

# Pesquisa

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# ALZHEIMER'S

*Depression, anxiety, loss of appetite, and sleep disturbances could be the first clinical signs of the disease*

A high number of c-sections increases the proportion of babies born prematurely

Startups develop new legal tools

Griaule sells its biometric solutions to the Pentagon

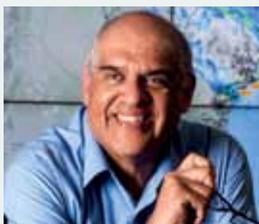
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PROTEIN TANGLE THAT FORMS IN THE BRAIN IN ALZHEIMER'S DISEASE



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SÃO PAULO STATE GOVERNMENT

## LETTER FROM THE EDITOR

# Brains and births

Alexandra Ozorio de Almeida | EDITOR IN CHIEF

The Biobank brain collection is a direct beneficiary of the University of São Paulo's link with the city's postmortem investigation service. The collection, which includes over 3,000 specimens donated by relatives of people subject to an autopsy, is a valuable contribution to research on aging, enabling advances in fields such as Alzheimer's disease.

Psychiatric disorders often associated with Alzheimer's disease could result from neurological damage typical of early stages of the disease, according to the analysis of 455 samples from the database. Previous research has suggested that depression and anxiety, which often accompany aging, could increase the risk of the development of Alzheimer's disease. Given that common symptoms, such as memory loss and dementia, only manifest years after the onset of neurological damage, a link to other psychiatric disorders could be useful for diagnoses. When diagnosed early, patients benefit more from existing treatments and could help test new drugs, as described in the cover story of this issue.

Brazil is notorious for its rate of cesarean sections, which is far above the proportion recommended by the World Health Organization. In 2015, 1.6 million babies were born via cesarean section in the country, representing 55.5% of all births. A study by researchers from universities in the state of Rio Grande do Sul shows that up to 48% of cesarean sections that year were performed before the mother went into labor. Excluding interventions for health reasons, estimates are that 370,000 babies were born by elective surgery before 39 weeks of gestation.

Contradicting common sense, data show that the higher the education level of the mother, the more likely the child is

to be born early. The report shows that among 163,000 women with four years of education or less, 13.2% had early-term cesarean sections, while the proportion among those with higher education was 49.2%. Early-term delivery is worrying because of the greater risk of various health complications in the first few weeks of life as well as cognitive development problems in the future. The risks in early life include respiratory difficulties caused by immature lungs and an inability to suck properly, which can lead to hypoglycemia and the need to administer formulas, exposing the infant to proteins that would otherwise be unnecessary and potentially causing food allergies.

\*

Images of the Brazilian National Museum in flames shocked the world. The 200-year-old institution, housed in a former imperial palace, was home to plants and animals collected during nineteenth-century expeditions throughout Brazil, mummies and minerals gathered by the Portuguese royal family, prehistoric fossils and meteorites, and artifacts of extinct indigenous peoples.

The São Cristóvão Palace was the main exhibition center, but the museum complex spreads across the Quinta da Boa Vista park. Thus, the fire in September 2018 affected different collections in different ways, sparing approximately 10% of the exhibits. The herbarium remained undamaged, while the archaeology, paleontology and geology sections suffered immense losses, as did the zoology department. The October 2018 special issue of *Pesquisa FAPESP* was entirely dedicated to the museum, with an overview of the collections and activities at the institution. In this international issue, we reproduce a brief history of the museum (page 28).

Sample of cerebral areas associated with memory, affected by microscopic lesions typical of Alzheimer's (brown section)



COVER

# BEFORE

# MEMORY LOSS

Psychiatric problems may be the first signs of Alzheimer's disease

Ricardo Zorzetto

PUBLISHED IN NOVEMBER 2018

**D**ifficulty finding the car keys, which were absentmindedly placed in the sock drawer instead of the usual key holder, or the terrifying inability to remember the way home after going for a run through the neighborhood, as experienced by the university professor in the 2014 movie *Still Alice*, may not be the first signs of Alzheimer's disease. The illness, which was identified slightly more than a century ago by German psychiatrist and neuroanatomist Alois Alzheimer and almost simultaneously by Czech psychiatrist and neuroanatomist Oskar Fischer, gradually destroys brain cells and is known for erasing memory and reducing the ability to plan and carry out daily tasks, such as writing a grocery list. These signs, however, are typical of the advanced stages of the disease. Much earlier, it can manifest in a more disguised manner, being confused with more common societal problems, such as depression, anxiety, or abrupt changes in sleep patterns or appetite.

For some time, it has been known that these psychiatric disturbances are more frequent among

people who develop Alzheimer's as they age than among the healthy senior population. Based on population studies, some neurologists and mental health experts argue that depression and anxiety appear first, caused by isolation and other difficulties one faces with aging, and, if left untreated, increase the risk of Alzheimer's. Evidence is beginning to appear that, at least in some cases, the opposite may occur: these psychiatric events result from neurological lesions in the initial stages of Alzheimer's disease.

There are solid indications from the work of Brazilian neuropathologist Lea Tenenholz Grinberg that psychiatric problems precede memory loss and dementia, which arise two to three decades after the first neurological damage of Alzheimer's. Tenenholz Grinberg, a professor at the University of São Paulo (USP) and the University of California in San Francisco (UCSF) in the United States, along with her Brazilian and North American colleagues, observed that after the first lesions appear the risk of psychiatric problems increases. The probability of developing anxiety

and changes (increases or decreases) in appetite and sleep is three times greater for those with the initial lesions than for those without. Furthermore, the risk of depression and of restlessness are four times and six times greater, respectively. “These results indicate that, in some cases, Alzheimer’s already exists in areas that modulate cerebral activity when the first psychiatric events appear,” confirms Tenenholz Grinberg.

**R**esearchers arrived at this conclusion after analyzing the brains of 455 people between the ages of 58 and 82. The brain specimens had been stored in the Biobank for the Study of Aging at USP, one of the largest brain collections in the world. This collection holds 3,000 specimens that have been donated by the families of individuals who had been autopsied by the Capital’s Death Verification Service in São Paulo. In the study, the authors did not analyze only the brain. They also inspected the brainstem, which, together with the cerebellum and the brain, comprise the encephalon, a group of structures housed in the skull. In 2009, Tenenholz Grinberg and the teams of the German neuroanatomist Helmut Heinsen, at the time with the University of Würzburg in Germany, and the teams of neurologist Ricardo Nitrini and geriatric physician Wilson Jacob Filho, both from USP, confirmed that one of the first structures damaged by Alzheimer’s was the brainstem and not the brain (see Pesquisa FAPESP issue no. 153).

More recently, in an article published in October 2018 in the *Journal of Alzheimer’s Disease*, the researchers grouped the cases according to the classification proposed by the German neu-

roanatomists Heiko Braak and Eva Braak (1939–2000). Presented in 1991, the scale organizes cases of Alzheimer’s in six stages, which increase in severity as the number of lesions and affected areas of the encephalon grows. The scale was revised in 2011 by Heiko Braak to incorporate evidence that the first regions to be affected by Alzheimer’s are in the brainstem.

Indications that psychiatric disturbances occur prior to memory loss were proven when the teams from USP and UCSF compared the evolution of brain damage observed under the microscope with the psychiatric problems and clinical signs of Alzheimer’s exhibited by patients months before dying. Even in stages 1 and 2, when there are few lesions, which are concentrated in the structures of the brainstem such as the dorsal raphe nucleus and the *locus coeruleus*, signs of depression, anxiety, restlessness, and changes in appetite and sleep were more frequent.

The brainstem, which is considered one of the more primitive regions of the encephalon, connects the spinal cord to the brain. In the history of evolution, it first appears in amphibians, and in humans, it takes the form of an inverted cone that is 10 cm in length. The brainstem has less than 1% of the 86 billion neurons of the encephalon—neurons are the cells that transmit, process, and store information. However, it houses various small structures that perform functions that are fundamental to life. They participate in controlling respiration, hunger, heart beats, blood pressure, and body temperature, as well as regulating sleep-wake cycles. They also connect with regions of the brain that regulate humor, anxiety, and the formation and retrieval of memories.



Specimens of brain tissue stored at the Biobank for the Study of Aging at USP

## GRADUAL PROGRESSION

The risk of exhibiting psychiatric problems increases with the accumulation of brain lesions

Severity  
of lesions  
— ■ ■ ■ +



In the initial stage, classified as 0 in the Braak Staging, the first lesions appear (pink areas) in the brainstem. There are no symptoms

The lesions intensify in a nucleus (arrow) in the brainstem and begin to appear in the cortex (circle) in stages 1 and 2. The risk of depression, anxiety, and restlessness increases

The lesions in the brainstem worsen in stages 3 and 4. They also advance to the cortex. The risk of depression, anxiety, and restlessness remains high. Memory loss occurs

In stages 5 and 6, cells die (dark areas) in the brainstem and lesions cover the cortex. Memory, coordination, and perception of surroundings are compromised. Delusions and hallucinations occur

SOURCE LEA T. GRINBERG LAB / UCSF

Some of these structures have special neurons that produce more than one neurotransmitter, the compound that is responsible for communication among brain cells. “Through their neurotransmitters, these structures increase or decrease activity in many areas of the brain,” explains Nitrini, coauthor of the current study and an expert in dementia.

**T**he new findings may represent two breakthroughs in the study and treatment of Alzheimer’s. The first is that the early identification of psychiatric signs can help in the testing of new medications, allowing, during initial stages of the disease, the assessment of the performance of compounds being developed to stop or slow the progression of Alzheimer’s—today, the majority of clinical trials are carried out with individuals in advanced stages, without encouraging results. Furthermore, for some researchers, the psychiatric manifestations of Alzheimer’s may make it possible to begin using available medications at an earlier stage. In an article published in 2015 in the magazine *Neurobiology of Stress*, the team of biologist Elisabeth Van Bockstaele, from Drexel University in the United States, suggests that the use of antidepressants could protect the structures of the brainstem from lesions or restore the function of these structures.

“One of the important aspects of the study coordinated by Tenenholz Grinberg is that it shows that depression in seniors may not be initially caused by social or environmental factors, but

rather, be the result of the degeneration of regions of the brain,” confirms psychiatrist Paula Villela Nunes, professor at the Jundiaí School of Medicine. This does not mean that it would be easier to treat these individuals. Villela Nunes, who is specialized in geriatric psychiatry and works as a researcher for the Psychiatric Institute (IPq) at USP, investigates the actions of compounds that are produced by the nervous system and protect the brain. However, she suspects that depression caused by Alzheimer’s will be less responsive to antidepressants due to the degenerative lesions in the brain. “Treating these cases of depression may be as challenging as treating dementia,” says Tenenholz Grinberg.

One of the brainstem structures first affected by Alzheimer’s is the *locus coeruleus*. This area contains noradrenergic neurons that produce noradrenaline, a neurotransmitter that controls interest, attention, stress, and other reactions to one’s surroundings. Changes in its functioning can cause sleep disturbances, anxiety, and depression, in addition to changes in memory and inflammation associated with the neurological lesions caused by Alzheimer’s. Another structure affected in the initial stages of the disease, which was identified by Tenenholz Grinberg and her team in 2009, is the dorsal raphe nucleus, an important center for serotonin production. Changes in the levels of this neurotransmitter are associated with depression and anxiety.

