waichman and Tupinambá are recent examples of the potential of the bioeconomy, a set of productive activities capable of generating income and wealth for the populations that live around the world's largest tropical rainforest, ensuring its preservation. Although there are no consolidated data on how much the sector generates in the region, analysis from the Amazon 2030 project published in April 2021 by Brazilian public administrator Salo Coslovsky, an associate professor at New York University, estimated that entrepreneurs located in the Amazon exported 955 products between 2017 and 2019. Of this total, 64 products are classified as "compatible with the forest" (nontimber forestry extractivism, agroforestry systems, fishing and tropical fish farming, and tropical horticulture and fruticulture) and generate an annual income of US$298 million.

Pharmacist Samara Rodrigues, the CEO of Pharmakos D'Amazonia, which produces cosmetics and food supplements and is located in Manaus, says that she is often sought after by companies interested in buying some type of raw material from the forest. She notes, "It is frustrating, because we are a technology-based company". One of the products in line for release by the company is a cream that contains the leaves of the wild passion fruit (*Passiflora nitida*), a plant that is native to the region. This product was developed in partnership with researchers from UFAM and the University of São Paulo (USP), the Federal University of Sergipe (UFS), and the Federal University of Rio Grande do Norte (UFRN). The antioxidant properties of the extract were described in an article published in September in the *Brazilian Journal of Pharmaceutical Sciences*. Rodrigues explains, "We have already done all the efficacy tests and the publication is the last demand of ANVISA [Brazilian Health Regulatory Agency] so that we can register the product and sell it". Ten years ago, she assumed leadership of the company created by her father, pharmacist Schubert Pinto, a retired teacher from UFAM. Today, Pharmakos D'Amazônia has approximately 80 cosmetic and food products in its catalog.

Sheila Melo, an intellectual property specialist from EMBRAPA Eastern Amazonia, a unit of the Brazilian Agricultural Research Corporation (EMBRAPA), in Belém, stresses the importance of having Amazonian women stand out on this path. She observes that "Many innovative products and services arise from this local vision, and we have a huge market to be explored. As a woman from Pará, I know that experience is a differential for innovating, by observing our reality and our potential". In her assessment, there is still much to be done along the path of innovation and female entrepreneurship. Indeed, she notes that "In daily life, we still see difficulties and barriers linked to gender equality. There is also a lack of diversity, such as Indigenous, Black, and LGBTQIA+ people in this innovative ecosystem".

Medical engineer Júlia Bussab Fonseca, who is doing a PhD at the University of Sussex in the UK and studies the intersections of gender and race in climate finance mechanisms in the Amazon, has seen some advances. As the financial director of Climática, a company that provides consultancy on climate change for other organizations, she has worked for clients who seek to create programs aimed at female entrepreneurs. She notes, "For around two years, we have seen institutions, such as banks, looking for us to include companies and projects with female leadership in their financial services". In one of these consultancies, she is collecting data and indicators, information that is still scarce, about the participation of women in the innovation and entrepreneurship ecosystem in the Amazon region. ■

PHOTOS 1 MSCOMPOST / INATURALIST 2 EDUARDO CESAR / PESQUISA FAPESP MAGAZINE 3 MADSISSI / INATURALIST 4 TOMAZ MELO / INATURALIST 5 MAYK OLIVEIRA / INATURALIST

View from the November 2022 expedition camp: the highest peak, at an altitude of 2,362 meters, is Mount Imeri, located in the northern Brazilian state of Amazonas, close to the border with Venezuela

FIRST EXPEDITION TO THE IMERI MOUNTAINS

Researchers have identified animals and plants isolated by altitude, which may help explain the relationships between species from high areas in northern South America

Gilberto Stam

PUBLISHED IN FEBRUARY 2023

It is difficult to reach the Imeri Mountains, which are located in the northern Amazonas near Brazil's border with Venezuela. At altitudes of up to 2,450 meters (m), the mountainous environment features bromeliad fields, rocky cliffs, and trees surrounded by fog. The area does not seem to have ever been visited by people and is probably home to many unknown animal and plant species. A team of researchers—12 from Brazil, one from Spain, and one from France (*see below*)—spent 11 days there in November 2022 on a scientific expedition carried out together with the Brazilian Army.

The biologists collected hundreds of specimens, some that appeared to represent species that have never been described, and gathered information that they hope will provide greater insight into the relationships between animals and plants in this and other high-altitude regions of Brazil.

"In almost 40 years of field research, I have never found such a large proportion of probable new species," says Miguel Trefaut Rodrigues, a zoologist from the University of São Paulo (USP) and leader of the expedition. In his laboratory,

a week after returning from the trip, he showed *Pesquisa FAPESP* dozens of glass jars containing lizards and frogs. Two lizards are similar to specimens of the genus *Riomlama* collected during a 2017 expedition he led to Pico da Neblina, 90 kilometers (km) to the southeast.

The Imeri Mountains and Pico da Neblina were part of a large plateau formed of sandstone rocks that occupied much of the so-called Guiana Shield before the formation of the Andes. Erosion of these rocks over millions of years helped form the soil in the surrounding lowland forests, leaving many animal and plant species stranded on the peaks of flattened or table-top mountains known as tepuis, such as Neblina, and isolated mountain ranges. Taran Grant, a zoologist from USP, collected a species of tree frog of the genus *Myersiohyla* from Imeri and observed similarities with species of the genus *Hyloscirtus*, which live in mountainous environments in the Colombian Andes, more than a thousand kilometers away.

The lizards were captured in traps or by hand during the day, while at night, they were usually found asleep between rocks or in trees. The frogs, meanwhile, were all caught at night. Grant and his team followed the nocturnal vocalizations of frogs to find them on stream and river banks. "We found four frogs and a caecilian—a type of amphibian—that could be new species," says Grant.

INHOSPITABLE ENVIRONMENT

Few species have adapted to the nutrient-poor, rocky soil and average daily temperature variations of 20 degrees Celsius (°C) at the top of the Imeri Mountains. The diversity there is therefore much lower than that in the neighboring lowland forests. Many of the species that exist in the region are endemic, meaning they are isolated species that can only be found there.

"We found few species for most of the families of collected plants, indicating that these lineages have not diversified much in the mountains or they gave rise to species that are now already extinct," says USP botanist Lúcia Lohmann, who specializes in vines of the Bignoniaceae family. "However, these mountains seem to have been the birthplace of many botanical groups." According to Lohmann, it is possible that various angiosperm families (plants that bear flowers or fruits) first emerged there before later spreading to the Atlantic Forest and lower areas of the Amazon, where they diversified greatly.

One example is *Brocchinia hechtioides*, a bromeliad that grows in wetland areas of the Imeri Mountains, identified by Rafaela Forzza of the Rio de Janeiro Botanical Garden, one of the expedition's participants. "It is a carnivorous bromeliad that has only been recorded twice in the country," she says. "Although we only found one

In the field (*from top*): Ana Paula Carmignotto, from UFSCar, goes to check traps for small mammals; Rafaela Forzza (*white sweatshirt*) and Lucia Lohmann (*blue shirt*), helped by Corporal Marcio Junior da Silva Garcia, descend ropes toward sampling sites; José Mario Ghellere looks for reptiles and amphibians during the night

HERTON ESCOBAR/ USP IMAGENS

species of the genus *Brocchinia*, it is abundant in the highlands of these mountains and it is one of the oldest lineages of Bromeliaceae, a particularly diverse family of plants in the Atlantic Forest." The 1,200 samples of 220 plant species collected by the team will be distributed among specialists from Brazil and other countries, who will collaborate to identify the material.

"Because small mammals arrived in South America later than other animals and plants on the geologic time scale, they were probably the last groups of animals to remain isolated in the mountain range and specialize there," says the zoologist Alexandre Reis Percequillo of USP's Luiz de Queiroz College of Agriculture (ESALQ). Ana Paula Carmignotto, a biologist from the Federal University of São Carlos (UFSCar), collected a marsupial, three rodent species, and three bat species, which preliminary assessments suggest are similar to species found in Pico da Neblina.

In addition to collecting plants and animals, some of the researchers on the expedition also carried out experiments. Agustin Guerrero, a zoologist from USP, placed reptiles and amphibians in a box connected to a heat source and slowly increased the temperature until the animals left the box. The results indicated which locations would be too hot for these species to survive.

"Imeri reptiles and amphibians have a low tolerance for high temperatures. They all left the box at less than 34 °C," noted Guerrero. "They would be in danger if their habitats reached that temperature."

Before the expedition, the scientists practiced boarding and disembarking the helicopter by rope, in case an emergency should occur—which fortunately did not happen. A group of 22 military personnel accompanied the team, transporting the biologists and their equipment on eight helicopter trips.

The expedition landed in an area of very wet ground at an altitude of 1,900 m. The helicopter that had carried the team had to land lightly on the ground to avoid sinking into the mud. The military team had tried in vain to find a way of accessing the area by land, but not even the Yanomami indigenous people—who are originally from the region—knew how to reach the top of the mountains due to the steep terrain.

On the first day at the camp, the group cleared three trails, each approximately 1 km long and some so steep that they could only be traversed with the aid of a rope. Three scientists injured their ribs, eyes, and shoulders and had to be treated by Army medical staff. Water from the incessant rainfall and mud washed into their tents. But their lives were a little easier when the sun came out.


1


2


3


4

Once collected, animals, such as rodents (*top*), plants, and blood samples are prepared and boxed to be examined in detail in the laboratory

PHOTOS 1 TO 5 HERTON ESCOBAR/USP IMAGENS **6** ANDRÉ DIB/DIVULGAÇÃO **INFOGRAPHIC** ALEXANDRE AFFONSO/PESQUISA FAPESP MAGAZINE

On top of the Amazon

Near Pico da Neblina and inside Yanomami land, the Imeri Mountains were previously unexplored

SOURCE JORNAL DA USP

5

6

An army helicopter transported scientists and equipment to the top of the mountain range; the team of researchers and soldiers who participated in the expedition (*above*)

PATHOGENS

General Sinclair Mayer, head of the Campinas branch of the Brazilian Defense, Industry, and Innovation Academy System (SISDIA), an agency run by the Army's Department of Science and Technology that helped organize the expedition, highlighted the importance of exploring new areas of Brazilian territory through such expeditions. At a meeting held at USP's Institute for Advanced Studies (IEA) on December 16, he highlighted the studies on pathogens carried out by USP parasitologist Bruno Fermino, who collected blood samples from amphibians, lizards, birds, mammals, and bloodsucking insects and claims to have found new protozoan species of the genus *Trypanosoma*.

These protozoa have existed for over 100 million years. They may have once infected dinosaurs, and they now live in all classes of vertebrates, from fish to mammals. "Species collected at Pico da Neblina and other areas in Venezuela may be related to this one, with shared ancestors millions of years ago," says Fermino. In humans, *T. cruzi* causes Chagas disease, and *T. brucei* causes sleeping sickness.

COLLABORATION

"The expedition would not have been possible without the Army. Everyone was very careful about our safety and very interested in what we were doing," acknowledges Rodrigues. Paulo Muzy, a physicist from the IEA, said during the December meeting that the partnership between USP and the Army began in 2015, with a view to enabling the trip to Pico da Neblina. Luís Fábio Silveira, a biologist from the USP Museum of Zoology who specializes in birds, spoke highly of the partnership: "The military were very helpful, they even came out at night to help us descend a cliff by rope to collect samples." Silveira collected 56 specimens of birds that he believes are exclusive to the region. Most are small with brown feathers and live in an area with few food resources.

The next goal for Rodrigues, 69, is to visit the Tulu Tuloi Mountains, which are also in the state of Amazonas, approximately 200 km northeast of Imeri. "There is another set of mountains there, isolated from Imeri by the valley of the Padauari River, which represents another natural evolutionary experiment," he says. "Since populations of the same species can change and give rise to new species when isolated, we wonder if there might be another group of endemic species related to those in Imeri." ■

Project

Comparative phylogeography, phylogeny, paleoclimate modeling, and taxonomy of neotropical reptiles and amphibians (no. 11/50146-6); **Grant Mechanism** Biota Program; **Principal Investigator** Miguel Trefaut Rodrigues; **Investment** R$6,183,134.96.

Most pregnancies result in a single cub

HOW MANY CUBS DOES A JAGUAR HAVE?

Scientists use technology to measure the birth rate of jaguars in the Pantanal

Letícia Naísa

PUBLISHED IN MAY 2023

At the end of 2021, biologist Edu Fragoso received a fairly common Christmas gift from his mother: a photo album. What was unusual, however, was that it did not contain memories of family moments or vacations but images of the researcher at work in the Pantanal with the subjects of his research: jaguars. Every time he and his team approached a jaguar to collect data for their research, he sent a photo of the animal to his mother, Bernadete, via WhatsApp, including details such as the animal's size, the name they had given it, and any interesting characteristics. The researcher's mother included this information on the back of each photo.

Fragoso has been monitoring jaguars in the Pantanal since 2015. In a recently published article, he and his team of 11 researchers from the nongovernmental organizations Onçafari and Panthera described how they assessed the reproductive habits of 180 individual jaguars that live freely in the Caiman ecological reserve in Mato Grosso do Sul, an area of 53,000 hectares that includes 56,000 square kilometers of legal preservation area.

A jaguar's pregnancy lasts an average of three months. The reproductive age of females starts at 2.5 years of age and can last until they are 13—they live to approximately 15 years old and reproduce every two years. A female jaguar will have an average of eight cubs over the course of her life. The majority (65.7%) of the births recorded by the study involved just one cub, a quarter involved twins, and the remainder involved triplets, according to an article published in the *Journal of Mammalogy* in January. Cubs become independent of their mothers at approximately 1.5 years old.

Fragoso and his team were delighted with the results. "These are important numbers. We observed a good level of population growth in the region; the environment is healthy and they can continue to survive for many years there," says the scientific coordinator of Onçafari. "The females have been very successful at raising their young to independence."

The survival of jaguars in the Pantanal is based largely on the amount of prey to which they have access. "These felines lead a good, peaceful life here," says Fragoso. The data behind the discoveries were collected for almost a decade with the help of cameras fitted with motion sensors, known as camera traps, which begin recording whenever movement is detected. The scientists also used GPS collars to monitor exactly where the jaguars were, to track their movements and to identify pregnant females, whose movement decreases considerably during pregnancy.