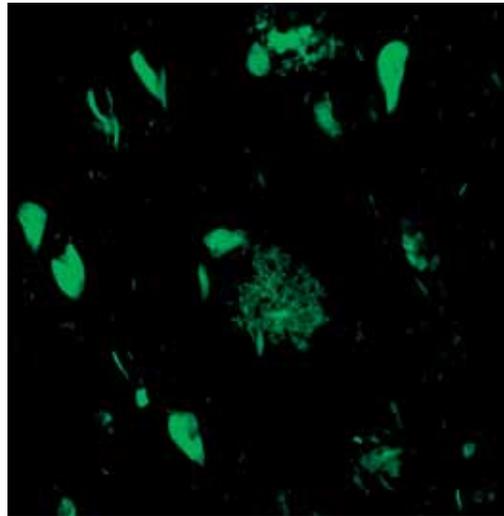
In the early stages of the disease, these structures exhibit only one of the two types of lesions

described by Alois Alzheimer in 1906—he only published these findings in 1907, the year in which Oskar Fischer publicized his data. During a psychiatric conference in Tübingen, Germany, Alzheimer reported the case of Auguste Deter, a woman who was hospitalized in 1901 with an outburst of paranoia and who gradually exhibited sleep difficulties, memory loss, aggression, and confusion. She died five years later at 50 years of age, with the most external layer of the brain (cortex) covered by two types of lesions that became known as beta-amyloid protein plaques and neurofibrillary tangles of the tau protein—only the latter appeared in the locus coeruleus of the brains assessed by the USP and UCSF groups.

**R**ecent analyses of postmortem brains and experiments with rats genetically altered to develop Alzheimer’s lesions suggest that the tangles of the tau protein are the first signs of damage to appear in the brainstem. Under normal conditions inside the cells, this protein plays the role of a wire that holds together a bundle of sticks: it encompasses and stabilizes groups of microtubules that define the cell’s structure. However, with Alzheimer’s, the protein is chemically changed, distorting it and freeing the sticks. Now untangled, they group together in an unorganized way, disrupting the function of the cell and sometimes killing it.

“The tangles are the first lesions that pathologists are able to observe, but I suspect they are not the triggers of the problem,” confirms biochemist Sergio Teixeira Ferreira, professor at the Federal University of Rio de Janeiro (UFRJ) and a specialist in the causes of Alzheimer’s. Like other experts, Ferreira perceives the origin of the problem in the abnormal degradation of the beta-amyloid precursor protein, which is essential to the survival of neurons, in the external surface of the cells. Various environmental factors—such as smoking, prolonged stress, or lack of sleep—seem to favor the detrimental dismantling of this protein, creating fragments called beta-amyloid peptides. These peptides tend to adhere to each other to form long fibers that, in turn, become the beta-amyloid plaques observed by Alzheimer in Auguste Deter’s brain.

In the mid-1990s, it was proposed that these plaques that accumulate outside the cells caused the death of a massive amount of neurons. However, it did not take long for doubts to arise. There were people whose brains were covered by plaques but they did not have dementia, while the opposite also occurred. In the last 20 years, increasing evidence has suggested that the most toxic effect is caused by smaller clusters: beta-amyloid oligomers, which produce both direct and indirect damage.



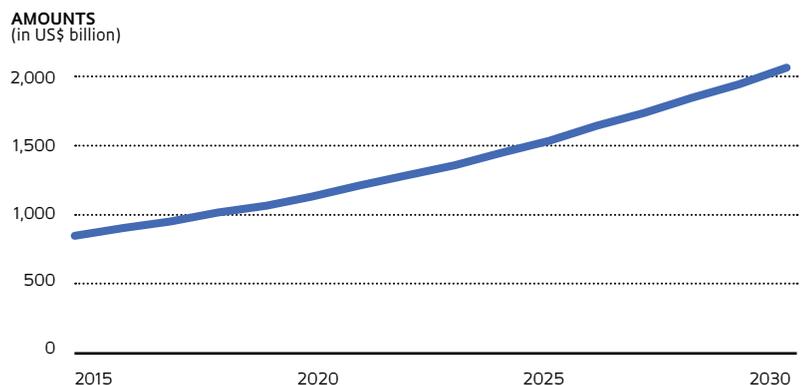
The structure that forms a web (center of the image) is a cluster of beta-amyloid plaques; the structures that form a candle flame are neurofibrillary tangles

First, the beta-amyloid oligomers seem to block synapses (connections between neurons), leading the cells to atrophy or die. The oligomers also penetrate the neurons and alter the tau protein, facilitating the formation of the neurofibrillary tangles, which are also lethal for the cells. At UFRJ, Ferreira and neuroscientist Fernanda De Felice are helping to discover the toxicity of the oligomers, which can be partly indirect. In experiments with cells and animals, they have shown that oligomers cause an inflammatory reaction: they stimulate microglia, which are key defense cells for the central nervous system, to produce cytokines such as tumor necrosis factor alpha. These inflammatory mediators, in turn, make the neurons more sensitive to the destruction caused by the oligomers.

Since Alzheimer’s characterization 112 years ago, tens of thousands of studies have been pub-

## COST OF THE DISEASE

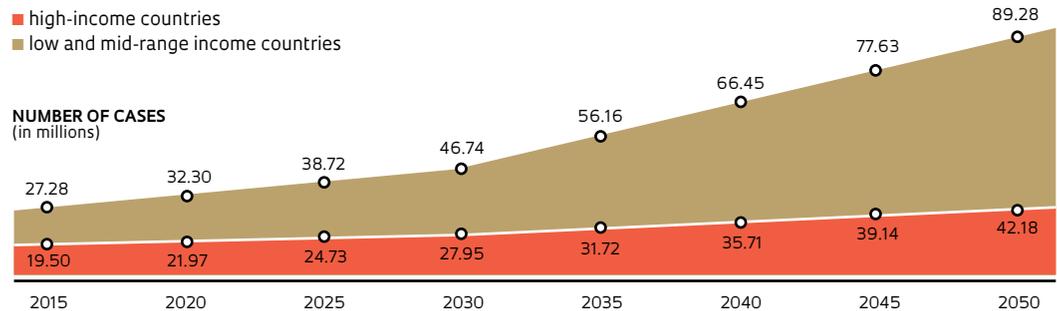
In 2015, a total of US\$818 billion was spent on the treatment of dementia; in 2030, this figure will likely reach US\$2 trillion



SOURCES WORLD ALZHEIMER REPORT 2015 / ALZHEIMER'S DISEASE INTERNATIONAL

## AT AN ACCELERATED PACE

Cases of dementia are likely to increase faster in countries with low and mid-range incomes due to the increase in life expectancy and greater risk of cerebrovascular disease



SOURCES WORLD ALZHEIMER REPORT 2015 / ALZHEIMER'S DISEASE INTERNATIONAL

lished, and dozens of compounds have been tested in an attempt to stop or slow the disease. Today, specialists predict that the solution lies in seeking ways of identifying lesions in the beginning or before they appear—brain imaging is being developed to detect the presence of oligomers in the brain—and using compounds that avoid damage before the appearance of clinical signs of the disease.

In January of this year, there were 112 compounds in one of the three phases of clinical testing on human beings who will take these medications prior to market availability. Of these compounds, 63% seek to change the course of the disease, according to assessments carried out by neurologist Jeffrey Cummings of the Cleveland Clinic in the United States, and published in the journal *Alzheimer's & Dementia*. In general, they are antibodies, biological molecules that adhere to the beta-amyloid peptides, to the tau protein, or to both, and neutralize them. When used in the advanced stages, they are not very effective, but there are an increasing number of attempts to test them in people without symptoms of Alzheimer's disease or those who have a higher risk of developing the disease. One of these studies is being carried out in Colombia by neurologist Francisco Lopera, professor at the University of Antioquia. He and his colleagues are using the monoclonal antibody crenezumab to treat 100 individuals from families who carry a genetic modification that accelerates the production of beta-amyloid and leads to dementia prior to 50 years of age. These participants will take the medication for five years, after which their results will be compared with those of individuals who took a placebo—the first data should be available in 2022. "For people without symptoms, upon beginning treatment, we expect greater success in

the neutralization of the amyloid," reports Lopera to *Pesquisa FAPESP*. "It may also be necessary to use antibodies that block the tau protein."

There is an urgent need to find effective treatments for Alzheimer's. The compounds used to slow memory loss act on the neurotransmitter acetylcholine and increase attention. However, they only work for a few years at most. Furthermore, the disease is becoming more common as people live longer. The World Health Organization calculates that there are almost 50 million people with dementia around the world, with 60% to 80% of cases resulting from Alzheimer's. This number should triple by 2050 (see graph above). Taking care of people with dementia costs US\$818 billion per year worldwide, according to the *World Alzheimer Report 2015*, published by the nongovernmental organization Alzheimer's Disease International. In Brazil, the treatment of each individual costs an average of US\$16,500 per year, as shown in data published this year by researchers from USP, the University of Taubaté, and the Santa Marcelina Hospital in *PLOS ONE*. Approximate calculations suggest that there are 1.2 million individuals with dementia throughout the country and that 100,000 new cases arise each year. ■

### Project

Nosological diagnosis of dementia in the Brazilian population (nº 06/55318-1); **Grant Mechanism** Regular Research Grant; **Principal Investigator** Ricardo Nitrini (USP); **Investment** R\$123,173.15.

### Scientific article

EHRENBERG, A. J. *et al.* Neuropathologic correlates of psychiatric symptoms in Alzheimer's disease. *Journal of Alzheimer's Disease*, v. 66, i. 1, p. 115–26. Oct. 16, 2018.

Other articles and projects consulted for this report are cited in the online edition.

# A time of uncertainty

Climatologist says that society can perceive climate change but has difficulty adopting adaptive measures

**Marcos Pivetta** | PORTRAIT Léo Ramos Chaves

PUBLISHED IN NOVEMBER 2018

**B**orn in Lima, climatologist José Antonio Marengo received a degree in physics and meteorology in Peru and spent eight years in the United States, where he completed a PhD and two postdoctoral fellowships, before putting down roots in the Paraíba Valley in the state of São Paulo more than two decades ago. He worked for 15 years at the Center for Weather Forecasting and Climate Studies (CPTEC) of the National Institute for Space Research (INPE) in the city of Cachoeira Paulista, where he became the scientific coordinator for climate forecasting. In 2011, he became general coordinator of the Center for Earth System Science (CCST), which is also linked to INPE. As a specialist in climate modeling and climate change, Marengo has contributed to the Intergovernmental Panel on Climate Change (IPCC) since the mid-1990s, when the second of its five famous reports was released. His great familiarity with these subjects led him to be chosen to head the research and development sector of the National Center for Natural Disaster Monitoring and Alerts (CEMADEN) in 2014, an agency of the Brazilian Ministry of Science, Technology, Innovation, and Communications (MCTIC) based in São José dos Campos. Among other activities, CEMADEN monitors risk areas around the clock in 957 Brazilian municipalities classified as vulnerable to natural disasters. In parallel to the center's activities, Marengo teaches meteorology and earth system science in INPE's postgraduate programs, participates in national and international research groups, and produces scientific papers and reports.