To fit these collars, another type of trap was used: a snare that consists of a loop connected to a transmitter, set up in the middle of a trail and then camouflaged. When the jaguar steps into the trap, the loop tightens around its paw, and the team receives a signal that it has been captured. The researchers quickly go to the location and anesthetize the animal with a dart gun.

After the tranquilizer has been applied by a veterinarian, the researchers have between 40 and 60 minutes to take measurements, such as weight and size measurements, collect material for laboratory analysis, such as hair, saliva, and blood samples, and fit a GPS collar, which has a shelf life, falling off by itself approximately 1.5 years later. The researchers stress that the collar is only placed on adult animals that will not grow any bigger and that the anesthetic is not harmful to pregnant females.

"In the moment, we are focused on doing what we came to do, but being there in such close contact with these animals is indescribable," says Fragoso. For the scientists, every jaguar is unique and is therefore given their own name: Esperança, Flor, Troncha, Ipê, Aroeira, Fera (and her baby, Ferinha). Fragoso's favorite is Natureza. "She was the first one I saw in the wild when I arrived in the Pantanal," he recalls. She has had 10 cubs since the biologist began monitoring her.

The researchers need to be particularly careful—and quick—when visiting the jaguars' dens, which they can only do thanks to the GPS collars. Females generally remain as close to their newborn cubs as possible, but when a camera trap identifies a female far away from her litter, the team splits up. Half of the team follows the mother, and the other half go to the den to count the number of cubs. This is an important task because it tells the team how many cubs were actually born, rather than just how many survive and emerge from the den when they are more independent. "The teams communicate by radio and have to move very quickly," says Fragoso, who emphasizes that the method is only used when the den is easily accessible, so that no changes are made that could expose the cubs to risks. "Without doing this, we could only see the cubs on the cameras once they reached 2 or 3 months old, but we couldn't know how many had actually been born." One of the next missions will be to measure the infant mortality rate of jaguars.

In addition to experience, being part of a team such as Fragoso's requires a high level of respect for safety protocols. The only way to get close to an awake jaguar is in a car. The jaguars in the re-

PHOTOS EDU FRAGOSO / ONÇAFARI

Long-term monitoring provides detailed data on the demography of jaguars in the Pantanal

gion where Onçafari operates are already used to the sound of vehicles, so the noise does not affect their natural behavior. In addition to researchers, Caiman is also a popular destination for tourists. To date, the biologist has never witnessed any serious accidents, despite dealing with the largest jaguars in the world. "Jaguars don't see humans as prey," says biologist Alan Eduardo de Barros, a PhD student at the University of São Paulo (USP) who is studying the consequences of wildfires on the jaguar population in the Pantanal.

Adult males from the region can weigh over 140 kilograms (kg), and females can weigh over 80 kg. Jaguars from the Caatinga (semiarid scrublands) are usually lighter, with adult males weighing less than 50 kg. Barros, who has no relationship with Onçafari, believes Fragoso's team was smart to carry out their study in the biome. "It is somewhat easier to observe large animals and birds in the Pantanal," he points out.

Ronaldo Morato, a veterinarian and head of Brazil's National Center for Carnivorous Mammal Research and Conservation (CENAP) at the Chico Mendes Institute for Biodiversity Conservation (ICMBIO), says that the Pantanal is a well-conserved biome with a high density of jaguars. "Some of the animal behavior there is more relaxed and there is less competition because there is more food available," he explains. "Having this as a reference will allow us to make predictions about regions where it is harder to collect information," he says.

Another advantage was that the team observed the jaguars in a wildlife reserve that has also invested in tourism, including safari tours, meaning the animals are used to the presence of humans. It is essential to align the interests of tourism to scientific research and preservation of the species, says Barros. "The potential is positive if it is done correctly," he notes.

Technological advances also contributed to the close observation of the animals. In the 1970s, researchers used collars that emitted very high-frequency (VHF) radio signals, not GPS signals. To capture these signals, Peter Crawshaw (1952–2021), a Brazilian pioneer in jaguar studies, had to fly over the Pantanal in an ultralight aircraft. "In the past, a really good study would identify around 60 location points over two or three years," recalls Morato, who was one of the first to monitor jaguars with GPS. "Now we can capture 60 locations in three days, so the volume of data we can collect has increased immensely, as well as its accuracy."

Modern computer technologies also allow researchers to analyze the large volume of collected data. "There are now ways of scrutinizing this information in much more detail," points out Morato. "We can identify complex associations that help us better understand the natural history of the species."

Reproducing Fragoso's study in other Brazilian biomes could be challenging, especially in areas where jaguars are endangered, such as the Atlantic Forest and the Cerrado (wooded savanna), or outside the country. The hope is that the data collected in the Pantanal will help scientists assess population viability and plan for reintroduction of the species. Morato sees jaguars as a symbol that can be used to engage society in preserving the environment and biodiversity. ■

Scientific article

FRAGOSO, C. E. *et al.* Unveiling demographic and mating strategies of *Panthera onca* in the Pantanal, Brazil. **Journal of Mammalogy**. Online. Jan. 12, 2023.

PHOTOS EDU FRAGOSO / ONÇAFARI

Scientific manipulation of the electrochemical cell used in the experiment

LÉO RAMOS CHAVES / PESQUISA FAPESP MAGAZINE

FROM WATER TO HYDROGEN

Research project carried out at the Sirius synchrotron sheds light on breaking water molecules with a new biocatalyst

Frances Jones

PUBLISHED IN JANUARY 2023

An experiment recently carried out at the Sirius synchrotron light source, based at the Brazilian Center for Research in Energy and Materials (CNPEM) in Campinas, São Paulo (*see* Pesquisa FAPESP *issue no. 269*), showed how a certain biological catalyst made water (H_2O) scission via electrolysis more efficient. This reaction, which was an electrochemical process that used electricity to decompose water into its constituent elements, is of great interest because, in addition to oxygen, it also provided hydrogen, which has been identified by many experts as the fuel of the future, since it generates no pollution (*see* Pesquisa FAPESP *issue no. 314*).

"We discovered that when manipulated in the lab, some enzymes found in nature, including bilirubin oxidase [BOD], accelerated the water-breakdown reaction," says chemist Frank Nelson Crespilho, a professor at the São Carlos Institute of Chemistry of the University of São Paulo (IQSC-USP) who led the study. "We did not know why this was happening. Thanks to new equipment developed especially for Sirius, we were able to determine how this enzyme, BOD, behaved during the water-oxidation process. We found that the copper atoms in the enzyme played important roles in the reaction."

Crespilho believes scientists will be inspired by the part of the enzyme that accelerated the reaction. "It is interesting that we recognized the important regions of BOD because now synthetic chemists who produce new materials can copy that part of the enzyme and synthesize it in the lab. This will make the catalyst much more affordable and greatly expand its application range," said the scientist. The catalysts currently used for the process generally contain noble metals, such as platinum and iridium, which are very expensive and thus make large-scale application unfeasible. An article describing the experiment was written by Crespilho's team, which includes Graziela Sedenho, Rafael Colombo, Thiago Bertaglia, and Jessica Pacheco, and was published in the journal *Advanced Energy Materials* in October. Scientists from the Brazilian Synchrotron Light Laboratory (LNLS) also participated in the study.

Bilirubin oxidase was extracted from the fungus *Myrothecium verrucaria*, which is commonly found in soils and on plants. When manipulated in the lab, it catalyzed the water breakdown reaction—something that does not occur spontaneously in nature. Inside the reactor, the enzyme acted more specifically in the formation of molecular oxygen, which is one of the two reactions needed to break down H_2O molecules. The other is the formation of hydrogen, and the two occur concurrently. "For hydrogen formation, which takes place on one side of the reactor, everything is already better known. There are cheaper and more efficient catalysts. The water-oxidation reaction, however, is very slow, and scientists all over the world are seeking better catalysts for this," explained Crespilho.

Researchers around the world are searching for new water-oxidation catalysts

The researchers were able to observe the behavior of the enzyme during the bioelectrochemical reaction in such detail thanks to the cutting-edge infrastructure at Sirius. The team used the Tarumã experimental station of the CARNAÚBA beamline, which is still in the scientific commissioning phase, a process involving testing, technical development, routines, and experimental strategies.

Monochromator: part of the CARNAÚBA beamline at Sirius, where the study was carried out

"Various experiments and scientific topics are addressed in this phase, with the aim of demonstrating the potential of the beamline," said physicist Helio Cesar Nogueira Tolentino, head of the Heterogeneous and Hierarchical Matter Division at LNLS. Of the 14 beamlines initially planned for Sirius, seven are already operational. Each operates with a different energy band using a proprietary technique. All seven are open to scientists from Brazil and abroad.

Operating since late 2021, the Carnaúba beamline is the longest at Sirius. It was designed for X-ray absorption spectroscopy, which enables experiments with different materials on the nanometric scale. In addition to the powerful, superfocused beam of light, Crespilho's group was also given access to a device recently developed by the LNLS team for biochemical studies.

"It is an electrochemical cell for *in situ* experiments. It is placed in front of the X-ray beam, which is focused on the material being studied at the moment the chemical reaction occurs. With this cell, we can also apply an electrical potential and measure the current or apply the current and measure the potential, which allows us to see how the material responds to these external stimuli, all while the chemical reaction is taking place," explains Itamar Tomio Neckel, a physicist from the CARNAÚBA group at LNLS and the lead developer of the new electrochemical cell, a device small enough to fit in the palm of the hand.

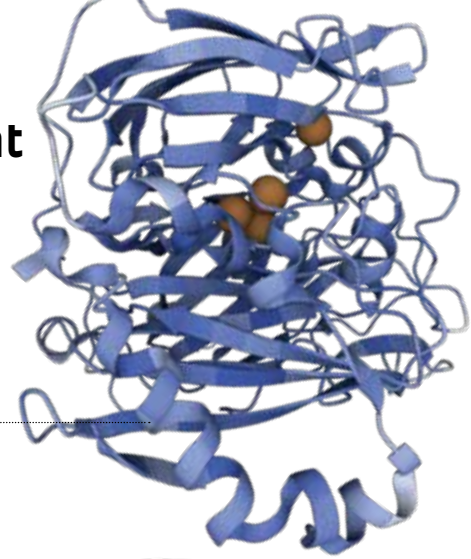
The biggest challenge, according to the researcher, is to miniaturize everything, since the reactions have to take place in extremely limited physical spaces. Additionally, the conditions found in the laboratories of different users must be simulated. The CARNAÚBA beamline is 100 times smaller than a strand of hair and is known as an X-ray nanoprobe.

The major difference is that the equipment allows the material involved in the experiment to be mapped *in situ*, so the researchers can see the state of the material—copper for the study in question—during the different stages of the chemical reaction. "In these *in situ* experiments, we studied the kinetics

PHOTO LÉO RAMOS CHAVES/ PESQUISA FAPESP MAGAZINE **INFOGRAPHIC** ALEXANDRE AFFONSO / PESQUISA FAPESP MAGAZINE

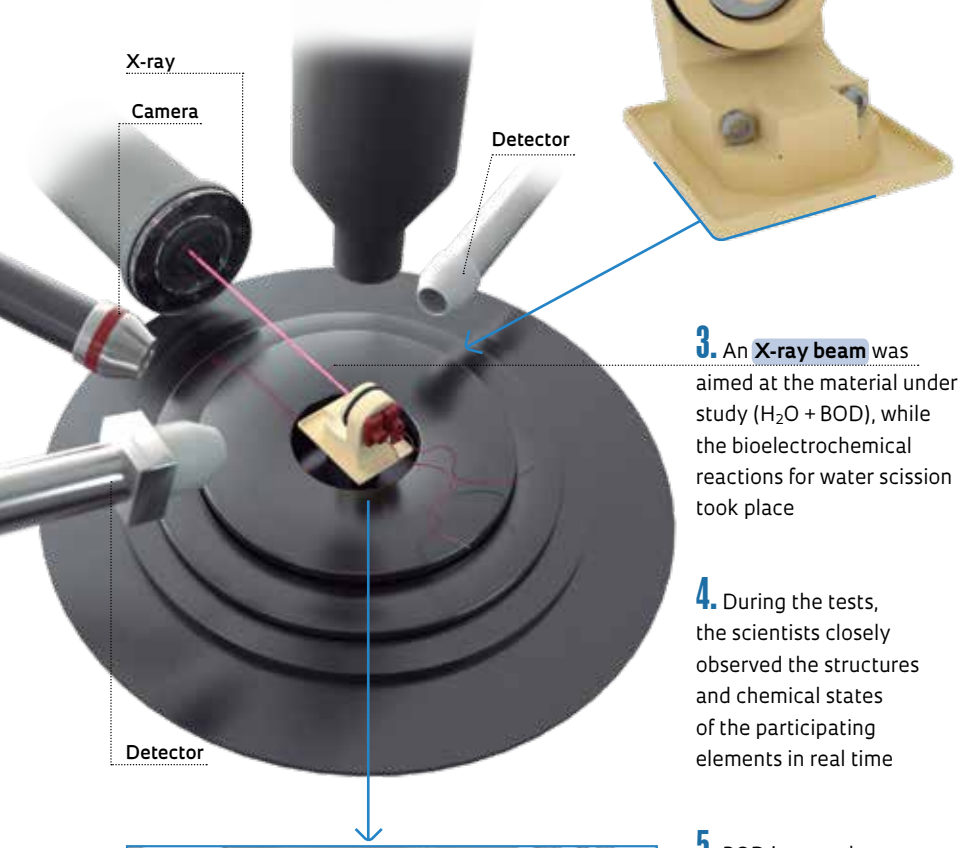
How the experiment was done

Researchers focused on the functions of an enzyme extracted from the fungus *Myrothecium verrucaria*



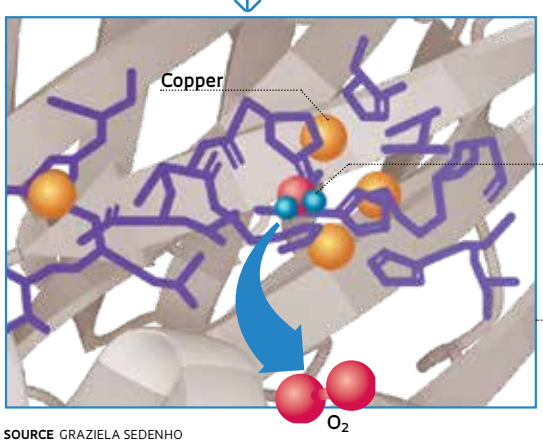
1. The **bilirubin oxidase enzyme (BOD)** catalyzed the breakdown (electrolysis) of water molecules (H_2O), an essential step in hydrogen fuel production

2. The experiment was carried out in an **electrochemical cell** at the **CARNAÚBA beamline** of the Sirius particle accelerator



3. An **X-ray beam** was aimed at the material under study (H_2O + BOD), while the bioelectrochemical reactions for water scission took place

4. During the tests, the scientists closely observed the structures and chemical states of the participating elements in real time



5. BOD is a catalyst (accelerator) for the formation of oxygen (oxidation), one of the reactions involved in **breaking down H_2O**

6. The researchers located the most important **regions of the BOD (catalytic sites)** and discovered that the oxidation state of the copper ions inside the enzyme were crucial to the reaction

SOURCE GRAZIELA SEDENHO

in real time. We produced an electrochemical reaction and studied all of its stages with a microscope that gave us real-time information about the structures and chemical states of the elements involved," explains Tolentino. "The experiments allowed us to understand the bioelectrocatalytic process, which is very important for hydrogen production. They open further possibilities for producing hydrogen through a reaction that is quite simple and involves common materials."