In this interview, the climatologist, whose humorous conversation is punctuated by his Spanish vocabulary and accent, details his view

**AGE** 60 years old

**SPECIALTY**

Climate modeling and climate change

**INSTITUTION**

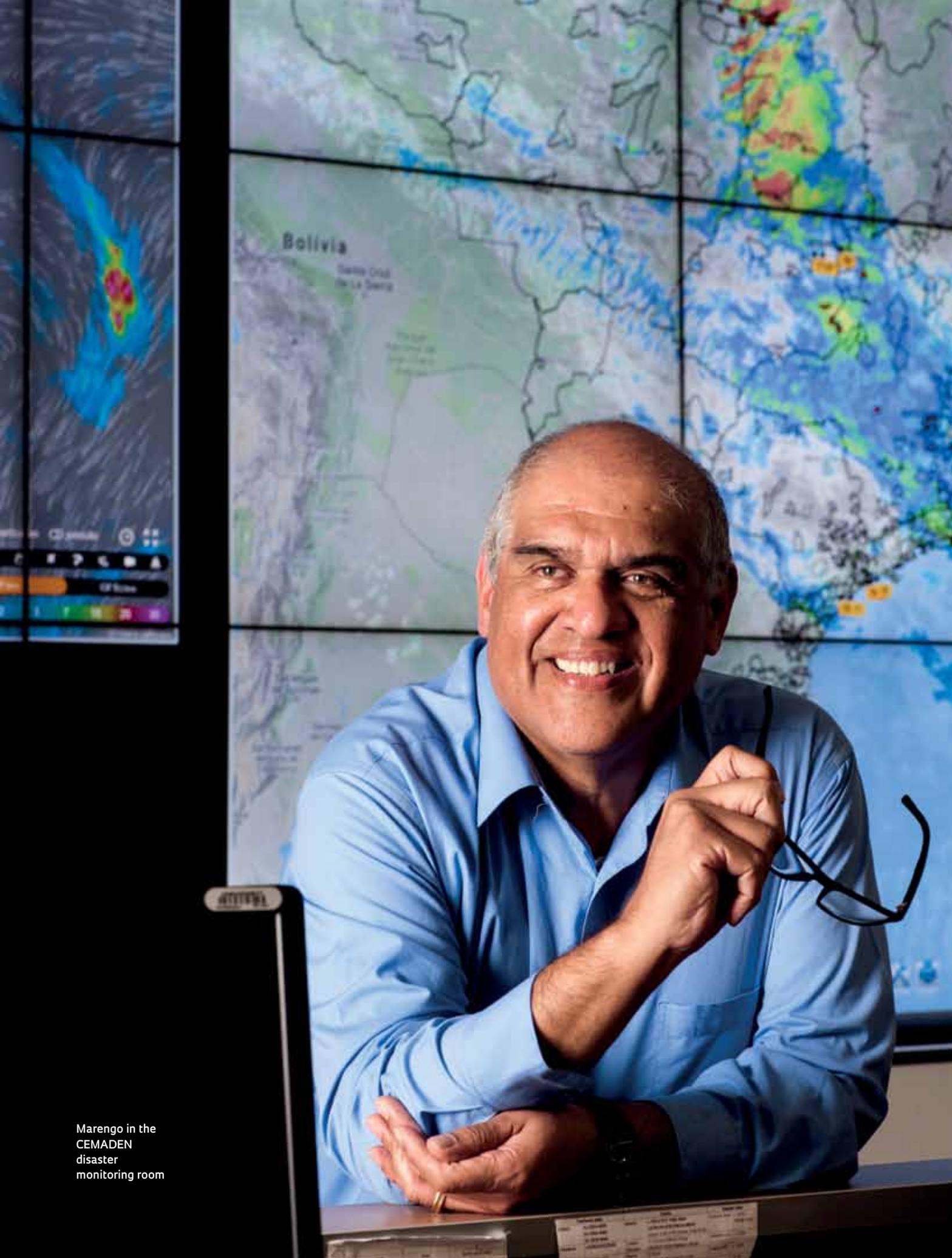
National Center for Natural Disaster Monitoring and Alerts (CEMADEN)

**EDUCATION**

Undergraduate degree in physics and meteorology at the National Agrarian University, Lima, Peru (1981), and a PhD in meteorology at the University of Wisconsin-Madison, USA (1991)

**SCIENTIFIC PRODUCTION**

188 scientific articles



Marengo in the  
CEMADEN  
disaster  
monitoring room

of how populations and governments perceive climate change and its possible consequences.

***Why did you come to work in Brazil?***

I was educated at the National Agrarian University of Lima, which has a five-year bachelor's degree program in meteorology and physics. I chose this area because my father was a meteorological technician and worked for the Ministry of Agriculture. In Peru, after five years in the bachelor's degree program, you have to write a thesis to become a meteorological engineer. I did my thesis on the Amazon. That was how my interest in the region began. The choice of thesis topic happens during your last year of school. At that time, in the early 1980s, I came across a work by Eneas Salati, a professor at the Center for Nuclear Energy in Agriculture at the University of São Paulo in Piracaba, on recycling in the Amazon, which had been published in the late 1970s. This caught my attention because Peru is also an Amazonian country. I did a master's degree in water resources at the same university, where I was a teacher for almost seven years.

***Then, you went to the United States to do a doctorate.***

I received a scholarship from the National Science Foundation in the United States and went to the University of Wisconsin-Madison. I spent four years there and wrote my thesis on the Amazon and climate modeling. Then, I did a two-year postdoctoral fellowship at Columbia University and NASA's Goddard Institute in New York, where I worked even more with climate modeling. Then, I did another two-year postdoctoral fellowship at Florida State University on tropical weather. My focus during this period was the climate of the Sahel, the semiarid belt across Africa between the Sahara desert to the north and the savannah to the south. After eight years in the United States, I wanted to return to South America. But at that time in the mid-1990s, Peru was in the midst of the terrorism crisis. Argentina wasn't a good option for me because I wouldn't be developing my area of research in climate modeling. Carlos Nobre [an INPE climatologist] invited me to come to Brazil as a fellow of the CNPq [National Council for



Heavy rainfall is not a natural disaster, but the impacts it causes on a vulnerable population are

Scientific and Technological Development]. I was single; I came, and I ended up staying. I got married, and I have a Brazilian son. I'll never leave here.

***Did you have a specific connection to Brazil?***

I didn't, but Carlos did. I studied in Wisconsin from 1987 to 1991. In 1988, my advisor invited Carlos to give a lecture there. I knew his articles, and he knew mine. He asked me where I was going when I finished my doctorate and encouraged me to come to Brazil, but I didn't know exactly what I was going to do. I was thinking of staying in the United States, but I knew that it would be difficult to arrange a stable position at a university there. Later, when I'd finished my postdoc, I talked to Carlos again and asked him if he remembered our conversation. He invited me to come to Brazil. I came to work at CPTEC, where I spent many years.

***What were you doing at CPTEC?***

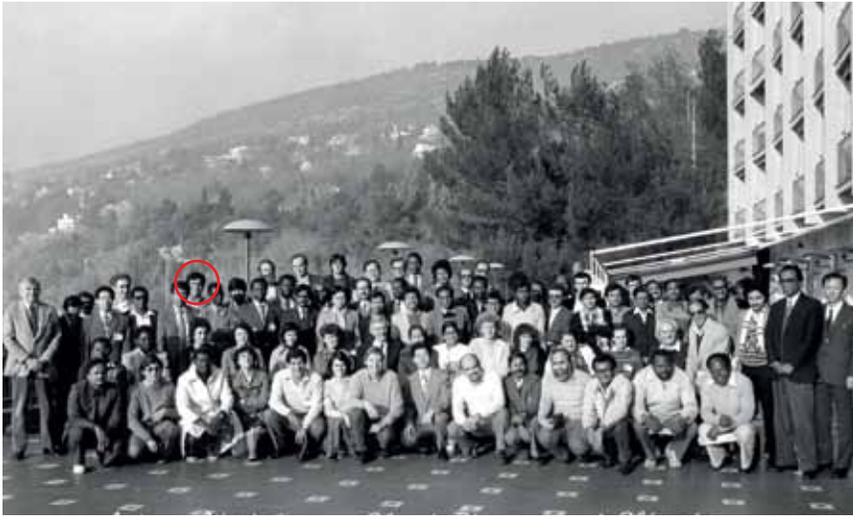
We began developing the climate studies area to do more research on El Niño [the warming of the Pacific Ocean waters that causes changes in weather] and to work on models for seasonal climate forecasting. Over time, the federal government got energized about these issues and realized more discussion is needed re-

garding the impacts of global changes. In addition, the IPCC received the Nobel Peace Prize in 2007, and this generated a lot of interest in the subject of climate change and its impacts on Brazil. I was part of the team of authors from Brazil who prepared the 2007 IPCC report. Then, INPE created the Center for Earth System Science in 2008. I headed the center from 2011 to 2014, and we began working, among other subjects, on the issue of population vulnerability to extreme events and the possibilities of adapting to these changes. I really like this subject. At that time, several studies on natural disasters began to emerge. Then, following the tragedy in the mountains of Rio de Janeiro in January 2011 [rains followed by landslides that killed more than 900 people], the federal government quickly created CEMADEN. We had supercomputers in this country, and something had to be done to try to avoid such disasters. Since I had worked a lot with extreme weather events, I could help in monitoring and managing the risks of natural disasters.

***Is it correct to say that natural disasters are always associated with extreme weather events?***

An extreme meteorological event, like an intense rain, is not a disaster. In this case, the disaster is the impacts caused by rain on a population that's vulnerable to this extreme phenomenon. There is no population in the middle of the Amazon. A strong rain can fall there and it won't produce a disaster of any sort because there aren't any people living there, or there are very few. In Brazil, high-impact disasters such as floods, torrents, landslides, and droughts occur in the Southeast, South, and Northeast regions, where there are the largest concentrations of people. We need to develop further studies on the disaster risks of possible future climate scenarios. Will vulnerability to this type of event be the same in a few decades, or is the situation going to worsen or improve? We have to work on adaptation scenarios for climate change and risk reduction. This is our agenda at MCTIC and the Ministry of the Environment.

***Is Brazilian society convinced that climate change is happening and of its risks?***



The climatologist (circled) at a theoretical physics course in Trieste, Italy, in 1985

Nature is sending signals here and around the world. The climatic extremes are getting worse. It's enough to recall the great drought in the Northeast that began six or seven years ago and the droughts and floods in the Amazon. People realize that the climate is changing; they even make jokes about it. We always try to explain that climate change is a natural process but that it's being accelerated by human activity. It's not man who changes the climate. But with increasing greenhouse gases and deforestation, man's role in this process is growing increasingly larger. That's what people still don't understand. Perhaps they don't understand the theoretical basis behind the changes, the attribution of causes of these changes that we scientists have adopted. The main message, that the climate is changing, is understood now. It's not necessary to wait until 2050 for this to be clear. Winters and summers are more intense. Elderly people may die as a result of heat waves. This is already happening in Europe, where the population is more adapted to colder weather.

**What are Brazil's biggest vulnerabilities?** These factors have begun to be evaluated only recently. For some time, Brazil fought for the cause of mitigating the changes and for the reduction of greenhouse gas emissions, believing that these measures would generate carbon credit mechanisms that would bring more money in for research. That didn't happen. Vulnerabilities in Brazil differ in each region. The Northeast has recur-

rent droughts, but the population hasn't yet adapted to these conditions. Israel has the same climate as the Northeast but is adapted to go through periods without rain and has advanced irrigation technology that allows it to adapt to drought conditions. Vulnerability has a physical basis, but there's also a social basis: people may—or may not—be adapted and live in exposed areas that are highly vulnerable to landslides or to urban or rural flooding. That is, they may or may not be vulnerable to natural disasters. For example, in the metropolitan area of São Paulo—an economic powerhouse with its 20 million inhabitants—there was a lack of water between 2014 and 2016, and rationing was started. In this case, the climate models indicated that this drought in São Paulo was a natural phenomenon but one that could be repeated in the future.

***Isn't it possible to attribute the São Paulo water crisis, at least partially, to human activity?***

Causal attribution studies for extreme weather events are beginning to appear now. They are very complicated in terms of statistics and modeling. In the Southeast, we had 47 days without rain between January and February 2014. Usually, this sequence of dry days lasts between 11 and 15 days. This is a meteorological phenomenon we call atmospheric blocking. A hot air bubble forms, and the moisture that usually comes from the Amazon cannot enter the region. It circulates back to Acre or

Rondônia. In January 2014, there were record rains there and a record drought in São Paulo. Moreover, on that occasion, the cold fronts which bring rain from the South also failed to reach the Southeast and stayed down there. There are studies that are attempting to determine if this meteorological phenomenon was a consequence of human activity or not. So far, there is nothing conclusive. But it can be stated that the water crisis in the metropolitan area of São Paulo, particularly in 2014, was due to the drought and aggravated by increases in population and water consumption during an excessively hot summer.

***Can climate modeling separate what's natural and what's human-influenced?***

With a model, anything is possible. Some include only the natural variability of the climate, while others also include anthropogenic variability or a combination of the two. If we run a model with only natural variability and realize that it doesn't explain what is being observed in nature, we start with the other approach. We use a model in which we include the effects that we attribute to the increase of greenhouse gases and compare it to see if the result is similar to what is actually observed. If this model is able to explain the conditions, we begin to adopt the view that human activity has some effect on the climatic event being analyzed. Of course, we do a statistical treatment to see if this human influence is significant. In the specific case of the drought in the Southeast, I haven't yet seen a paper stating whether it was natural or anthropogenic. Nothing shows that the 47 days without rain generated by atmospheric blocking had an anthropic cause. Perhaps the water crisis itself had anthropogenic causes but not the lack of rainfall.

***In what sense?***

The average temperature during the summer of 2014 was almost two degrees higher than normal. The reservoirs emptied quickly—and the population of São Paulo never stops growing. Under these conditions, even if it had rained a little, it wouldn't have been sufficient to end the water crisis. Some research centers in the United States and the United Kingdom say that the intense heat waves and extreme summers in Europe, which have

been recurring over recent years, have a clear human cause linked to global warming. It is very difficult to attribute a particular event to a long-term trend. Throughout the world, climate attribution studies are appearing, which is a new line of research. They're important because they could convince decision makers that what is occurring has a significant contribution from human activities. As I said, the process is natural, but human activities aggravate it.

***What is the degree of reliability of climate models? To what extent is it possible to extrapolate the future climate?***

We use models developed by climate centers around the world, including Brazil, which contribute to the IPCC reports. A model is a mathematical representation of reality. The entire process is represented by systems of equations that are solved with the help of a supercomputer. But the different modeling centers—from Europe, Asia, Latin America, Australia, South Africa, and the United States—each have their own model developed by their researchers. All of these models are used to project the future climate up to 2050 and 2100. Regarding some areas and for some climate variables, the models converge. All the models indicate a reduction in rainfall in the eastern Amazon and the Northeast and increased rainfall for southern Brazil, northern Argentina, and the northern coast of Peru and Ecuador. The trend in the models is the same; only the values obtained differ a bit. In areas such as the Central-West and Southeast, some models show more rains and others less. In these cases, uncertainties arise. If I'm asked if it's going to rain more or less in Brasília in the coming decades, I have to answer that it depends on the model that's adopted. Some show an increase in rainfall, others a decrease. On the issue of temperature, all the models indicate global and regional warming. All of them. There is consensus. We have a greater degree of certainty about temperature than about rainfall. That's why global warming is spoken of so much.

***You mentioned the eastern Amazon. What do the models indicate about the future climate in the western Amazonian region?***

In the models used in the fifth IPCC report, extreme rainfall was projected



Deforestation in the Amazon is harmful to the fight against climate change

to increase in western Amazonia. The representation of the forest is better in current models than in the past models. This leads us to think that perhaps the models are improving, that they may be closer to reality. It's necessary to be careful when projecting the future climate because there are uncertainties that we can't eliminate. We must remember that there is no model in the world that can represent reality 100%. There is no perfect model.

***Is it a mistake to see the Amazon as a unique region from the point of view of the climate?***

We can talk about three different situations. We have the region's eastern part, which is near the mouth of the Amazon river; the west, near Colombia and Peru, which is rainier; and the southern Amazon, where Mato Grosso and the so-called arch of deforestation is. There is less consensus among climate models regarding the southern Amazon. There are studies saying that deforestation in this region will produce less rainfall and others saying it will produce more. Why would there be more rain? When an area is deforested, there are sectors without forest alongside others where the forest is preserved. The contrast creates a kind of breeze that could produce rain along those borders. This is a regional detail that the large-scale models don't capture. That is why we also use regional models, which give more detail.

***What is the resolution of INPE's regional model?***

The regional model can predict the climate for an area equivalent to a square of 40 by 40 kilometers for all of South America and Central America. But for some areas of Brazil, such as the Southeast, the resolution can get down to a square of 5 by 5 kilometers. We did a study with this level of detail in Santos, on the coast of São Paulo. We found that the port may not be affected by climate change in the future, but the city will be hit by more high-surf events, which are the result of more winds being generated by storms near the coast. Our studies have indicated an intensification of storms at that location. We aren't saying that the sea level will swallow the city, as is shown in environmental disaster movies. A small increase in sea level causes waves to enter further into the city. We're already seeing news images of water from storm surges reaching the city sidewalks and flooding the underground parking lots of the buildings in Santos. It's a situation that has serious impacts, even more so if it becomes the norm in the future. For this reason, the authorities in Santos are paying attention to the studies.

***Are the studies on Santos the most detailed regarding the possible impacts on a place in Brazil?***

I would say so, yes. We have been able to do projections for the city both with and without the adoption of measures for adapting to changes in the climate. We define these measures together with the local population. Managing ecosystems, such as revitalizing the city's mangrove

swamp, is much cheaper than investing in infrastructure, such as building a concrete dike along the beach. The mangrove acts like a filter or a sponge and reduces the risk of flooding due to rising sea levels. In Ponta da Praia, one of the city's districts, the mitigation option discussed was to build a dike, but the residents didn't like having a wall on the beach. They said it would be ugly. However, studies indicate that either a dike is built there or they live with the floods.

***Is it still possible to prevent the planet's average temperature from rising at least 2 degrees by the end of the century?***

If, right now, all the world's countries were to zero their carbon dioxide—CO<sub>2</sub>—emissions, the world would still continue to heat up, since there's already a lot of this gas stored in the atmosphere. In a utopian world, forests and oceans could handle absorbing this CO<sub>2</sub> and clean up the atmosphere. But this, unfortunately, is not happening. Studies indicate that in some areas, the ocean is saturated with CO<sub>2</sub> and can't absorb more gas. In addition, we know that forested areas are in decline. People cut down trees that are 50 or 100 years old and say they'll compensate for it with reforestation. The effect of this compensation is small. The trees will be slow to grow. The ideal option would be ending deforestation and increasing the forested area. If there are intense mitigation measures, it may be possible to limit global warming to 1.5 degrees or a maximum of 2 degrees. With uncontrolled warming, if the global temperature rises more than 4 degrees, we'll enter what we call dangerous climate changes. In that case, adapting will no longer be possible.

***In some parts of the world?***

I would say in general. People say that if it gets really hot, they'll turn on the air conditioning. It happens that air conditioners need electrical energy, which depends on hydropower, which depends on rain. But if it gets too hot, the water evaporates and won't turn the turbines. People still don't understand the issue of adaptation. Using a water truck in the Northeast only during a dry spell is not adaptation. It's palliative. Adaptation is something that's prepared and permanent. In that sense, what could help the world is a large-scale increase in for-



**For the climate, there's no difference whatsoever whether a tree has been cut down legally or illegally**

ested area, which absorbs greenhouse gases. There are those who envision that injecting CO<sub>2</sub> into holes in the ground would be a mitigation alternative for combatting global warming. This could solve the atmospheric problem and create one that's geological. There is serious research in this area, called geoengineering, but there aren't any concrete results from studies showing that such intervention works. It's a new area. In the 1970s, when climate modeling began, no one believed in it either. Today, everyone uses modeling. Maybe this will happen in the future with geoengineering, but it's still too early to bet on it.

***Is any part of Brazil adapted to extreme events?***

To some extent, it appears that the greater metropolitan area of São Paulo has adapted to the water crisis. Authorities say they have improved the water distribution network, which was quite old, and have also begun to collect water from the Paraíba do Sul River. This measure could be considered a type of adaptation. But which districts can adapt to extreme weather events? When it rains a lot in the city of São Paulo, people can't get around. Cars are lost, trucks can't transport food to supermarkets, buses stop running, and people can't get to

work. This happens every summer. I've been in Brazil for 20 years, and I've seen it every year. The city has not adapted to intense rains, which are increasing. In the worst case, when adaptation isn't possible, people can try to migrate, as is still happening in the Northeast.

***What good examples of adaptation to climate change stand out in the world?***

Venice is one of them, with the city having lived for so long with the lagoon. Perhaps the best example would be the Netherlands. The city of Amsterdam is below sea level. Without the dikes to hold back the water, the population dies. The country grew as it advanced on the sea. Today, this process would be described as an adaptation. There are projections indicating that more intense storms coming from the North Sea could reach the Netherlands. What if they breach the dikes? In the United States, there was the case of Hurricane Katrina in 2005. Its winds pushed the Mississippi River over the walls of the levees that protected New Orleans. They resisted category three hurricanes, but Katrina came in at category five. The city was flooded, and 1,500 people died. This happened in a country in the so-called First World.

***Will poor countries be the most affected by climate change?***

Changes in climate are democratic. They affect rich and poor. The environmental agenda is marvelous. But with the recent economic crisis in Europe and the United States, it's been pushed to the back burner. The carbon-based economy generates a lot of jobs, and governments prefer to fight the crisis by encouraging activities that are polluting. That's why the United States hasn't ratified the Kyoto protocol and left the Paris climate deal. In Brazil, it's not very different, although the country continues as a signatory of the international climate agreements. Brazil has committed to ending illegal deforestation. But to me, the right thing would be to simply end deforestation, any deforestation, legal or illegal. For the climate, there's no difference whatsoever whether a tree has been cut down legally or illegally. If it's been cut down, it ceases to be an agent acting against the increase of the greenhouse effect. ■

# Hotter and DRIER CITIES

Modeling indicates that temperatures will rise and rainfall will be halved in São Paulo, Rio de Janeiro, and Santos by the end of the century

**Marília Carrera**

PUBLISHED IN NOVEMBER 2018

In the worst-case scenario modeled in the most recent Intergovernmental Panel on Climate Change (IPCC) report, greenhouse gas emissions would continue to increase through the end of the century, and average atmospheric temperatures would warm by approximately 4 °C from current temperatures. If these global climate predictions materialize in the coming decades, maximum summer temperatures could rise by up to 9 °C and rainfall would be halved in Brazil's two largest metropolitan areas—São Paulo and Rio de Janeiro—and in Santos, home to Brazil's most important port. The minimum temperatures in these areas could also be expected to rise by approximately 4 °C by the end of the century, meaning winters would also be warmer.

These projections for parts of Brazil's Southeast are from a paper published by researchers from the Brazilian National Institute for Space Research (INPE), the Federal University of Rio de Janeiro (UFRJ), and the Center for Natural Di-

sasters Monitoring (CEMADEN) in the April issue of *Theoretical and Applied Climatology*. “If the current greenhouse gas emissions trends continue, the probability of the study data materializing will likely be high,” says meteorologist André Lyra, a postdoctoral fellow at INPE and the study's lead author.