The work by Crespilho's team was one of 30 projects external to the LNLS that were funded in a call for research to commission the station, which was launched in October. The article published by the IQSC-USP group was the first in the field of bioelectrochemistry, but other experiments have been carried out on the same theme and are soon to be published, including one by a group from Argentina.

"The results obtained by the USP group in collaboration with CNPEM show the potential of *in situ* electrochemical studies in conjunction with synchrotron radiation for elucidating important reaction mechanisms in biocatalysis," says chemist Ana Flávia Nogueira, from the Institute of Chemistry at the University of Campinas (UNICAMP), who was not part of Frank Crespilho's team. She emphasized the unprecedented use of the technique and its research potential. "In this study, copper catalytic sites were identified at the nanometric scale. The partnership shows the Brazilian community that our scientists can benefit from the advanced technologies available at Sirius and earn recognition worldwide for characterizing materials at the nanoscale." ■

Projects

1. Toward a convergence of technologies: From sensors and biosensors to the visualization of information and machine learning for data analysis in clinical diagnostics (no. 18/22214-6); **Grant Mechanism** Thematic Project; **Principal Investigator** Osvaldo Novais de Oliveira Junior (USP); **Investment** R$14,050,528.68.
2. High-performance electrodes in organic batteries and biofuel cells (no. 19/12053-8); **Grant Mechanism** Regular Research Grant; **Principal Investigator** Frank Nelson Crespilho (USP); **Investment** R$185,392.57.

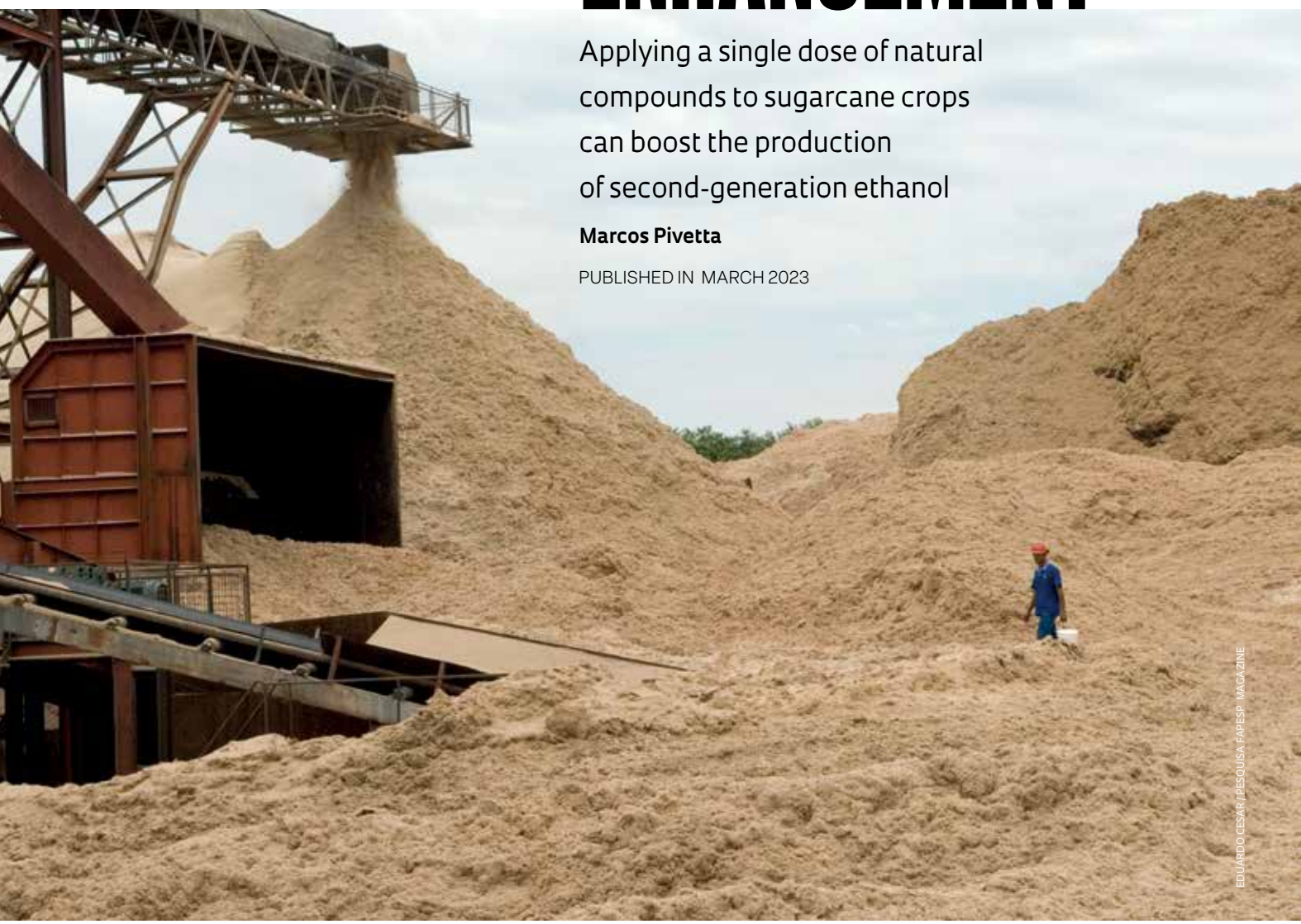
All research projects and scientific articles consulted for this report are listed in the online version.

LIQUID ENHANCEMENT

Applying a single dose of natural compounds to sugarcane crops can boost the production of second-generation ethanol

Marcos Pivetta

PUBLISHED IN MARCH 2023



EDUARDO CESAR / PESQUISA FAPESP MAGAZINE

A pile of bagasse at a sugar and ethanol mill in São Paulo. Bagasse, a byproduct from sugarcane processing, can be used to produce second-generation ethanol

Applying a single dose of natural compounds to sugarcane crops can lead to subtle cell wall changes that can significantly improve yields for second-generation ethanol or ethanol produced from sugarcane bagasse and straw. A paper published last December in the journal *Biomass and Bioenergy* suggests that this can improve saccharification by 120% in 12-month-old sugarcane bagasse. Saccharification, also known as hydrolysis, is a chemical process that utilizes enzymes to convert complex carbohydrates such as cellulose and hemicellulose—which do not naturally ferment—into simpler sugars such as sucrose, which can be fermented to make ethanol.

"We conducted field trials using very low doses of these compounds, which were rapidly eliminated and still resulted in the desired changes," says Wanderley Dantas dos Santos, a biochemist at the State University of Maringá (UEM) in Paraná and the lead author of the paper. "We observed no undesirable side effects; the plants developed normally without any effect on yields." Santos has been investigating this approach, known as "physiological engineering," since 2008 as part of his postdoctoral research under Marcos Buckeridge, a botanist at the Institute of Biosciences at the University of São Paulo (IB-USP).

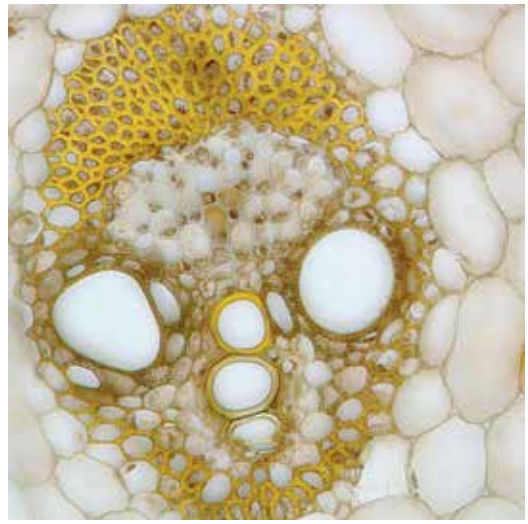
According to the authors of the study, the new approach could be a simpler alternative to attempting genetic modifications in sugarcane DNA to make its biomass more readily fermentable. The sugarcane genome is complex, with over 100 chromosomes, many of which are repeated, making the creation of viable transgenic varieties challenging. First-generation ethanol production, which accounts for over 98% of the biofuel produced in Brazil, does not require the hydrolysis or saccharification step, as the sugars from sugarcane juice or molasses ferment naturally.

Treatment with these substances has also shown promising results beyond sugarcane: in 90-day-old soybean residues, the compounds increased saccharification by 36%; in Brachiaria grass, commonly used as pasture in cattle farming, the saccharification rate increased by 21% within 40 days of applying the compounds. "The main focus of the experiment was sugarcane, but this approach could also potentially lead to the production of pasture that is more readily digestible, or soybeans with damage-resistant hulls, a desirable trait in the industry," notes Buckeridge, who led the research team and serves as head of the National Institute for Bioethanol Science and Technology, an organization funded by FAPESP and the Brazilian National Council for Scientific and Technological Development (CNPq). The research team also received funding from the Research Center for Greenhouse Gas Innovation (RCGI), an initiative sponsored by FAPESP and by the oil and energy giant Shell.

Three compounds that function as inhibitors of enzymes associated with lignin synthesis in sugarcane and other plants were tested: methylenedioxy (cinnamic) acid (MDCA), piperonylic acid (PIP), and daidzin (DZN). Lignin, along

with cellulose and hemicellulose, is present in the cell walls of all terrestrial plants, providing mechanical strength and rigidity and acting as a barrier to the entry of pathogens. Without lignin, plants cannot stand upright and lack an impermeable vascular system to transport water from the roots to the stem.

Different dosages of the compounds were diluted in water and sprayed onto the leaves and roots of the plants at various stages of development. At the end of the experiment, the researchers determined the optimal timing and most effective dosage for applying the substances. PIP proved to be the best-performing compound.



A scanning electron microscope image reveals the presence of lignin (highlighted in yellow) in the cell wall of sugarcane stalks

1

The sugarcane bagasse composition is roughly half cellulose, one-quarter hemicellulose, and one-quarter lignin. Although essential for plants, lignin creates added challenges in the production of second-generation ethanol. As a nonsugar, it is not fermentable. This, however, is not the biggest challenge. The presence of lignin in sugarcane biomass makes it much more complex and expensive to convert the long carbohydrates in cellulose and hemicellulose—which are not inherently fermentable—into smaller, fermentable sugars. In addition to being difficult to separate from cellulose and hemicellulose in the cell wall, lignin also produces substances that hinder the chemical saccharification process.

Currently, sugarcane bagasse is treated with heat and a combination of enzymes to enable hydrolysis of the biomass. This is the most expensive step in producing second-generation ethanol, accounting for at least 30% of the final production cost. "We cannot simply reduce the amount of lignin in a plant as that would be detrimental," explains Buckeridge. "When we examined the cell wall of sugarcane treated with these compounds under a microscope, we saw no discernible difference. The changes need to be very subtle."

In the article, the researchers note that the use of the compounds did not decrease the overall amount of lignin in the sugarcane bagasse, nor did it alter the lignin composition. However, they noted that the concentration of lignin changed in different tissues of the plant, with a slight increase in the fibrous portion and vessels and a decrease in the parenchyma, which is a filler tissue in plants. It is possible that this redistribution of lignin in different parts of the sugarcane plant may have contributed to the higher saccharification efficiency reported in the study.

Mario Murakami, a biochemist and the scientific director of the National Biorenewables Laboratory (LNBR) in Campinas, affiliated with the Brazilian Ministry of Science, Technology, and Innovation (MCTI), believes that modulating lignin synthesis using compounds could be a promising approach to potentially enhance the efficiency of second-generation ethanol production. While he finds the results reported by his colleagues from UEM and USP to be encouraging, he emphasizes the need for validation under industry-relevant conditions. "These experiments need to be conducted under conditions that are closer to those found at plants producing second-generation ethanol to see if real-world saccharification gains match the experimental results and there is no loss of efficiency in the

Sugarcane treated with lignin modulators in Maringá, Paraná

2

PHOTOS 1 DEBORA LEITE/MARCOS BUCKERIDGE 2 WANDERLEY DANTAS DOS SANTOS/UEM 3 MAXUEL DE OLIVEIRA ANDRADE/RENATA RABELO/LNBR

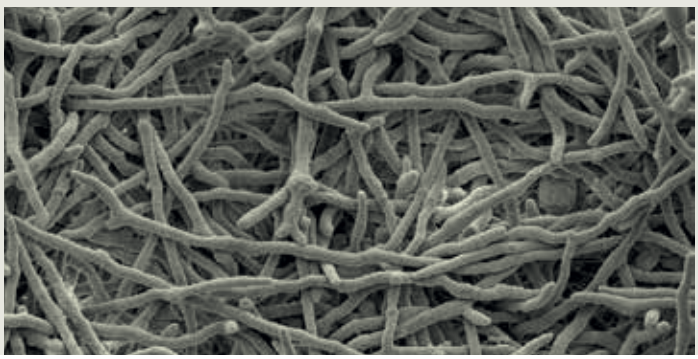
DEVELOPING AN IMPROVED ENZYME COCKTAIL

The breakdown of sugarcane cell walls into fermentable sugars relies on the action of enzymes

A crucial step in the production of second-generation ethanol is the use of an enzymatic cocktail to hydrolyze cellulose and hemicellulose. Using a combination of enzymes, the complex carbohydrates found in these components of sugarcane bagasse are broken down into smaller, fermentable sugars, such as glucose and xylose. The market for saccharification enzymes is dominated by the Danish company Novozymes. "Enzymes represent between 30% and 50% of the final cost of second-generation ethanol production," says Mario Murakami, a biochemist and scientific director of the National Biorenewables Laboratory (LNBR). As a result, several research groups in Brazil are actively exploring more cost-effective and, ideally, better-performing alternatives to current products.

In 2019, Murakami and his team utilized the CRISPR/Cas9 gene editing technique to modify six genes of the fungus *Trichoderma reesei*, maximizing its production of biotechnologically relevant enzymes, particularly those used for the hydrolysis of plant biomass. Fungi from this genus are commonly employed in the commercial production of enzymatic cocktails designed to promote the saccharification of sugarcane bagasse, enabling the production of second-generation ethanol. In a study published in *Bioresource Technology* in late 2022, LNBR researchers reported a remarkable reduction in the time taken to produce the enzymes, from 14 to just 9 days. "Our enzymatic cocktail is not only low-cost but also stable, with a one-year shelf life at room temperature," highlighted Murakami. The cocktail has been successfully tested in the laboratory's pilot plant and has demonstrated the ability to degrade approximately 60% of the long carbohydrates in sugarcane biomass, a performance similar to that of some commercial products.

Botanist Marcos Buckeridge from the Institute of Biosciences at the University of São Paulo (IB-USP) suggests that exploring different microorganisms could hold the key to producing enzymatic cocktails for a simpler and more efficient hydrolysis process. In addition to the better-known *T. reesei*, researchers have also studied fungi found in the Amazon, insects such as cockroaches, and even sugarcane itself as potential sources of enzymes to enhance the process. "The origin of the enzymes is not as crucial," says Buckeridge, "as mastering the technology for producing an efficient enzymatic cocktail. The high cost of imported products discourages investments in second-generation ethanol.



3

Six genes of the fungus *Trichoderma reesei* were modified to enhance its action in breaking down the cell walls of sugarcane

process," notes Murakami. "The potential impacts of using these compounds on the cost of second-generation ethanol production also need to be determined."

These questions are expected to be answered soon, as Raízen, one of the two companies producing second-generation ethanol in Brazil (the other being GranBio), is set to begin testing the use of lignin modulator compounds in pilot sugarcane fields later this semester."Within a year, we may have a clearer picture of whether the saccharification increase is maintained in a commercial operation," says Santos. Raízen, a joint venture between Shell and the Brazilian group Cosan, is running the experiments in collaboration with RCGI.

The participating researchers believe that lignin modulators, which can also be synthetically produced in the laboratory, could be developed into a commercial product for the sugarcane and ethanol sector in the future and possibly for other agricultural applications as well. They have already obtained a patent in Brazil for use of these lignin modulators in agricultural crops, and Santos and a group of students from the Department of Biochemistry at UEM have established a startup, BioSolutions, to explore the commercialization of these compounds. Created in 2021, the company is supported by the Brazilian Micro and Small Business Support Service (SEBRAE) in Paraná and the TIM Institute. ■

Projects

1. INCT 2014: National Institute for Bioethanol Science and Technology (no. 14/50884-5); **Grant Mechanism** Thematic Project; CNPq-INCTs Cooperation; **Principal Investigator** Marcos Buckeridge (USP); **Investment** R$5,261,561.47.

2. Research Center for Greenhouse Gas Innovation - RCG2I (no. 20/15230-5) **Grant Mechanism** Research Centers in Engineering Program; BG E&P Brazil (Shell Group) Cooperation; **Principal Investigator** Julio Meneghini (USP); **Investment** R$13,604,936.28.

Scientific article

SANTOS, W. D. *et al.* Natural lignin modulators improve lignocellulose saccharification of field-grown sugarcane, soybean, and brachiaria. **Biomass and Bioenergy**. Dec. 5, 2022.

GLASS AGAINST CANCER

Bioglass in powdered and pellet form: magnetic particles give them black coloring

LÉO RAMOS CHAVES / PESQUISA FAPESP MAGAZINE

Researchers have developed composite materials with the potential to kill carcinogenic cells and regenerate bone

Suzel Tunes

PUBLISHED IN MAY 2023

Materials engineer Geovana Lira Santana, from the state of Paraíba, discovered the properties of F18, a bioactive glass capable of stimulating bone regeneration, after she arrived at the Federal University of São Carlos (UFSCar) to pursue a master's degree. She saw in the new material the possibility of realizing an old desire to become a scientist and conduct research on cancer. Using F18, a creation of the Vitreous Materials Laboratory (LAMAV) of the Department of Materials Engineering (DEMA) at UFSCar, Santana worked on the development of a compound with magnetic particles for the treatment of bone cancer.

With collaboration from the Center for Research, Teaching, and Innovation in Glass (CERTEV) and the Functional Materials Development Center (CDMF), two Research, Innovation, and Dissemination Centers (RIDCs) funded by FAPESP, Santana developed a new material to be applied as a graft on bone affected by cancer. Into the glass matrix formed from the F18 bioactive glass (or bioglass), patented by UFSCAR in 2015, she incorporated doped lanthanum manganites, i.e., lanthanum manganites enriched with strontium, a material that heats up when exposed to an external alternating magnetic field.

The result was a composite—a material formed from two or more components with complementary or superior properties to those of the original items—with a dual function. The first function is combating tumor cells through controlled heating of the magnetic particles; the second is the regeneration of bone tissue as a result of the osteoinduction capacity of the bioglass. "The bioactive glass frees ions that change the pH of the medium, stimulating the proliferation of bone cells. It not only creates a favorable environment for bone regeneration, like the bone substitutes available on the market, but also promotes the formation of tissue," summarizes the researcher, who is currently pursuing a PhD in the same department. Additionally, F18 bioglass has a strong bactericidal effect that prevents post-surgical infections.

The project, which was begun in 2018, received guidance from materials engineer Edgar Dutra Zanotto, the coordinator of LAMAV and CERTEV, and involved collaboration with Murilo Crovace, a professor from DEMA. The preliminary results, published in the scientific periodical *Materials* in 2022, are promising.

Another relevant feature of the new material is that it can be heated to a maximum of 45 degrees Celsius (°C). This limit prevents overheating of the area and damage to healthy cells neighboring the tumor. In laboratory tests, the magnetic particles of the composite reach 40 °C in a few minutes when subjected to an external magnetic field.

"It is very close to the ideal temperature for treatment of the tumor, approximately 43 °C," says Santana. "The formation of a layer of hydroxycarbonate apatite, which is naturally present in human bone, permits the connection of the composite with the bone tissue." In addition to seeking the ideal heating levels, the next stages of the project will include *in vitro* testing and clinical studies but do not yet have a scheduled date. An application to patent the composite was filed in 2021.

Medical radiologist Marcos Roberto de Menezes, coordinator of the area of radiology and image-guided intervention of the Institute of Cancer of São Paulo (ICESP), expects that, once validated by clinical studies, the new material may provide new prospects in oncology treatment. Menezes is a specialist in the treatment of cancer by thermoablation, a technique that consists of the image-guided insertion of needles to destroy tumor cells by increasing temperature or freezing.

According to the radiologist, the use of temperature as a therapeutic resource in oncology could be a less invasive alternative to surgery in specific cases, such as the treatment of metastasis. "Hyperthermia [a sharp increase in body temperature] therapy is already well established for tumor cell destruction. The big advantage of this new material would be the possibility of destroying the tumor and maintaining the structure and function of the bone," explains Menezes. He adds that hyperthermia treatment destroys the tumor, but depending on the size and severity of the lesion, there may be weakening of the affected bone, causing loss of function and pain. The osteoinduction capacity of bioactive glass could solve this problem.

Although multiple stages of development remain necessary before the material can arrive on the market, the bioactive glass with magnetic particles from UFSCar already has a company interested in selling it: the startup Vetra, founded in 2014 by former CERTEV students and incubated in Supera, the business park for innovative companies of Ribeirão Preto.

The bioglass used as the matrix for the composite developed by Santana was a result of the master's project of dentist Marina Trevelin, a founding partner of Vetra, which she carried out in LAMAV-DEMA-UFSCar between 2009 and 2011. For her PhD, the researcher expanded the project, advancing to preclinical trials and exploring different uses for the technology, such as the regeneration of wounds of the skin and nerves.

Trevelin received a FAPESP grant to pursue her PhD in materials science and engineering, and Vetra received funding from FAPESP's Innovative Research in Small Businesses (PIPE) program for the industrial production of F18. The startup holds the patent for the material, licensed by UFSCar in 2016 (*see* Pesquisa FAPESP *issue no. 241*), and today provides it to companies that specialize in medical and dentistry products.

Santana's project is the successor of an even older story that dates back to 1977, when Zanotto created LAMAV at UFSCar. At that time, bioactive glass was still new in Brazil. It was invented less than 10 years earlier, in 1969, by US materials engineer Larry Hench of Florida University in the USA, from a composition of sodium, calcium, silicon, and phosphorus.

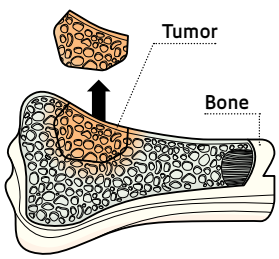
The new material gained attention for its ability to react with bodily fluids, forming a layer of hydroxycarbonate apatite, which enables it to chemically bond to bone tissue and promote bone regeneration. It was patented as Bioglass 45S5, a name that would become popular for similar materials with different compositions.

Bioglass quickly gained prominence on the biomaterials market. "In Europe and in the USA, it has been used to produce bone grafts, membranes for the regeneration of skin ulcers, and, in powdered form, dental products for repairing defects in the enamel and the treatment of dentin hypersensitivity," notes Zanotto.

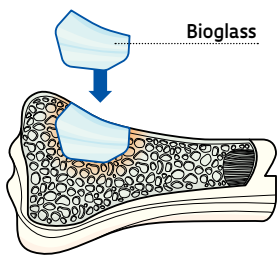
However, the material invented by Hench presented limitations due to its low mechanical resistance. This characteristic prevents its use as an implant in locations subjected to large loads and limits the possibility of molding it into different formats. One day, during an informal chat at a table in a bar, Zanotto and Hench speculat-

FIND OUT HOW THE NEW COMPOSITE WORKS IN THE BODY

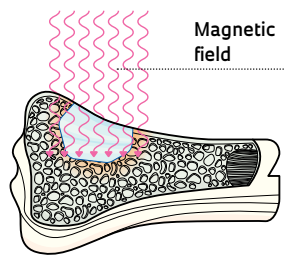
The implanted vitreous material helps to rebuild the bone



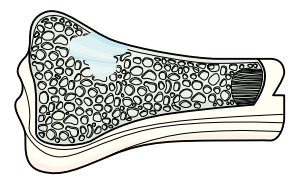
1. To treat bone cancer, the compromised tissue is removed. After the intervention, there is a risk of recurrence of cancerous cells



2. Physicians implant the bone graft made from F18 bioglass with LSM (strontium-doped lanthanum manganite)



3. Next, an external alternating magnetic field is applied in the region, leading to the death of the remaining tumor cells



4. The vitreous composite is gradually absorbed by the body and replaced by newly formed bone tissue

SOURCE GEOVANA SANTANA

Samples of bioglass with different compositions of magnetic material

ed about these limitations when the idea of a new project arose. "We imagined that it would be possible to crystallize the bioglass to give it greater resistance," recalls Zanotto. This project became the materials engineering PhD topic of Oscar Peitl, currently a professor at DEMA-UFSCar. From this research, concluded in 1995, biosilicate was created and later patented in 2003.

Zonotto explains that biosilicate is a vitroceramic (*see* Pesquisa FAPESP *issue no. 191*). In the crystallization process, through the insertion of additives and exposure to high temperatures, the initially disorderly structure of the material changes to a regular geometric arrangement. The crystallinity gives the vitroceramic superior mechanical properties to bioactive glasses but generally reduces the bioactivity index. Therefore, the challenge for the UFSCar team was to design a formula that would provide bioactivity similar to that of bioglass while maintaining high mechanical resistance. The result pleased the researchers.

"In the past years, we have conducted three different clinical studies with biosilicate, all successful," informs the coordinator of LAMAV. According to Zanotto, in addition to being efficient for the treatment of dentin hypersensitivity, the material in powdered form has enabled the production of implants of the middle ear ossicles and an ophthalmic implant. This glass ocular prosthesis presents movement and appearance very similar to that of the natural eye.

Years later, in the creation of F18 bioglass, the researchers wanted the opposite result to biosilicate: a material that did not crystallize when subjected to high temperatures, enabling greater control of the material in the production of fibers, vitreous tissues, and complex 3D parts. Trevelin says that 17 attempts were made before the ideal formula—F18—was obtained. "We arrived at a composition that was stable and highly bioactive, as well as bactericidal. Since the start of the preclinical trials, in 2011, F18 has shown promise in tissue regeneration," says Trevelin.

Trevelin, of Vetra, intends to take advantage of the bactericidal properties of F18 by employing it as a bone graft in patients affected by osteomyelitis, a bone disease caused by pathogenic microorganisms. She has already begun research in this direction, with funding from PIPE. Conducting clinical trials now depends on investments into the infrastructure of the startup, which the researcher expects to achieve with the aid of PIPE Invest, a modality of support for startups and small and medium businesses.

At the Federal University of ABC (UFABC), in Santo André, São Paulo, a research group led by materials engineer Juliana Marchi has also developed a vitreous composite to fight bone cancer using hyperthermia. In addition to magnetic nanoparticles to heat the affected region, the composite material has two other therapeutic agents: the chemical element holmium (Ho) for the application of brachytherapy, a type of internal radiotherapy used to destroy the tumor, and zoledronic acid, a drug used for treating bone metastasis.