The Brazilian team modeled potential temperatures and rainfall rates in the three metropolitan areas by assuming two of the IPCC's global climate scenarios: the worst-case scenario, technically designated as RCP8.5, and the best-case scenario, RCP4.5. In the second scenario, greenhouse gas emissions would stop rising in the 2040s. However, even when this less alarming projection is assumed in the Eta Regional Climate Model, which was partly developed by INPE, the modeling results are not substantially different. The maximum temperatures in São Paulo, Rio de Janeiro, and Santos rise by as much as 7 °C, and rainfall is reduced by half, although the lower rainfall rates affect a smaller por-

tion of the metropolitan areas. While these scenarios carry some degree of uncertainty, they indicate that relatively intense climate change is likely.

The researchers used an enhanced version of Eta with a spatial resolution of 25 square kilometers (km<sup>2</sup>) or a square with 5 km sides. The previous version had a resolution of 400 km<sup>2</sup> (a square with 20 km sides). “The new model is important for an understanding of climate change impacts on certain aspects of South American topography,” says meteorologist Chou Sin Chan of INPE, who coauthored the paper. “A study with 5 km resolution provides a higher level of detail than a study with 20 km resolution.” In this version of Eta, there are fewer calculation errors for climate predictions in areas with rugged terrain. This enhancement has important implications when investigating locations near mountainous areas, such as Serra do Mar and Mantiqueira, two mountain ranges in the vicinity of the study area.





São Paulo city could have heat waves lasting approximately 60 days by the end of the century, according to model projections

Climate projections in the three metropolitan areas were compared with historical data within the model from 1961 to 1990. The projections were divided into three slices, 2011–2040, 2041–2070, and 2071–2100. In addition to a general trend of warming and lower rainfall, the paper predicts extreme events such as extended droughts and severe storms will increase in intensity. In the metropolitan area of São Paulo, for example, the number of days with heat waves could increase by 60 days, and the number of cold wave days could decrease by three days by around 2100. The study also predicts that days and nights will become more uncomfortable in the three study areas, placing an increased demand on cooling equipment and consequently increasing energy consumption. This effect could also create potential health risks for the poor and elderly.

“Extremes have a bigger effect on our lives,” says Claudine Dereczynski, a meteorologist at the Federal University of Rio de Janeiro (UFRJ) and a coauthor of the paper. “The increasing occurrence of events of this kind is a greater concern stemming from climate change than changes in average precipitation or temperature.” The model also predicts that extremely heavy rainfall events will intensify toward the end of the twenty-first century, causing frequent landslides. Dereczynski notes that the projections are more reliable for changes in temperature than in rainfall.

The study underscores how the high population density in the metropolitan areas of Rio and São Paulo, where 33 million people live, has led to improper land use and severe degradation of natural resources. “Climate-change research depends heavily on acceptance by different industries and public awareness of the importance of taking action to mitigate the effects of greenhouse gas emissions,” says sociologist Pedro Ro-

berto Jacobi, a professor at the Institute for Energy and the Environment at the University of São Paulo (IEE-USP). “Our research shows that municipal governments could even implement decarbonization initiatives on a local scale, such as erosion control through changes in land-use legislation or improved solid waste management policy. However, global action is needed—which depends on agreements between nations—to mitigate climate change.” ■

#### Project

An integrated framework to analyze local capacity for decision-making and adaptation to large-scale environmental change: Community case studies in Brazil, the UK, and the US (no. 12/51876-0); **Grant Mechanism** Thematic Project; FAPESP-Belmont Forum Agreement; **Principal Investigator** José Marengo (CEMADEN); **Investment** R\$711,506.53.

#### Scientific article

LYRA, A. *et al.* Climate change projections over three metropolitan regions in Southeast Brazil using the non-hydrostatic Eta regional climate model at 5-km resolution. **Theoretical and Applied Climatology**. v. 132, i. 1-2, p. 663–82. Apr. 2018.

# Reaping dividends



Investment in research has increased farm productivity in São Paulo and generated economic returns for the state

Fabício Marques | PUBLISHED IN SEPTEMBER 2018

A study of the effects of human-capital investment on agriculture in the state of São Paulo has found that every R\$1 applied toward research and development (R&D), higher education, and rural extension has generated a return of R\$12 to São Paulo's economy through improved productivity. The study, led by researchers from the University of São Paulo (USP), focused on the contributions made by institutions that fund, produce, or disseminate knowledge of interest to agriculture. FAPESP funding for grants, research, and infrastructure in the fields of crop science and agriculture, for example, has yielded returns of R\$27 for every R\$1 invested, a figure surpassed only by public universities training skilled professionals for agriculture, which return R\$30 for every R\$1 spent.

The data from the study were published in the recently released book *Con-*

*tribuição da FAPESP ao desenvolvimento da agricultura no estado de São Paulo* (FAPESP's contribution to the development of agriculture in the state of São Paulo), which presents the findings from research conducted between 2013 and 2018. "Agribusiness is the one industry keeping Brazil's economy afloat amid the crisis. This has been the result of long-term research investment and public policies that have been upheld with relative consistency by public agencies in São Paulo over the last 60 years," says economist Alexandre Chibebe Nicolella, a researcher at USP's Ribeirão Preto School of Economics, Administration, and Accounting (FEARP), who led the research alongside crop scientist and economist Paulo Cidade de Araújo from USP's Luiz de Queiroz College of Agriculture (ESALQ-USP), who passed away in 2016 at the age of 84. Funding from state agricultural research institutes

such as the Agronomy Institute, in Campinas (IAC) and the Food Technology Institute (ITAL), and from the São Paulo chapters of the Brazilian Agricultural Research Corporation (EMBRAPA), have provided returns of R\$20 for every real invested. Investments in rural extension—providing technical assistance and information to farmers—have delivered per-real returns of R\$11.

São Paulo's agribusiness market was worth R\$267.9 billion in 2017, or 13.5% of the state's Gross Domestic Product (GDP). Recent years have seen a marked expansion of the sugar and ethanol industry in the state—in 2013, sugarcane plantations occupied 23% of its 24 million hectares (ha) of cropland, compared with 12% ten years prior. Crop yields grew from 80,000 to 90,000 kilograms per ha during the first decade of the century. São Paulo also produces 72% of Brazil's supply of citrus. Orange

juice, however, accounts for only approximately 3% of São Paulo's agribusiness GDP, notes crop scientist and economist Geraldo Sant'Ana de Camargo Barros, a professor at ESALQ-USP and coauthor of the study. "The citrus industry adds very little value to the raw material. It processes R\$1.66 billion worth of orange crop into R\$1.97 billion worth of orange juice, or an added value of 18.7%. The sugar and ethanol industry turns R\$4.8 billion worth of sugarcane into R\$13.6 billion of sugar and ethanol, almost tripling the value of the raw material," says Barros, according to Agência FAPESP.

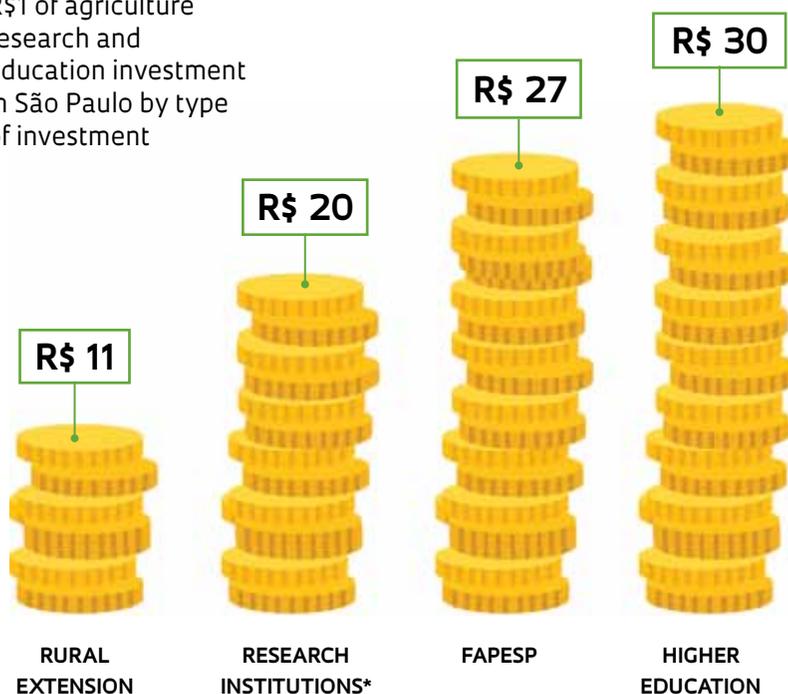
**A**griculture in São Paulo is highly diversified. The southeastern state produces 25% of Brazil's timber and pulp, 17% of the country's poultry, and 9% of its coffee. São Paulo is a nationally leading producer of 16 of its 25 major crops. Crop yields are high. "With just 11.7% of Brazil's total cropland, São Paulo produced 18% of the country's total crop value during the three-year period of 2010 to 2012," wrote Maria Auxiliadora de Carvalho, a retired researcher at the Institute of Agricultural Economics, in a chapter of a book describing the recent history of agriculture in São Paulo.

Although the study measured the impact of different institutions individually, their activities are mutually reinforcing. "We have world-class universities—such as ESALQ-USP, which is consistently rated one of the world's top universities in its field in different rankings—and important research institutions. Much of their past and present performance is thanks to funding institutions such as FAPESP," explains Alexandre Nicoletta. "We have high-quality education, research, and extension programs, and all require funding."

The study was based on Total Factor Productivity (TFP), a widely accepted method of measuring the impact of technological development and the influence of R&D investment on output growth. The methodology was originally developed in 1958 by economist Zvi Gri-

## What is the payback on investment?

Returns on every R\$1 of agriculture research and education investment in São Paulo by type of investment



\* Note: In another methodology that excluded the contribution from EMBRAPA units in São Paulo, research institutes generated higher returns on research investment

SOURCE CONTRIBUIÇÃO DA FAPESP AO DESENVOLVIMENTO DA AGRICULTURA DO ESTADO DE SÃO PAULO, 2018

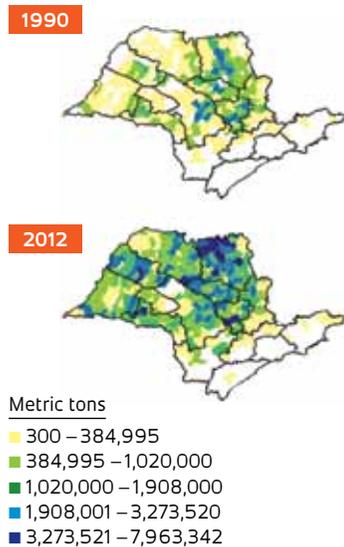
liches, then a researcher at the University of Chicago, who became a leading authority on the economics of technological change and empirical studies on the diffusion of innovation and returns on R&D investment. Griliches pioneered the measurement of rates of return on innovation in the development of hybrid corn in the US and estimated that every dollar invested in research yielded US\$8 in return. In 1972, a paper published by researchers from the University of Arizona and Purdue University used this methodology for the first time in Brazil to determine the rates of return on R&D investment in cotton-crop improvement, such as investment by IAC in developing new cultivars.