According to Marchi, this multidisciplinary approach allows the development of a new methodology, described in an article published in the journal *Biomaterials Advances* in 2022, which resulted in a glass with high bioactivity and magnetization. One distinguishing property of the material is the possibility of controlling dosing by adjusting the delivery rate of the therapeutic agents associated with the composite. "We can modulate the dose of brachytherapy at the time the bioactive glass containing the incorporated radioactive property of holmium is implanted," she explains. The project, funded by FAPESP, is in the *in vitro* testing phase. ■

Projects

1. Development and characterization of highly bioactive flexible vitreous tissues (no. 11/22937-9); **Grant Mechanism** Doctoral (PhD) Fellowship; **Supervisor** Edgar Dutra Zanotto (UFSCar); **Beneficiary** Marina Trevelin Souza; **Investment** R$168,950.29.

2. Development of the methodology for the production of particulate bioactive glasses of high purity at industrial scale (no. 15/17175-3); **Grant Mechanism** Innovative Research in Small Businesses (PIPE); **Principal Investigator** Marina Trevelin Souza (VETRA); **Investment** R$600,150.88.

Scientific article

SANTANA, G. L. *et al.* Smart bone graft composite for cancer therapy using magnetic hyperthermia. **Materials**. April 2022.

The other research projects and scientific articles consulted for this report are listed in the online version.

PHOTO LÉO RAMOS CHAVES / PESQUISA FAPESP MAGAZINE **INFOGRAPHIC** ALEXANDRE AFFONSO / PESQUISA FAPESP MAGAZINE

TRANSGENIC MOTHS ON THE HORIZON

The fall armyworm (*Spodoptera frugiperda*) is responsible for losses of up to 50% on maize farms

PRODUTORA SÃO PAULO / OXITEC

New technology developed to combat the main threat to maize crops

Frances Jones

PUBLISHED IN MARCH 2023

Brazilian farmers will soon be able to use a new tool to combat what is considered by agribusiness as maize farming's worst pest. The company Oxitec do Brasil is preparing for the commercial launch of its genetically modified moth, which can be released in maize fields to combat the fall armyworm (*Spodoptera frugiperda*). The armyworm is found in every maize-growing region of Brazil and can cause crop losses of up to 50%. In 2021, Oxitec's transgenic moth, called Spodoptera do Bem, was granted approval by Brazil's National Biosafety Commission (CTNBio), the office of the Ministry of Science, Technology, and Innovation (MCTI) responsible for authorizing the release of genetically modified organisms in Brazil.

"Spodoptera do Bem is a safe and effective product", says geneticist Natalia Ferreira, executive director at Oxitec do Brasil. "We are in the phase of engaging farmers, talking to distributors, and continuing with trials on farms to understand how the product fits into the agricultural producer's routine," she explains. The company says that the product's commercial launch will take place within the next few years.

Spodoptera do Bem is the commercial name of the genetically modified OX5382G strain, developed by the original company in the UK and tested on two Brazilian farms, one in Mato Grosso and another in São Paulo. Oxitec was founded in 2002 as a spinoff from the University of Oxford and is now a subsidiary of the American company Third Security, based in Virginia.

Brazil is the first and only country in the world to release transgenic moths into the field. The genetically modified version of the fall armyworm carries two different genes that were introduced in the laboratory. One of these genes, known as tTAV, prevents the development of females so that only males hatch from the eggs of the next generation, drastically affecting the insect's ability to reproduce.

"In the lab, we improved a gene that already exists in *Spodoptera* and other insects and arachnids, inserting a promoter [a specific DNA sequence] that tells the cell to produce a lot of that gene," said Ferreira. "It's like an overdose. Like if instead of producing organ cells, my entire body started producing only collagen," he says. "The result is that I would no longer produce blood, saliva, or anything needed to sustain my life; I would die due to a lack of these substances."

The second inserted gene, DsRed2, is a marker derived from a species of marine coral that produces a fluorescent protein, helping to distinguish modified animals from wild insects.

The technique for combating the pest consists of releasing genetically modified males into the field to breed with wild females. These pairings only produce male larvae, which after the pupal stage become moths carrying the self-limiting gene in their DNA that in the future will again prevent any female offspring from being born. Thus, within a few generations, the insect population will significantly decrease, according to the company.

The same technology is used in Aedes do Bem, sold by the company in Brazil since 2021 to reduce *Aedes aegypti* mosquito populations. The objective is to reduce cases of dengue and other diseases transmitted by mosquitoes, such as Zika and Chikungunya (*see report on Page 54*). The small group of transgenic animals approved for

sale in Brazil by CTNBio includes the modified *Spodoptera*, two versions of *Aedes aegypti* created by Oxitec, and a salmon developed by the Canadian company AquaBounty.

Maria Lúcia Zaidan Dagli, a veterinarian from the Experimental and Comparative Oncology Laboratory at the School of Veterinary Medicine and Zootechnics of the University of São Paulo (FMVZ-USP) and a member of CTNBio, sees the release of Spodoptera do Bem in Brazil as a positive move. She was involved in the decision to approve Oxitec's first version of *Aedes aegypti*.

Dagli explains that to be authorized for sale by CTNBio, a product must be approved by the agency's four sectors, which verify its impact on humans, animals, plants, and the environment, certifying that it is safe based on data and studies presented by the applicant company. After approval is granted, the product is monitored closely for five years, during which time the company has to submit annual reports to CTNBio.

"It's the same process that takes place with new drugs released by other regulatory agencies. If a problem is reported, depending on the severity, sale of the product may be suspended," underscores the researcher. She points out, however, that no CTNBio-approved product has ever been suspended.

There are approximately 200 chemicals available on the market in Brazil to help farmers combat the fall armyworm, according to the Brazilian Agricultural Research Corporation (EMBRAPA). However, *Spodoptera* has demonstrated resistance to conventional insecticides. There is also concern about the unwanted effects these pesticides may have on the health of nontarget organisms and the environment.

In addition to insecticides, there are nine biological products registered in the country and another four soon to be launched. Transgenic maize that expresses proteins from the bacterium *Bacillus thuringiensis* (Bt) to kill larvae has also been used since the 2008/2009 harvest. However, the insects already show resistance to the modified crop.

"When we use insecticides or transgenic plants to control a pest, we end up involuntarily selecting individuals capable of surviving these technologies in the wild," explains Alberto Soares Corrêa, head of the Molecular Ecology of Arthropods Laboratory at USP's Luiz de Queiroz College of Agriculture (ESALQ). "A single female *Spodoptera frugiperda* can lay up to 1,500 eggs in its life cycle. It's an extremely complex species to address due to its polyphagy [ability to feed on different plant species] and dispersal capacity. Native to the Americas, it has recently become a cosmopolitan pest with reports of its detection in countries in Africa, Asia, Europe, and Oceania," says Corrêa.

To delay the insect's resistance to transgenic maize, farmers are advised to reserve some land—between 10% and 20% of the crop, although there is no consensus on the exact area—for the cultivation of conventional, nontransgenic plants,

1

In addition to maize, the moth feeds on 50 other plant varieties

2

Oxitec employees in the field conducting a pilot study of Spodoptera do Bem

known as a refuge. The idea is that the resistant moths will breed with those from the refuge that do not have the alleles (different forms of a given gene) that confer protection. "The problem is that farmers often do not bother planting a refuge area, and as a result, the insects develop resistance faster," says the ESALQ researcher.

According to Oxitec, transgenic *Spodoptera frugiperda* is a highly effective method of controlling resistance to Bt maize. "Spodoptera do Bem has never seen insecticides, it has never seen Bt in its life, it's totally susceptible," explains Ferreira. "When transgenic males on a farm mate with nonmodified females, any male descendants inherit the part of the father's genome that does not provide resistance. The effect of all insecticides, pesticides, and Bt maize is thus restored. This is a technology that will allow farmers to use less pesticide and to recover or extend the lifespan of biotechnological seeds."

Corrêa explains that autocide—when a genetically modified insect is used to control the population of a species through breeding—is an old technique. "The classic example is the screw-worm fly [*Cochliomyia hominivorax*], which was eradicated in the United States after millions of sterile insects were released starting in the 1950s," he says.

The important difference is that instead of transgenic versions, males rendered sterile by gamma-ray irradiation were released. It is hoped that the use of transgenic insects will overcome some of the previous method's weaknesses, at least initially. "Exposure to radiation can harm the insects in various ways, impacting their biological characteristics and behavior, which can make the strategy less successful. The idea is that with transgenic insects, individuals can better compete with wild males, mating with more females that do not produce any offspring, reducing the population of the target species."

Corrêa is reluctant to speculate on the risks and potential ecological consequences of releasing a transgenic insect into nature. "There are no scientific data available in the literature to answer the biggest questions. This has never been done before on a large scale," says the researcher. "In the case of *Spodoptera frugiperda*, if CTNBio approved it, then they must believe it meets the minimum safety criteria for the technology to be applied."

He notes that the same questions arose with transgenic plants. "Today, we know that they are extremely safe. Thus, their use has expanded worldwide. With animals, however, there is a large difference in reproductive and biochemical issues and with regard to genome structure. We can't simply say: it worked with transgenic plants, so it'll work with transgenic animals."

Biologist José Maria Gusman Ferraz, a visiting researcher at the Laboratory of Ecological Engineering of the University of Campinas (UNICAMP), studied *Spodoptera frugiperda* during his PhD. He sees the new technology as adding another string to the bow to help fight the pest but has doubts about its efficiency, since adult fall armyworms can travel long distances and maize is generally planted in large open areas. "The history of this type of technology is that it only works well in isolated areas, like islands," he says.

Ferraz would also like to see more data on possible damage to parasitoids (the moth's natural enemies) and the risks of transgenic DNA remaining in the environment. "New technologies can work in a short time frame, but they can also

PHOTOS 1 EDUARDO CESAR/ PESQUISA FAPESP MAGAZINE **2** PRODUTORA SÃO PAULO / OXITEC

have negative effects and then stop working," he points out. "The basic principle of life is diversity, and when we reduce that diversity, the system becomes fragile."

Another advantage of genetically modified organisms (GMOs) over irradiated organisms is practicality and cost, explains Margareth Capurro, a biochemist from USP's Institute of Biomedical Sciences (ICB) and technical coordinator of a study on transgenic Aedes mosquitos carried out in Bahia. According to Capurro, 44 countries are preparing to release sterile males to control insect populations, although no other countries are using GMOs to do so.

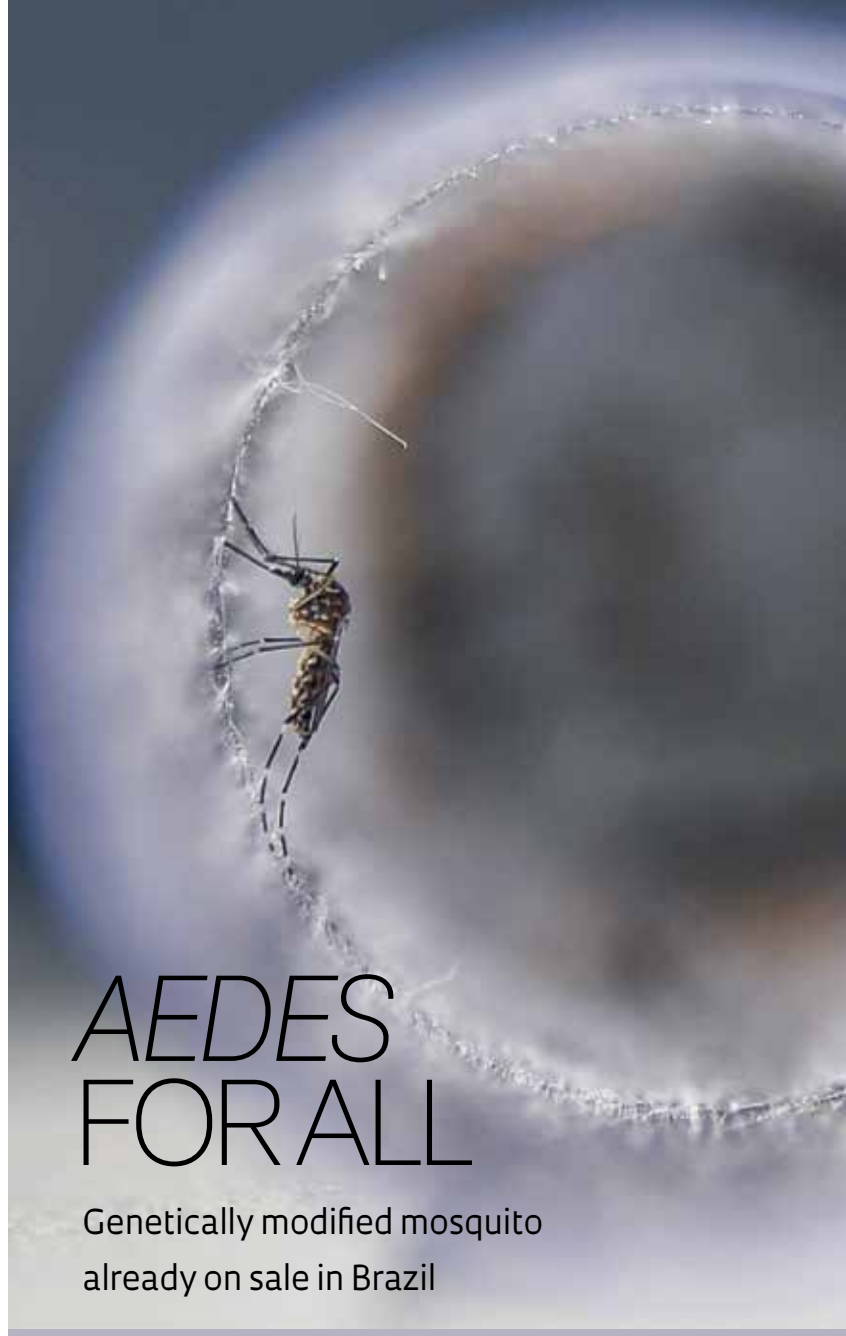
"For sterile males, all you need is to set up a biofactory and pay ongoing production costs; for transgenic insects, you need to pay the company that manufactures them. Transgenic versions, however, make life easier because they eliminate the need for equipment that costs between one and two hundred thousand dollars. How would you have an irradiator in every state in Brazil?" she asks. "It's not feasible. The logistics of the sterilized male *Aedes aegypti* mosquitos requires that they be produced near the irradiator and transported and released within 24 hours."

One difference between the screwworm fly eradicated from the United States last century and *Spodoptera frugiperda* is that the former is monogamous—females mate only once and with only one male. The latter can breed multiple times. Unlike *Aedes aegypti*, which is an exotic mosquito from the region of Egypt, the fall armyworm is native to the American continent. In addition to attacking maize, *Spodoptera* also causes problems for other important crops, such as cotton, soy, wheat, rice, and beans. It feeds on approximately 50 plant varieties from more than 20 botanical families, according to EMBRAPA data.

To eradicate the pest, a public policy would be needed that would promote action across the national territory and even in neighboring countries of the American continent. "Brazil is an enormous country with an extremely long border. We have problems uniting government agencies, companies, and farmers to implement pest monitoring and control strategies," ponders Corrêa. "Eradicating the pest in Brazil would be practically impossible. I don't think that is the company's objective." ■

Scientific article

REAVEY, C. E. *et al.* Self-limiting fall armyworm: A new approach in development for sustainable crop protection and resistance management. **BMC Biotechnology**. Jan. 27, 2022.



AEDES FOR ALL

Genetically modified mosquito already on sale in Brazil

Brazil pioneered the release of transgenic *Aedes aegypti* mosquitoes, with testing carried out in towns in the states of Bahia and São Paulo over the last decade. One controversial article was published in the journal *Scientific Reports* in 2019 about a study in Jacobina, Bahia. The article concluded that the modified insects transferred the transgenic genes to the wild population, generating hybrid mosquitoes. After criticism, the journal attached a note of editorial concern to the paper in 2020, supported by six of its 10 authors (*see* Pesquisa FAPESP *issue no. 285*).

Transgenic *Aedes aegypti* mosquitoes could help contain dengue outbreaks

APU GOMES/ AFP VIA GETTY IMAGES

Two years after the controversy, the Brazilian government authorized Oxitec to sell the genetically modified mosquito throughout Brazil based on a favorable opinion from the Brazilian National Biosafety Technical Commission (CTNBio). "We are introducing Aedes do Bem to a large customer base of both companies and individuals, and it is being adopted by many of them," says Matheus Valério, a biologist at pest control company Detecta. "We have to demonstrate this new concept, because most people are used to conventionally applied products." Headquartered in Campinas, São Paulo, Detecta started selling the product as an Oxitec distributor in October 2022.

The company recommends releasing the mosquitoes for at least eight consecutive months, preferably including October to March. The basic kit consists of two boxes, enough for 5,000 square meters (m²). Each box contains approximately 2,300 eggs, but only 1,200 male mosquitoes are born from each—the females do not survive. The boxes have to be refilled with new eggs every 28 days.

The kit also includes four sachets used to control water quality, which is essential to the mosquito's development. Each box sold by Detecta costs R$460, and a refill costs R$196. Valério highlights, however, that the total cost varies widely. "It depends on the size of the area, whether the product needs to be moved around, and who is taking care of the boxes. Each project is unique."

In the USA, the mosquitoes are still being released on an experimental basis and only in Florida. In 2020, the USA's Environmental Protection Agency (EPA) authorized Oxitec to carry out pilot tests of the technology with its second-generation mosquito (of the OX5034 lineage) in parts of Florida and California.

The American agency, however, took an extra precaution, prohibiting the company from releasing mosquitoes less than 500 m from possible sources of the antibiotic tetracycline, such as sewage treatment plants, farms producing apples, pears, and citrus fruits, and cattle or pig farms. Tetracycline is commonly used in both animal and human health care, as well as in agriculture. Because it can sometimes pass through the body without being metabolized in the digestive tract, it can contaminate the surrounding environment, even at low concentrations.

Oxitec's transgenic mosquito is raised in a tetracycline-rich environment. Similar to *Spodoptera*, the lethal gene introduced is tTAV, made from synthetic DNA based on a fusion of sequences from the bacterium *Escherichia coli* and the herpes simplex virus. "In the lab, high concentrations of tetracycline can inhibit expression of the lethal gene. In the field, the male transgenic insect mates with the female, who then lays the eggs. The eggs hatch and become larvae, which are aquatic. The offspring do not encounter high concentrations of the antibiotic in this medium, so the lethal gene is expressed, and the larvae die. This is a general summary of the process," says ESALQ agronomist Alberto Soares Corrêa.

In a 2022 statement, the EPA argued that there is a "remote chance that environmental sources of tetracycline could have enough tetracycline present to act as a counter agent to the OX5034 female mosquito-lethal trait." The aim is to reduce any chance of transgenic females surviving and reproducing. Only female *Aedes* bite humans and transmit disease.

In Brazil, there are no restrictions on where transgenic moths or mosquitoes can be released. Fernando Hercos Valicente, an agronomist, entomologist, and researcher at EMBRAPA Maize and Sorghum who joined CTNBio while the first version of Oxitec's *Aedes aegypti* was under approval, says the subject was discussed at the time. "Someone mentioned dog food, which can contain tetracycline. But there was a big difference between the amount that can be in dog food and how much is needed for the insect to survive. A much larger dose would be needed. It's not a problem," says Valicente. For him, "the positive results of the tests carried out in Brazil demonstrate the benefit of the technology."

José Maria Gusman Ferraz, a biologist who was also working at CTNBio and voted against approving the transgenic mosquito, says the authorities have been extremely careless and much more research on the impacts on the ecosystem as a whole is needed. "The precautionary principle is not being followed. The release will only be reevaluated if a highly serious problem occurs. But by then it might be too late. When we authorize a product, we don't just authorize the transgenic plant or insect. We authorize a technology that could cause environmental changes." ■ **Frances Jones**

Scientific article

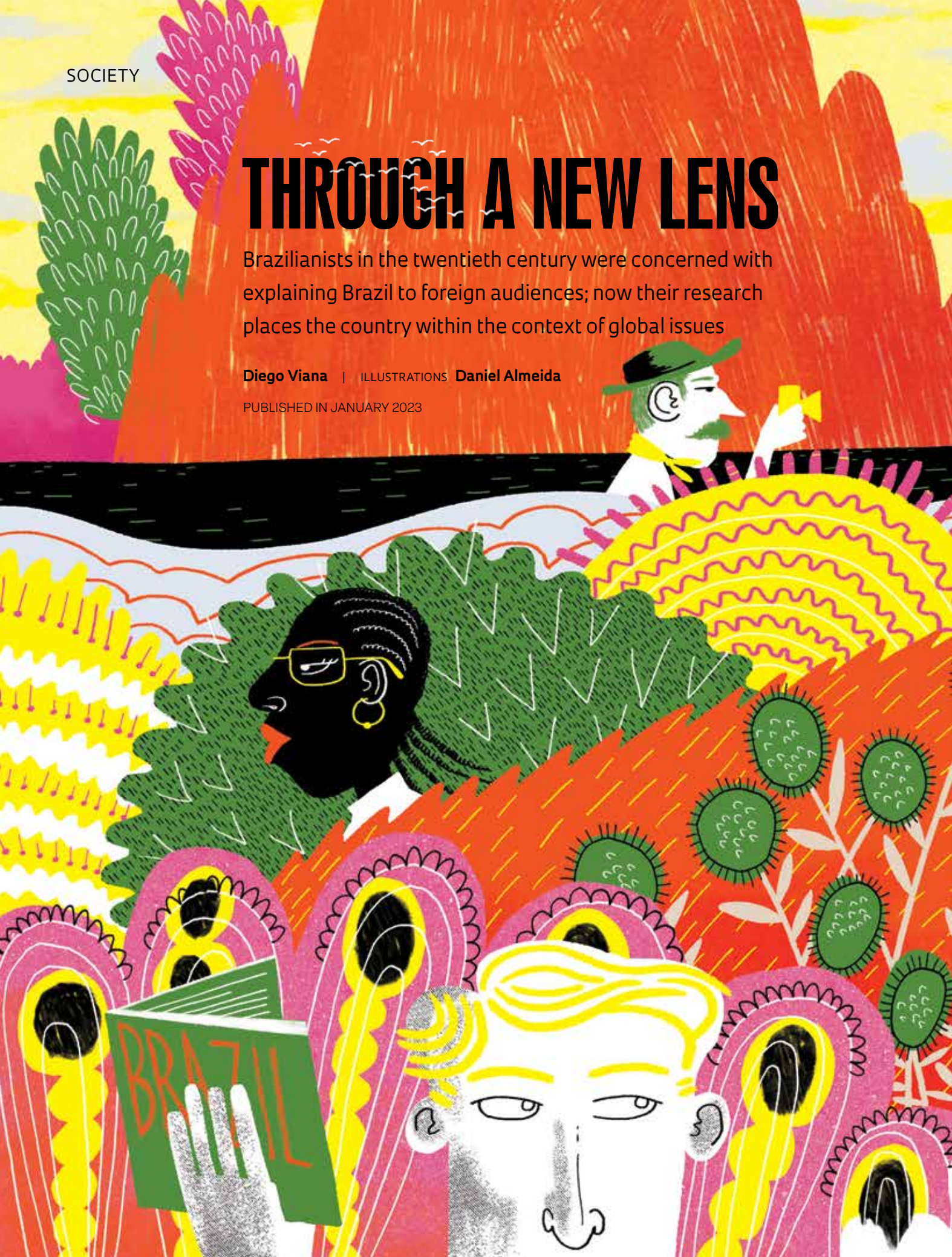
EVANS, B. *et al.* Transgenic Aedes aegypti mosquitoes transfer genes into a natural population. **Scientific Reports**. Sept. 10, 2019.

THROUGH A NEW LENS

Brazilianists in the twentieth century were concerned with explaining Brazil to foreign audiences; now their research places the country within the context of global issues

Diego Viana | ILLUSTRATIONS **Daniel Almeida**

PUBLISHED IN JANUARY 2023



In a 2016 article in *Revista Brasileira de História* (the Brazilian Journal of History), American historian Barbara Weinstein, from New York University (NYU), asks herself: "Am I still a Brazilianist?" In the article, she questions the usefulness of the label "Brazilianist" even though Brazil remains her primary field of research. The term is commonly used to denote a researcher who studies Brazil from outside the country, whether they are foreign or Brazilian by origin. By this definition, the study of Brazil can be considered a branch of the field commonly referred to in the US as "area studies," with Brazilianists sitting alongside other "Latin-Americanists" such as "Mexicanists" and "Cubanists." A Brazilianist is thus a person who conducts research on Brazil with the aim of explaining it to a foreign audience. Brazilian studies, more than other area studies, entail unique aspects that have brought the term "Brazilianist" into more common usage.

"It is still a relevant designation, certainly more so than other Latin American specializations," Weinstein argues. "Although it is very unlikely you can obtain a degree or find a job in the US that is devoted exclusively to the history of Brazil, it makes sense to specialize in the country within the broader framework of Latin American, African diaspora or other studies. It is easy to move between Spanish-speaking countries, for example, but Brazil has a different language, history, and a much vaster scale," she adds.

Weinstein—who has authored books such as *The Amazon rubber boom* (Stanford University Press, 1983); *For social peace in Brazil* (University of North Carolina Press, 1996), which deals with social services created by industrialists in São Paulo, and *The color of modernity* (Duke University Press, 2015), on the role of racial ideas in the making of São Paulo's self-image—notes that Brazilian studies has made a departure from the previous century, when Brazilianists were focused on understanding the country as a whole and its own historical process. "The new generation is more concerned with broader themes and no longer focuses solely on the history of a single nation. This is why we may speak in terms of the history of the Atlantic World, of the African diaspora, of indigenous movements, and so on. These are topics that transcend national contexts."

Today, researchers are unlikely to author a paper on "the history of gender relations in Brazil," for instance. "Why would they? What makes

gender relations specific to Brazil?" Instead, we might investigate the "history of women's suffrage in Brazil." "In this case, the focus would be on the way women's voting rights were won and evolved in the country, which cannot be fully understood by looking at Brazil alone and ignoring the international context," says Weinstein. "Themes like this fall both within and outside the boundaries of a given country."

According to Weinstein, the end of the Cold War (1947–1991) led to declining US interest in Latin America and Brazil as the threat of Soviet expansion dissipated. On the other hand, it expanded the range of research interests across transnational themes such as slave trafficking, gender and race relations, and urban development. As a result, while previous generations of scholars were primarily historians—with some political scientists and economists tucked in—today, they also include geographers, anthropologists, and literary critics.

These shifts in perspective raise questions about the continued usefulness of the term "Brazilianist." American geographer Jeff Garmany, from the University of Melbourne in Australia, does not consider himself a Brazilianist despite doing research on urban issues in Brazil and having coauthored the book *Understanding Contemporary Brazil* (Routledge, 2019) with American political scientist Anthony Pereira, director of the Kimberly Green Latin American and Caribbean Center at Florida International University, in Miami.

"I never refer to myself as a Brazilianist, but others often do. As a geographer, my research interests are mainly in urban and political development, with a particular focus on inequality. My research has always been rooted in Brazil, and my work deals with international debates in political and urban theory within a Brazilian empirical context," he says. "I believe the term Brazilianist is now used more often in reference to others' work than to an actual field of study."

However, the concept remains in current use, including in the Brazilian press, which will often consult foreign specialists on national issues. Behind the usage of the term is a historical process of both rivalry and extensive collaboration. In 1990, historian José Carlos Sebe Bom Meihy, a retired professor in the Department of History at the School of Philosophy, Languages and Literature, and Humanities at the University of São Paulo (FFLCH-USP), published the book *A colônia brasilianista: História oral da vida acadêmica* (The Brazilianist colony: an oral history of academic life; Nova Stella), in which he interviewed foreigners devoted to research on Brazil. In his book, Meihy refers to "anti-Brazilianism" as a "childhood disease of Brazilian historiography" and criticizes the resistance of Brazilian intellectuals to foreigners' research.

ALONGSIDE HISTORIANS, POLITICAL SCIENTISTS, AND ECONOMISTS, TODAY'S BRAZILIANISTS ALSO INCLUDE GEOGRAPHERS, ANTHROPOLOGISTS, AND LITERARY CRITICS

This resistance partly arose after the 1964 coup, when Brazilian scholars became more restricted in their access to public archives than their foreign counterparts. For instance, within just a few years of the coup, American historian Robert M. Levine (1941–2003), at the University of Miami, was given privileged access to documents from the Department of Political and Social Order (DOPS), run by dictator Getúlio Vargas (1882–1954) from 1930 to 1945. This created a rift between Levine and his Brazilian colleagues, who complained of special treatment being given to a foreigner. However, the resulting book would nonetheless become one of the most important references for the Vargas period, although it was censored in Brazil until 1980.