The project led by Nicoletta looked at agricultural output and expenditure on inputs in São Paulo from 1970 to 2014 to identify factors that enabled farmers to produce more with fewer resources. Because the effects of investments are not felt in the same year in which they are made, the researchers used different econometric models with different time lags. In one of the models, with an investment-to-impact lag estimated at three years, a 10% increase in spending on human capital, research, education, and rural extension led to an increase of 4.8% in TFP, with each R\$1 invested generating a return of R\$12. In the second model, a variable lag was used—one year for FAPESP investment and rural

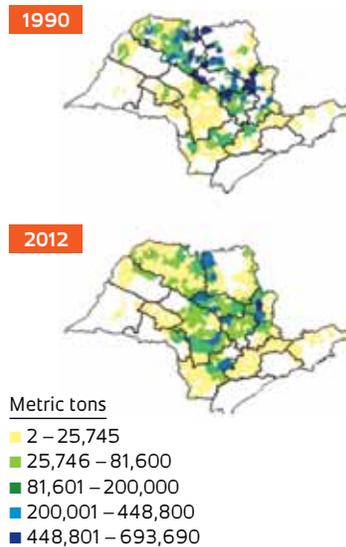
# A changing crop landscape

A comparison of municipal production of sugarcane, oranges, and coffee in 1990 and 2012, in metric tons

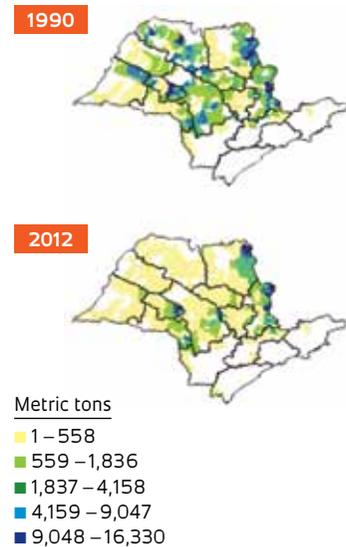
## SUGARCANE



## ORANGES



## COFFEE



SOURCE IBGE

extension, two years for research, and four years for higher education—and, as previously noted, a return of R\$27 was generated for every R\$1 in FAPESP funding (see the chart on the page 17). In a third model, EMBRAPA was excluded from the calculation to measure the impact from state research institutes alone. This calculation yielded a return of R\$11 for every R\$1 invested in rural extension, R\$23 for FAPESP funding, R\$29 for research institutes and R\$35 for higher education. “Whatever the model, the results are always positive and substantial. The rate of return is higher than for the vast majority of investments, showing that the relevant public policies have paid off,” says Nicolella. “Money invested in training human resources and generating knowledge has resulted in increased productivity, more abundant food supply and, ultimately, lower food prices.”

A problem in this type of analysis, according to Nicolella, is that it is unable to factor in the important impacts of private investment due to a lack of available data or the incorporation of technologies from other sources. It is also difficult to measure indirect effects from funding. “We are unable to measure the overflow

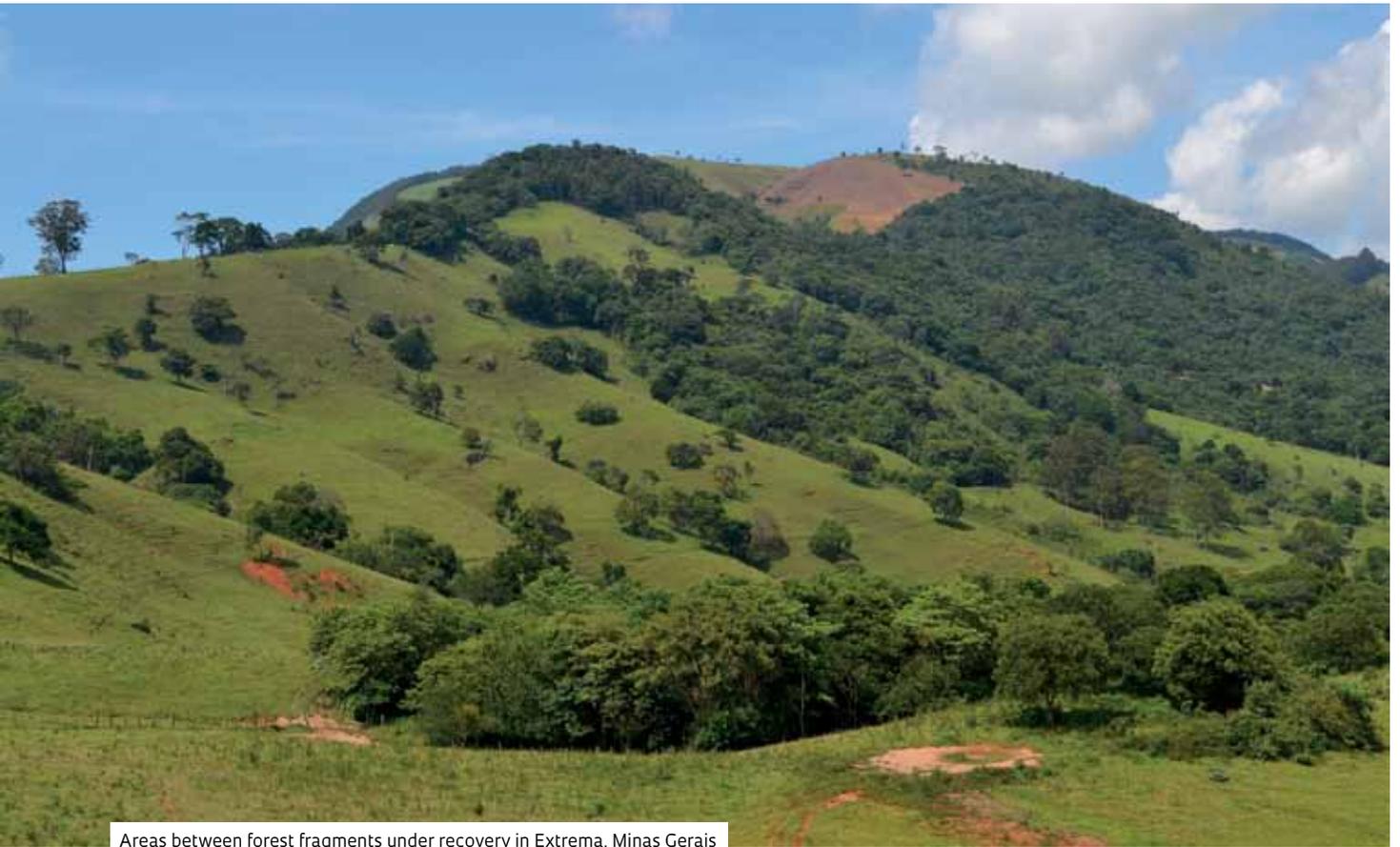
effects from each investment: for example, the extent to which money invested in building a laboratory at a university has produced diluted impact over time. The calculation gets fuzzy,” he says. FAPESP funding for agriculture projects in São Paulo totaled R\$3.4 billion between 1981 and 2013. In the early 1980s, agriculture absorbed 5% of FAPESP investment; in 2013, that figure had reached 20%. Out of total funding, 41.3% has gone to regular research grants, 37.2% to other grants, 11.3% to special programs, such as Bioenergy Research (BIOEN), and 10.2% to R&D programs.

### SOURCES OF FUNDING

The study shows that federal sources of funding have played an important role in boosting agriculture performance in São Paulo. Between 2001 and 2014, EMBRAPA invested R\$240 million in projects at its units in São Paulo State, with investment peaking in 2006 (R\$46.6 million), 2009 (R\$38.7 million), and 2011 (R\$33 million). In the same period, the Brazilian National Council for Scientific and Technological Development (CNPq) directed R\$331.3 million (adjusted for inflation) to agriculture projects and research grants at São Paulo

State institutions. For other agencies, the exact amount of investment could not be determined. The Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES) issued 10,500 graduate grants in agriculture programs in São Paulo between 2000 and 2014, but consolidated data on the amounts involved are not available. The Brazilian Funding Authority for Studies and Projects (FINEP) and the Brazilian Development Bank (BNDES) have funded projects in industry, with especially strong investment in technology and innovation. BNDES provided R\$3.5 billion to agriculture in São Paulo State between 2002 and 2014, largely to the sugarcane, citrus, beef, and pulp value chains.

This was not the first study to investigate the extent of economic returns from investing in agricultural R&D in São Paulo. In 2002, Paulo Cidade de Araújo, from ESALQ-USP, also assessed the impact of human-capital investment on agriculture in the state, albeit using less complete data sources than in the current project. The rates of return found in this previous research were lower than in the current study, but because the two studies relied on different data, they are not directly comparable. ■



Areas between forest fragments under recovery in Extrema, Minas Gerais

# Life goes on

Environmental legislation helps reconnect Atlantic Forest fragments in agricultural regions across Brazil

**Rodrigo de Oliveira Andrade**

PUBLISHED IN SEPTEMBER 2018

The restoration of riparian forests on the banks of lakes, rivers, and springs by agricultural workers has nearly doubled the coverage of Atlantic Forest on rural properties in the states of São Paulo, Minas Gerais, Rio de Janeiro, Paraná, and Mato Grosso do Sul over the last two decades. In a study published in the journal *Tropical Conservation Science* in July, researchers evaluated how efforts by private landowners to comply with Brazilian legislation has affected Atlantic Forest cover and connectivity on 2,408 farms scattered over 748,000 hectares of Brazil. The land is mostly used to grow coffee, oranges, and sugarcane, as well as for grazing.

Environmental legislation has fostered the creation of ecological corridors, which are essential to biodiversity conservation. Despite improvements, the total forest cover area on the evaluated properties is still below the 20% that was anticipated by Brazilian law. The research group, coordinated by biologist Ricardo Ribeiro Rodrigues, from the Department of Biological Sciences of the Luiz de Queiroz College of Agriculture at the University of São Paulo (ESALQ-USP), reached their conclusions after analyzing the Brazilian Forestry Code, satel-



Permanent preservation areas (outlined in white) were fragmented in the surrounding region of this sugarcane mill in São Paulo state

## Forest cover is still lower than the targets set by Brazilian legislation

lite images, and data from ESALQ-USP's Environmental and Agricultural Adaptation Program, which has been working in partnership with farmers to develop environmental and agricultural planning strategies in Brazil for the past 20 years.

The program began at a time when environmental oversight of agricultural properties in Brazil was becoming stricter. "Many agricultural producers who were worried about complying with legislation asked us to perform an environmental analysis of their farms," says Rodrigues. He explains that farmers are required to maintain or restore riparian forests in permanent preservation areas, as well as a proportion of natural vegetation called "legal reserve," which can be sustainably exploited within limits established by the law. "We began to prepare plans for establishing these properties, taking into account the type of original vegetation to be recovered, the most ap-

propriate methods for restoration, and the presence of low-capacity agricultural areas to be converted into legal reserve." The program has already been implemented on 4.2 million hectares (ha) of agricultural land within the country, with more than 20,000 ha of riparian forest being actively restored and more than 150,000 ha of forest fragments gaining protection and undergoing recovery.

By comparing past and present satellite images, the researchers found that since the ESALQ-USP program was launched, Atlantic Forest cover has doubled in the permanent preservation areas under study, from 57,554 ha in 1999 to 108,337 ha in 2012. "We are mainly talking about the recovery of riparian forests along the banks of rivers and springs, which help protect these bodies of water from silting," explains agronomist Ricardo Viani, from the Center for Agricultural Sciences at the Federal Uni-

versity of São Carlos (UFSCAR), one of the authors of the study.

In addition to greater forest cover, the researchers also found that the Integral Index of Connectivity (IIC), which is used to estimate the level of connection between remaining fragments of native vegetation, significantly increased. At a sugarcane mill in Araras, São Paulo state, for example, the connectivity of forest fragments in permanent preservation areas increased by 236% (*see map*). This led to the formation of ecological corridors and the restoration of animal and insect flows.