On the other hand, foreign scholars, often in collaboration with Brazilian peers, have played an important role not only in exposing the international community to new interpretations of Brazil but also in creating new research programs within the country. One such scholar was American economist Werner Baer (1931–2016) at the University of Illinois in Urbana-Champaign. From the 1960s to 1980s, he helped create graduate programs in several Brazilian universities, including USP, the University of Brasília (UnB) and the Federal University of Minas Gerais (UFMG), and was also a cofounder of the National Association of Graduate Programs in Economics (ANPEC).

At that time, Brazil did not have an extensive and globally connected university system. Today, collaboration between Brazilian and foreign researchers is both more widespread and more necessary than ever, says Sidney Chalhoub, a Brazilian historian at Harvard University and president of the Brazilian Studies Association (BRASA). "No one can be taken seriously as a Brazilianist in the US, writing for US audiences, without drawing on research produced in Brazil and without thoroughly engaging with Brazilian academic literature," says Chalhoub, adding that part of BRASA's mission is to bridge the divide between foreigners and expatriates, on the one hand, and researchers based at Brazilian universities, on the other.

Founded in 1992 as an offshoot from the Latin American Studies Association (LASA), BRASA is the foremost organization devoted to promoting Brazilian studies abroad. "BRASA does justice to the unique position Brazil holds on the continent," says Chalhoub. "Within LASA, Brazil is diluted. In Latin American history programs, Brazil accounts for only 10% or [fewer] of classes, even though it has 40% of the continent's territory and population. BRASA gives the country the prominence it deserves."

American historian Kenneth Serbin, at the University of San Diego, California, who served as president of BRASA from 2006 to 2008 and has also headed the Brazil Section of LASA, says that "an association of Brazilianists serves to beget more Brazilianists," citing American political scientist Timothy Power of Oxford. "This was my mission as president of BRASA. How did I set out to achieve it? By encouraging others to do what I had done in 1986: visit Brazil," says Serbin. "We secured enough funding to establish a Brazil Initiation Scholarship (BIS), which funds two or three people visiting the country each year for field research." BRASA holds biennial congresses and sponsors awards programs, such as the Roberto Reis BRASA Book Award, for books on Brazil.

In 2017, a European counterpart to BRASA—the Association of Brazilianists in Europe (ABRE)—was founded during the first European Congress of Brazilianists in Leiden, Netherlands. The initiative was led by Dutch Marianne Wiesebron, who holds the Chair of Brazilian Studies at Leiden University, and Mônica Raisa Schpun, a Brazilian historian from the School of Advanced Studies in the Social Sciences (EHESS) in Paris. "European Brazilianists regularly collaborate with counterparts in Brazil, but often have never met. ABRE aims to change this," says Czech Šárka Grauová, the current president of ABRE and a professor of Portuguese literature at the University of Carolina in Prague. The ABRE currently has 237 researchers from 16 countries in Europe as members. The organization holds biennial congresses and awards an annual prize for the best doctoral thesis.

Grauová believes that the main difference between Brazilianism in Europe and the United States is that, with its diversity of cultures, traditions, and languages, Europe produces a wider range of interpretations of Brazil. "At the 3rd

International ABRE Congress in Prague, we had a panel on the reception of Machado de Assis [1839–1908] in different European countries. We learned a lot, not only about the different traditions but also about the wealth of possible interpretations within different contexts," she says. Grauová notes that the history of European Brazilianism has roots more in language and literature studies than in social sciences, in contrast to the American version.

Meihy's book of interviews classifies Brazilianists into different generations, starting with "The Pioneers," who studied the country for a wide range of reasons, including personal interest. One of the earliest references to a Brazilianist in foreign academic publications is American Samuel Putnam (1892–1950), who translated Euclides da Cunha's (1866–1909) *Os sertões* into English. In 1971, American historian C. Harvey Gardiner (1913–2000) wrote an article highlighting the role Putnam played in spreading interest in Brazil among US scholars. American anthropologist Charles Wagley (1913–1991) and historian Richard Morse (1922–2001) also represent this generation of Brazilianists.

The second wave, dubbed "Children of Castro" by Meihy, saw the term "Brazilianist" become widely used in the Brazilian media. This name stems from the US response to the Cuban Revolution of 1959 and Fidel Castro's (1926–2016) rise to power: to prevent the continued spread of communism in the region, the US State Department began funding research on countries in the region, with a particular focus on Brazil. The Ford and Tinker foundations and the Social Sciences Research Council (SSRC) created research grant programs for Latin American studies. Meanwhile, the US Congress passed the National Defense Education Act to fund studies in sensitive areas of the world, including Latin America. In an interview, Brazilian historian José Honório Rodrigues (1913–1987) recalled receiving job offers from American universities, with salaries equivalent to that of a high-ranking general in Brazil.

HISTORIAN MEIHY CLASSIFIES BRAZILIANISTS INTO ONE OF THREE CATEGORIES: THE PIONEERS, CHILDREN OF CASTRO, AND THE SPECIALISTS

Many of the "Children of Castro" were historians, including British Kenneth Maxwell from Harvard University and Americans Warren Dean (1932–1994) and Stuart Schwartz from Yale University. During this period, the work of American historian and anthropologist Ralph Della Cava, from the Institute of Latin American Studies at Columbia University, was especially noteworthy, including his book *Miracle at Joaseiro*—one of the most important works on parish priest Padre Cícero (1844–1934)—published in 1970. In an interview with Meihy, American Thomas Skidmore (1932–2016) admitted that "the reasons which led [him] to study Brazil depended on the US political context and its reflexes on [the] university system."

Weinstein represents the third generation of Brazilianist scholars, who began publishing around the 1980s and are classified by Meihy as "The Specialists." Brazilianists in this period are less connected to the American context and more interested in studying Brazil itself, deepening their engagement with Brazilian scholars. The book *Beyond Carnival: Male homosexuality in twentieth-century Brazil*, by American historian James Green of Brown University, for example, is considered groundbreaking in its portrayal of homosexual culture in Brazil.

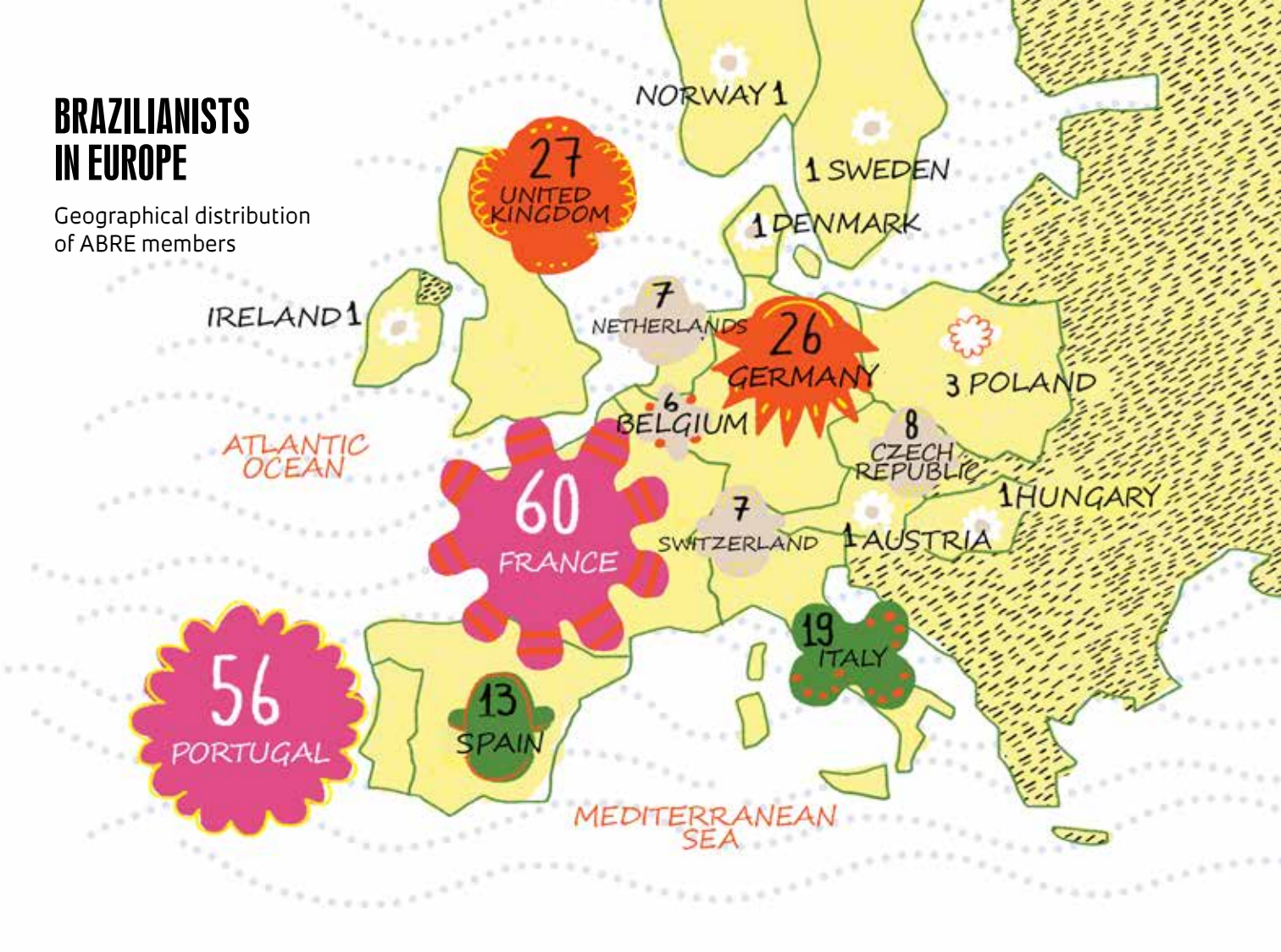
Fellow American historian John French of Duke University recounts how he was about to start his PhD in Mexico in the late 1970s, under the supervision of Brazilian historian Emilia Viotti da Costa (1928–2017) at Yale University, when Costa asked if there was any other topic that might interest him more, especially as it would be a lifetime dedication. "At that time, the ABC Paulista workers' movement was being widely reported in the media during its first strikes in opposition to the military regime (1964–1985)," he recalls. "So I chose to specialize in this topic." His latest book is a biography of Luiz Inácio Lula da Silva, the leader of the strikes, who would later be elected president of the country for three terms.

It was during this period that Serbin first visited Brazil. "The trip was life-changing. I had intended to study Mexico, but instead I fell in love with a Brazilian woman and now consider myself a bicultural person, with Brazil as my second home. Through his friendship with a Luxembourgish novice sent to São Paulo, he was introduced to members of the clergy and went on to author books about the Brazilian Catholic Church.

Among the recurring themes in Brazilian studies is racial relations, including the particularities

BRAZILIANISTS IN EUROPE

Geographical distribution of ABRE members



and present-day impacts of slavery as practiced in the country. French noted, "It is impossible to study Brazil without dealing with the issue of slavery and the theme of race. Brazil is a country marked by entrenched hierarchies—regional, racial, and gender-based—and this needs to be taken into account." Among the notable contributions in this field are the works of American political scientist Gladys Mitchell-Walthour at the University of Wisconsin-Milwaukee, who served as president of BRASA from 2018 to 2020 and is now studying income transfer and affirmative action policies in Brazil, in comparison to similar initiatives in the US.

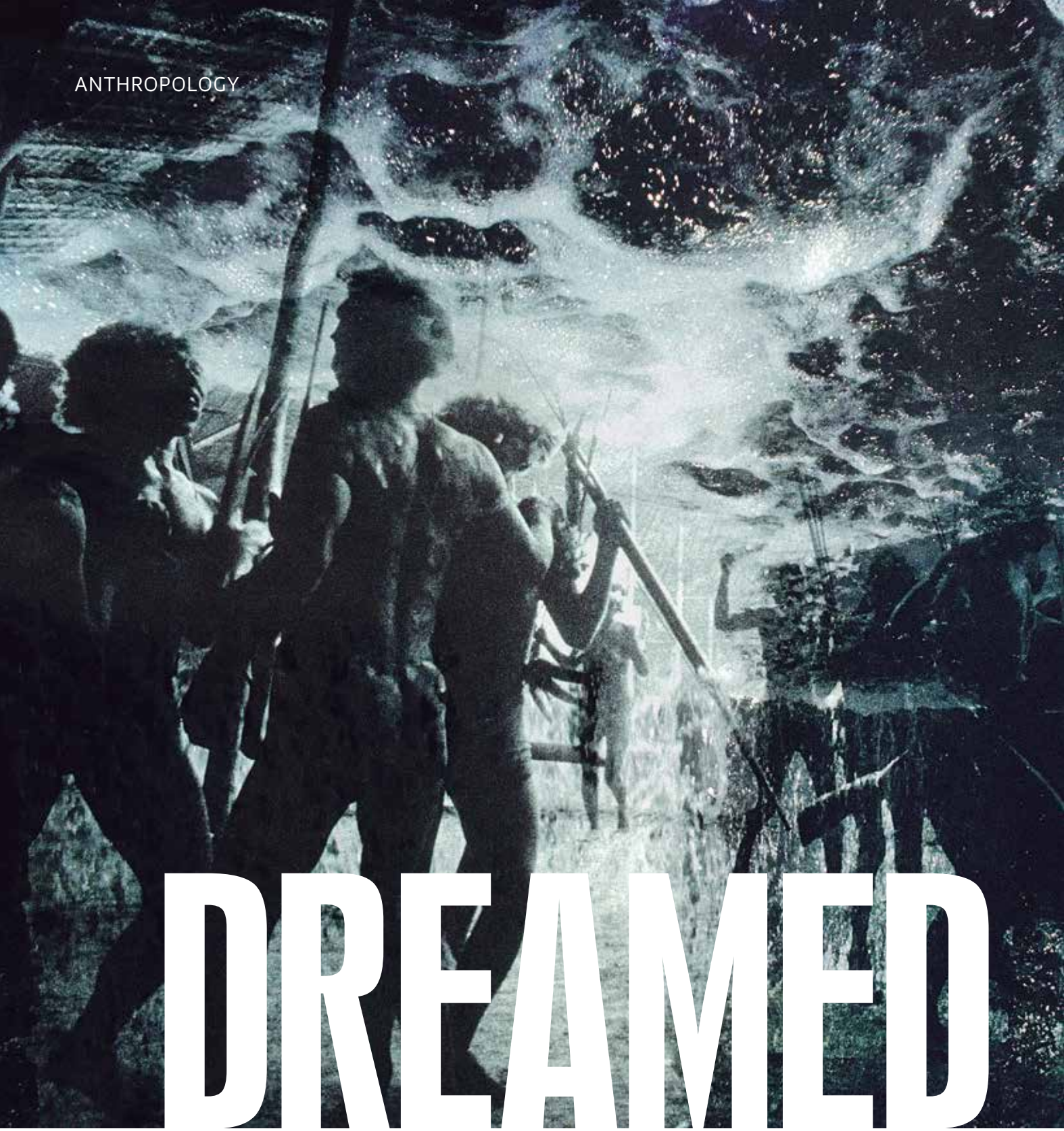
French also has an ongoing research project on affirmative action in collaboration with legal scholar Silvio Almeida at Mackenzie Presbyterian University. His research is focused on the Brazilian Supreme Federal Court's 2012 decision on the country's affirmative action law. "We examined the participants in the hearings, who were predominantly white but also included members of the Black civil rights movement. We're looking to understand their discourse, strategy, and how they successfully won their case for the affirmative-action quotas," he says.