"Fragmentation is considered a serious environmental problem because it affects the migratory routes used by animals and plants to move from one area to another, compromising the sustainability of these regions," explains Rodrigues. This can damage a number of ecological functions that are important to natural



In just under a decade, the connectivity between these fragments increased by 236%, enabling the formation of ecological corridors (highlighted in red)

regeneration and forest maintenance, such as pollination and seed dispersal. "Most Atlantic Forest fragments are now partially isolated on private land scattered around the country," says Viani.

#### LASTING EFFECTS

Permanent preservation areas and legal reserves account for approximately 20% of the land on rural properties. "However, restoration of these environments is essential to the conservation of many species, some of which are close to becoming extinct." In June 2017, after analyzing 22 forest fragments surrounded by sugarcane plantations in the state of São Paulo, a team led by biologist Mauro Galetti, from the Ecology Department at São Paulo State University (UNESP) Rio Claro campus, was able to identify 90% of the medium and large mammals expected to be found in the state. Environmental restoration strategies are

important, but there is a consensus that it is impossible to fully restore past biodiversity levels and ecosystem services.

The animals found included giant anteaters (*Myrmecophaga tridactyla*), tapirs (*Tapirus terrestris*), and peccaries (*Tayassu pecari*), all of which play important roles in native seed dispersal. However, in the smaller forest fragments, only 20% of the species expected in the region were recorded, suggesting that up to 80% of them are locally extinct. The study, published in the journal *Biological Conservation*, suggests that it may still be possible to protect the mammals of Brazil, as long as ecological corridors continue to be recovered, reconnecting these forest fragments.

"Our findings suggest that recovery projects designed to comply with environmental legislation can significantly help to increase the connectivity of agricultural landscapes through the restoration of ecological corridors," says Rodrigues. However, he points out that the total remaining forest cover on the evaluated properties is approximately 13%, which is below the 20% established by law as ideal for avoiding the extinction of certain species in agricultural regions.

According to biologist Ramon Felipe Bicudo da Silva, from the Center for En-

vironmental Studies and Research at the University of Campinas (UNICAMP), the study clearly demonstrates how environmental restoration and conservation can be reconciled with agricultural activity. "The research also highlights that these practices are most effective when they are accompanied by a restoration plan that considers neighboring properties in a joint effort to connect fragments," says Silva, who did not participate in the study. For Rodrigues, compliance with environmental programs by rural landowners has the power to strengthen production chains through environmental certification. "This can increase the added value of agricultural products," concludes the biologist. ■

#### Project

Ecological restoration of riparian forests, native forests used for economic production, and degraded forest fragments (in PPAs and LRs) based on the restoration ecology of reference ecosystems to scientifically test the precepts of the New Brazilian Forest Code (no. 13/50718-5); **Grant Mechanism** Thematic Project; **Program** Biota; **Principal Investigator** Ricardo Ribeiro Rodrigues (USP); **Investment** R\$1,945,311.16.

#### Scientific article

ROTHER, D. C. *et al.* How legal-oriented restoration programs enhance landscape connectivity? Insights from the Brazilian Atlantic Forest. **Tropical Conservation Science**. v. 11, p. 1–9. July, 2018.

# 2017 report

The *Activities Report* shows that FAPESP increased funding for innovative research and business partnerships

PUBLISHED IN NOVEMBER 2018

In 2017, FAPESP invested a total of R\$1,058,591,892 in 26,026 scientific and technological research projects; of these, 10,186 were new proposals contracted during the year, and the rest were ongoing projects. In nominal terms, the disbursement was 6.9% lower than that in 2016 when R\$1,137,355,628 was invested in 26,445 projects, of which 10,480 were new projects. The *FAPESP 2017 Activities Report*, published in August, is available online at [fapesp.br/publicacoes](http://fapesp.br/publicacoes), where it is also possible to consult the foundation's annual investment summaries all the way back to 1962, which was the year that it was established.

When FAPESP was first formed, it received a federal grant of US\$2.7 million to help establish an investment fund and thereafter received an annual budget of 0.5% of the state's tax revenue. The state constitution of 1989 increased this amount to 1%, which is to be invested in scientific and technological research. FAPESP's total revenue in

2017 was R\$1,338,994,358, compared to R\$1,344,197,902 in the previous year. The São Paulo state government provided R\$1,111,410,356 in 2017, which is an increase of 5% in nominal terms over the 2016 amount of R\$1,057,714,553. This contribution accounted for 83% of the foundation's revenue in 2017; a further R\$129,959,471 came from FAPESP's own resources, which it uses to fund part of its activities. In 2016, these resources represented a smaller proportion of revenue, R\$71,328,947. A third source of funding comes from agreements and compacts with other agencies, institutions, and companies. In 2017, this source totaled R\$97,624,721, which is less than half of the R\$215,154,402 obtained in 2016.

Despite the decrease in the number of agreements with other institutions, FAPESP managed to increase its funding for more daring scientific research, invest more in innovation at small businesses, and increase the number of collaborations between universities and companies. One of the highlights of the

# Where funding is targeted

FAPESP investment in four categories in 2017

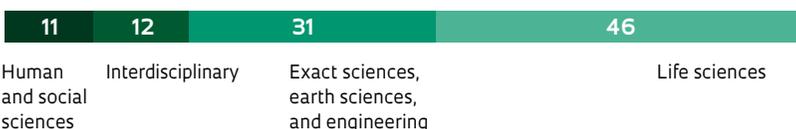
**R\$ 1,058,591,892**

## FAPESP FUNDING BREAKDOWN (IN %)

### BY AREA OF APPLICATION



### BY FIELD OF KNOWLEDGE



### BY INSTITUTIONAL LINK

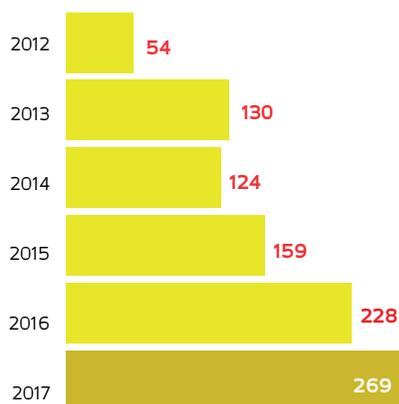


### BY FUNDING LINE



## THE GROWTH OF PIPE

Evolution in the number of research grants\* approved under the Technological Innovation in Small Businesses program



**5**  
projects per week  
in 2017

last year was the Technological Innovation in Small Businesses (PIPE) program. "The R\$71.9 million invested in 2017 was the largest since the PIPE program began," said physicist José Goldemberg, president of FAPESP between 2016 and September 2018. The program, which celebrated its 20th year in 2017, agreed to more new partnerships than in any other year in its history, 269 projects, which is 18% more than in the previous year, not including fellowships and funding linked to key projects. The result was equivalent to accepting a new project every business day. Over its first two decades, PIPE has supported 2,060 projects at 1,244 businesses in 132 towns in the state of São Paulo. "The small businesses supported by the program are mostly located in places where there are good universities or research institutes, which produce entrepreneurs capable of using modern science and technology to create competitive business opportunities," wrote Carlos Henrique de Brito Cruz, FAPESP's scientific director, in a special edition of *Pesquisa FAPESP* celebrating the program's 20th anniversary, which was published in December 2017.

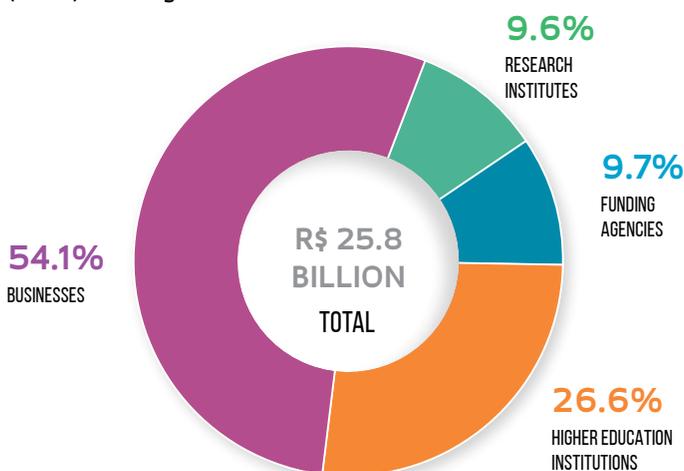
Another highlight with respect to supporting collaborations between universities and businesses was the approval of two new Engineering Research Centers, which were officially confirmed in 2018: the Genomics for Climate Change Research Center, which involves the Brazilian Agricultural Research Corporation (EMBRAPA) and UNICAMP, and the Center for Innovation in New Energies (CINE), a partnership among Shell, USP, UNICAMP, and the Nuclear and Energy Research Institute (IPEN). "As an organization, we have talked a lot about energy transition in recent years; we can see that the time for change is coming and will soon become a reality," said André Araújo, president of Shell Brazil, at the CINE inauguration event. According to the company's projections, global energy demand in 2060 will be almost 60% higher than it is today; hence, there is a need to invest in the development of new renewable energy sources.

At the new engineering research centers, every R\$1 invested by FAPESP is matched by R\$1 from the company and R\$2 from the university or research in-

\* Does not include scholarships/fellowships

# R&D

Sources of research and development (R&D) funding in São Paulo



stitute where the center is based. The two new initiatives have added to the five existing centers that work on innovative solutions such as biofuel engines (Peugeot-Citroën and UNICAMP), gas (Shell and USP), sustainable chemistry (GSK and UFSCAR), new molecular targets against inflammatory diseases (GSK and the Butantan Institute), and wellbeing (Natura and USP). In 2017, R\$14.7 million was invested in research conducted at these five centers. Calls for bids were also issued for new centers, this time in partnership with Koppert do Brasil, Statoil, and Grupo São Martinho. FAPESP also coordinates with companies interested in creating research centers in advanced manufacturing engineering.

## THEMATIC PROJECTS

In 2017, FAPESP funded 128 new thematic projects, which is 45% more than in 2016 when there were 88, and higher than the average for recent years (*see table*). This grant mechanism is designed to support research with more daring objectives, developed by teams of researchers from various institutions, over a longer term of up to five years. The growth over the previous year was influenced by a call for proposals by the Brazilian National Institutes for Science and Technology (INCT) program, which

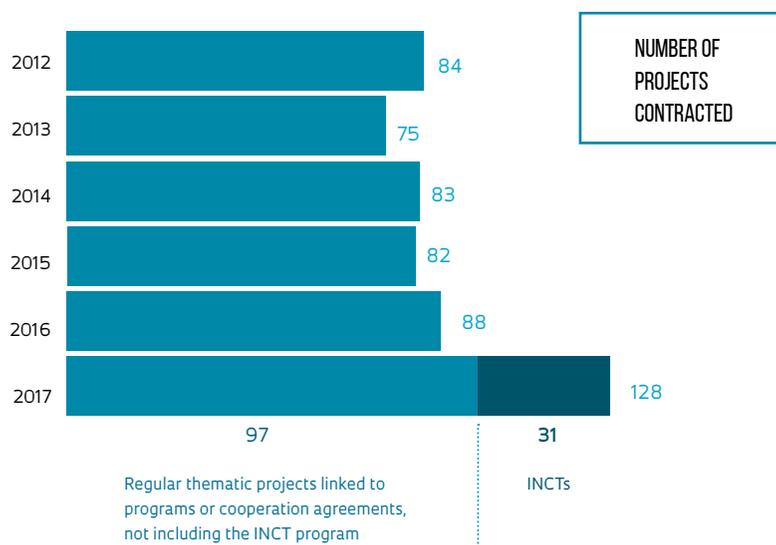
was born of a partnership between the federal government and state research funding agencies, and aims to create networks of researchers working in strategic fields and on pioneering issues. FAPESP provides 50% of the funds allocated to INCT institutes in São Paulo and accepted 31 new thematic projects under the program in 2017. Even excluding those projects under the INCT pro-

gram, the number of thematic projects contracted in 2017 was 97, which is nine more than in 2016.