Other Brazilianists are interested in the works of renowned Brazilian writers and thinkers. Grauová, for instance, has published articles on Lima Barreto (1881–1922), as well as authors such as Machado de Assis, Mário de Andrade (1893–1945), and Chico Buarque de Holanda. In the US, Peggy Sharpe, a literary critic at the University of Florida, devotes her research to Brazilian female writers such as Marina Colasanti, Adalzira Bittencourt (1904–1976), Júlia Lopes de Almeida (1862–1934), and Nísia Floresta (1810–1885). In Germany, literary theorist Berthold Zilly has authored a vast body of research on Euclides da Cunha (1866–1909).

Another field that has attracted a large contingent of scholars is the environment, especially in the context of Amazon occupation. "Graduate and postgraduate students have shown increasing interest in issues surrounding the Amazon," says Serbin. Garmany concurs: "Concerns over deforestation reflect the growing recognition that events in one place have ripple effects across the planet." ■

The research projects and books cited in this article are listed in the online version.

ANTHROPOLOGY



DREAMED

Ethnographic studies shed light on how indigenous peoples such as the Yanomami interpret dreams

Christina Queiroz | PUBLISHED IN JANUARY 2023

LIVES

Dreams were rarely studied in anthropology until the mid-1990s, but academic interest in the topic is now growing. New interpretations of how indigenous peoples perceived dreams—a topic about which little was previously known—have emerged in recent years. The Yanomami ethnic group, for example, sees dreams as real experiences that can have collective impacts and change the course of events. This perspective is opposed to the widely accepted psychoanalytical theory of dream expressions, according to which the dream world is generated by the individual subconscious. "The waking life and dreamed life are of the same importance for indigenous peoples in the Americas. Recent studies have looked at dreams as events that have consequences in the real world," says anthropologist Renato Sztutman of the University of São Paulo (USP), one of the organizers of a special volume of essays on the subject, published by *Journal of Anthropology* in December.

According to the researcher, the importance of dreams to indigenous people has been observed as far back as the precolonial era, when the first European travelers to arrive in the Americas noted descriptions of dream beliefs in their travelogues. Despite this documentation, Sztutman points out that for a long time, anthropology treated dreams as a secondary topic. "Studies on indigenous cosmologies generally cover the issue of dreams, but specific ethnographies on dream worlds are still scarce," he stresses.

In recent years, however, this scenario has changed. Dreams are earning increasing attention in ethnographic research, leading to renewed debates on classic themes, such as mythology and shamanism, which have come to be considered inseparable from dream activity. Sztutman believes that new studies on indigenous ways of dreaming allow scientists to expand on the reflections of Austrian neurologist and psychiatrist Sigmund Freud (1856–1939) in his book *The Interpretation of Dreams* (1900). In the book, Freud provides a bibliographic review of the subject in Antiquity and elaborates his interpretation method, analyzing 50 of his own dreams and hundreds of reports from others, reaching the conclusion that dreams are the disguised realization of repressed desires.

However, a common thread running through many articles in the *Journal of Anthropology*, according to Sztutman, is that for indigenous peoples, the dream world is not seen from the perspective of psychoanalytical theory, which is a representation of individual desire and a means of accessing the subconscious. "Indigenous Americans see dreams as ways of entering realities that are inaccessible while awake," says the researcher.

This is part of how the Yanomami conceive dreams, as identified by anthropologist Hanna Limulja in her PhD thesis, defended at the Federal University of Santa Catarina (UFSC) in 2019 and published in the book *O desejo dos outros: Uma etnografia dos sonhos yanomami* (The wishes of others: An ethnography of Yanomami dreams; Ubu Editora, 2022). Limulja has been studying the Yamonami since 2008 in dialogue with shaman and leader Davi Kopenawa. She has transcribed and analyzed more than 100 reports of dreams from children, teenagers, and adults who dreamed of hunts, festivities, myths, dead and absent relatives, distant places, and the unknown. The testimonies were collected in the community of Pya ú in the Toototopi region, located in the Yanomami Indigenous Reserve, close to the border with Venezuela. At the time of the fieldwork, carried out between November 2015 and February 2017, the region consisted of 10 communities with family ties, with a total population of 748 people. Pya ú was the largest in the region, with 154 inhabitants.

Limulja first made contact with the Yanomami in 2008 while working with an intercultural education project run by the nongovernmental organization Comissão Pró-Yanomami, as well as other teacher-training initiatives. At the time, she told Kopenawa about her own dreams, and he offered her explanations for them. In the book *A queda do céu* (The fall from the sky; Companhia das Letras, 2015), an autobiographical testimony and shaman manifesto by the Indigenous leader written together with anthropologist Bruce Albert, Kopenawa states several times that white people "only dream of themselves" and that they sleep in a "spectrum state," like an "ax on the ground." This means that white people are "stuck in their own personal stories, they don't travel far, and don't turn dreams into an instrument of knowledge about the world," the anthropologist writes in the book. Limulja explains that in contrast to this, the Yanomami believe that dreaming is a way of seeing the invisible.

In her work, she reports that dreams are a form of knowledge to the Yanomami. She explains that when a Yanomami person dreams, their body remains lying in the hammock, but the *pei utupë*, their image, is detached and travels to places that the dreamer has been in during the day or to unknown places. The Yanomami believe that in dreams, a person's image can meet up with close, distant, and even dead relatives, and everything they experience in a dream is considered something that has already happened or could happen, which could affect the life of the entire community.

"The Yanomami know that what they experience in their dreams is different from what they experience when they are awake. However, what they experience when dreaming is seen as just as important as the experiences of their waking lives. They are two complementary ways of existing in the world and relating to it," explains the anthropologist. As such, for this ethnic group, dreams are related to other people and not to their own ego, highlights Limulja. "In the same way that there are elements of the world that we cannot see with the naked eye, such as insect skeletons or the microscopic structures of a leaf, the Yanomami believe that dreams allow them to see invisible worlds," she says, noting that shamans also believe they can access other

Above and on the previous pages, images from the series *Yanomami dreams*, by Claudia Andujar, produced shortly after the demarcation of their lands in the 1990s and presented in full for the first time in 2021

universes through the use of psychoactive substances. Limulja points out that whenever the indigenous people were asked about their dreams, they talked about myths, and as a result, she established a connection between the two. "All myths are dreamed by them," she explains.

Manuela Carneiro da Cunha, an anthropologist from the University of Chicago and USP, says that Limulja's work can be interpreted as an addendum to the book *A queda do céu* (The fall from the sky) by Kopenawa and Albert. "Limulja's book reveals the domestic and everyday side of a Yanomami village, showing how and what ordinary people—not just shamans—dream. The world of women and children appears more prominently than usual, and in this sense, her work is a complement to the story of Helena Valero, a girl who was kidnapped by the Yanomami in the 1930s and spent three decades with them, during which time she got married and had children," she says. The anthropologist also praises the exemplary and didactic nature of the author's effort to describe her own itinerary and research experience. "The text begins with a somewhat vague and imprecise theme and takes shape as she abandons direct questions, arriving at effective ways for the Yanomami to talk about the topic and reaching a stage where living together is enjoyed without the central theme being pursued obstinately," she says.

"While Freud maintained that dreams represented repressed desires, Limulja argued that Yanomami dreams are events that manifest the desires of others. In other words, when you dream, a part of you, your 'double,' goes out and meets beings that inhabit other worlds, which until then were invisible. This represents an inversion of psychoanalytic concepts," says Sztutman from USP. He notes that Limulja's research is part of a flourishing field of recent studies on dreams that is not restricted to anthropology. By way of example, he highlights texts by Indigenous leader and philosopher Ailton Krenak, as well as by neuroscientist Sidarta Ribeiro of the Federal University of Rio Grande do Norte (UFRN). He also cites the work of French anthropologist Nastassja Martin, an expert in indigenous peoples from the extreme North, including the Evens of the Kamchatka Peninsula in Siberia, who dream of nature in the form of people and believe that the dream world gives access to a "soul dimension." One aspect the French scientist has been investigating in the dreams of these populations is how they perceive climate change. "As Kopenawa and Limulja point out, you have to stop dreaming solely about yourself in order to travel farther and open yourself up to multiple worlds," concludes the anthropologist. ■

Book

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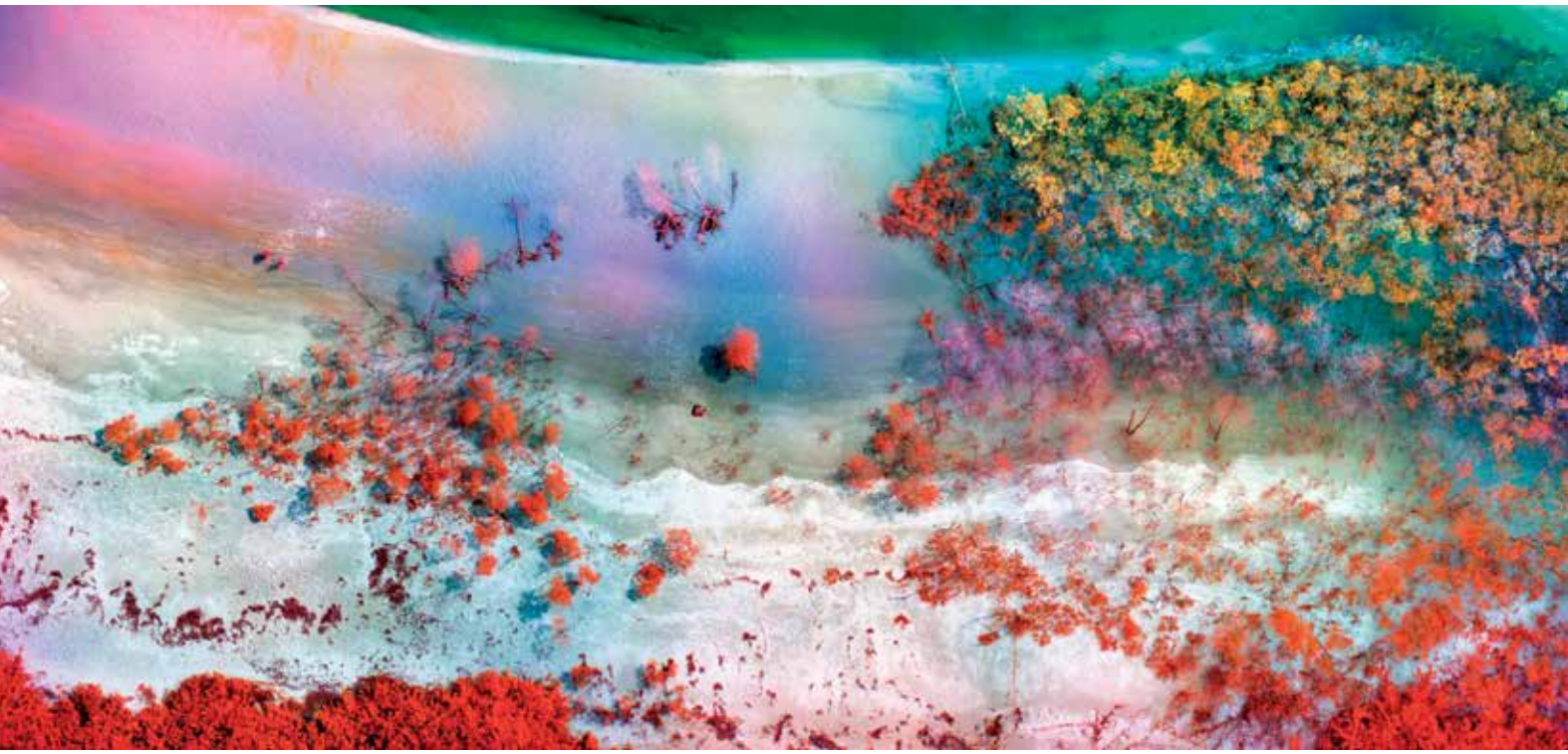
SHIRATORI, K. *et al.* (orgs.). Novas perspectivas sobre os sonhos ameríndios: Uma apresentação. **Revista de Antropologia**. 65(3). Nov. 2022.



PUBLISHED IN MARCH 2023

Seeing trees differently

If we could see light in the infrared range of the light spectrum, trees would appear red. However, not all trees are the same. In this image, captured on the island of Cardoso off the coast of São Paulo, the mangroves appear grayer, while the more vivid colors show the restinga (a type of tropical forest that forms on sandbanks). This is partly a reflection of leaf density. A group led by oceanographer Luis Americo Conti uses high-resolution images captured by a drone, in which each pixel represents approximately 2 centimeters, to analyze vegetation structure at different locations along the Brazilian coastline. The objective is to monitor the characteristics and degradation of ecosystems.

Image submitted by Luis Americo Conti, from the School of Arts, Sciences, and Humanities at the University of São Paulo