There were 469 thematic projects in progress during the year, receiving a total investment of R\$145,664,720. The most commonly funded fields were health (28.11% of the total), biology (18.87%), engineering (8.49%), agronomy and veterinary medicine (8.3%), physics (8.11%), and human and social sciences (7.17%). In the last 5 years, 60 thematic projects involved international collaborations as a result of cooperation agreements among FAPESP, funding agencies from other countries, and international organizations or as part of the São Paulo Excellence Chairs (SPEC) program, which invites renowned scientists from abroad to coordinate research in their fields at universities and laboratories in São Paulo.

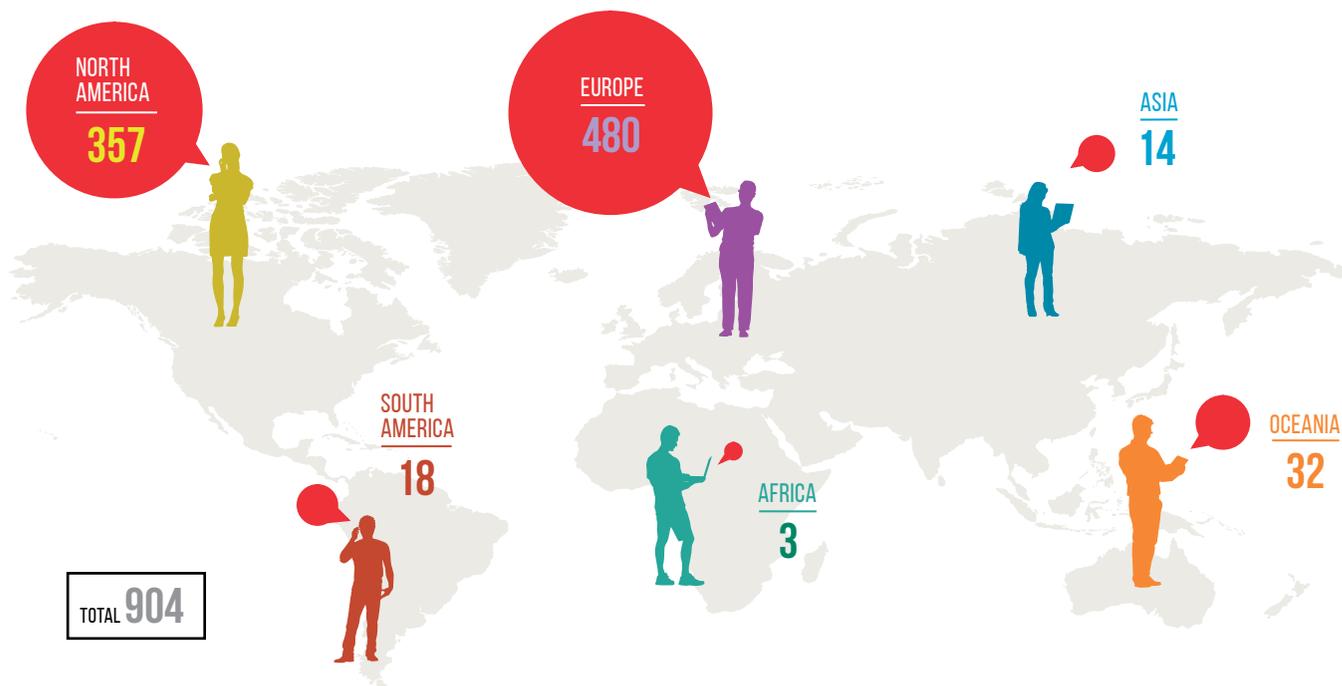
In 2017, FAPESP invested R\$429,689,013 in 14,034 regular research grants. Just over three-quarters of these funds were used for grants in Brazil, and 24% were used for research conducted abroad. Grants within Brazil were most commonly offered to PhD students (45% of the total), while, for researchers working abroad, 63% of the funding was invested in postdoctoral fellowships. In 2017, FAPESP awarded 904 Internship Grants for Research Abroad (BEPEs), the same number as in 2016. The pro-

## THE EVOLUTION OF THEMATIC PROJECTS



# Overseas fellowships

Destination of Internship Grants for Research Abroad (BEPes) awarded in 2017



gram is aimed at FAPESP undergraduate, master's, PhD, and postdoctoral fellowship recipients in São Paulo to help internationalize their research activities. The largest number of these fellowships, which can last anywhere from one month to six years, are located in Europe, with 480 fellows, followed by North America (357), South America (18), Asia (14), Oceania (32), and Africa (3).

The report also gave a current overview of the science and technology (S&T) structure in the state of São Paulo, comprising 15,000 innovative companies, six public universities, 65 state and federal technology colleges, 34 research institutes and S&T institutions, and 21 private research centers. São Paulo was responsible for 30% of the patents filed with the Brazilian National Institute of Intellectual Property (INPI) and 32% of the computer programs registered. The number of researchers working for state-owned companies was estimated at 39,065, which is equivalent to 62% of the total in Brazil. R&D expenditure in São Paulo, according to data compiled in the report, reached R\$25.7 billion; of this amount, 54.1% (R\$13.9 billion) came from companies. Higher education institutions, especially the state universities of São Paulo, account-

**There are 39,065 researchers working at state-owned companies, which is equivalent to 62% of the total in Brazil**

ed for 26.6% of this figure, followed by federal and state government funding agencies (9.7%) and federal and state research institutes that operate in São Paulo (9.6%). Businesses are playing an increasing role in R&D, particularly in São Paulo, although this has not translated into the greater representation of Brazilian companies on the global market. According to data compiled by the Brazilian Association for Research

and Development of Innovative Companies (ANPEI), Brazil's private sector invested more in R&D prior to the economic crisis, at a similar percentage of national GDP as Spain, but obtained a significantly lower number of patents. A survey comparing patents granted in the United States shows that Brazilian companies were awarded 197 patents per year between 2011 and 2015, while Spanish companies achieved a yearly average of 524 over the same period. Figures showing the same trend were published in the Data section of *Pesquisa FAPESP* in July 2016 ([bit.ly/2Ow2PG9](http://bit.ly/2Ow2PG9)).

The graduate system in São Paulo produced 7,288 doctors in 2017, which is equivalent to 34% of the total in Brazil, and 11,384 master's graduates (23% of the national total). USP was the leading institution in this regard, with 3,006 PhD and 3,467 master's graduates. The report also shows how the impact of scientific output has evolved. In 2016, articles by authors from institutions in São Paulo had an average impact of 1.04, compared to 0.91 in 2015. This is the first time that this value has surpassed 1. Therefore, on average, each article produced has been cited at least once by other papers. The relative impact of publications by Brazilian authors in 2016 was 0.89. ■ **Fabício Marques**



São Cristóvão  
Palace's facade  
in 1930



AUGUSTO MALTA / INSTITUTO MOREIRA SALLES

# Memories indelible by fire

For 200 years, the National Museum contributed knowledge in the natural sciences and inspired the creation of several other science museums

PUBLISHED IN OCTOBER 2018

**D**uring a visit to the French Academy of Sciences in Paris, in mid-1886, Dom Pedro II was told about a large meteorite lying in a streambed in the *sertão* (badlands) region of Bahia. The rock had been found in 1784 by a boy named Joaquim da Motta Botelho, who spotted it as he herded cattle in an area near the present-day town of Monte Santo. News of the finding had soon reached Rodrigo José de Meneses e Castro, governor of the then Captaincy of Bahia, who arranged for it to be transported to Salvador. The plan was to set the meteorite on an ox-cart pulled by several pairs of oxen and haul it to the state capital. But the cart collapsed under the weight of the 5-metric-ton space rock, sending it tumbling down into the dry Bendegó streambed, 180 meters from where it was originally found.

It remained there for another century. When he learned about the meteorite,

the emperor organized a commission of engineers to relocate it to Rio de Janeiro. The operation was highly complex and involved the use of a specially built cart running on rails and pulled by teams of oxen. The trek lasted 126 days, with the meteorite arriving in Salvador on May 22, 1888. On June 1, it was boarded onto a steamship bound for Recife. From there, the vessel sailed to Rio, arriving in June 15. The rock was delivered to the Court's Navy Arsenal for investigation. When the examination was completed, it was taken to the National Museum, where it was exhibited just outside the entrance.

The Bendegó meteorite was among the objects left virtually unscathed by the fire that destroyed Brazil's National Museum and much of its collection on September 2. Alongside the space rock, the institution had, over the course of two centuries, amassed more than 20 million items brought from expeditions.

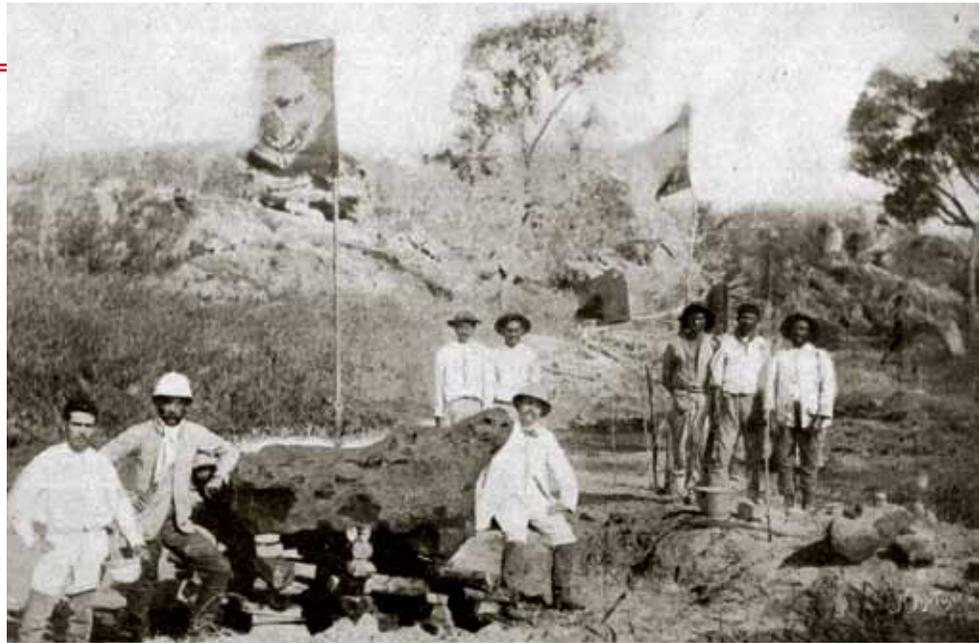


The collection was organized in sections that provided material for research in fields such as anthropology, botany, entomology, and paleontology.

The museum was founded by Dom João VI (1767–1826) in June 1818, then as the Royal Museum, at a time when interest in natural history had been heightened by the coming of European naturalists to map out the territory, prospect for plants and minerals, and disseminate new farming techniques. It traces its roots, however, to the House of Natural History, created in 1784 under viceroy Luis de Vasconcelos e Souza (1742–1809). Popularly known as “Casa dos Pássaros” (House of the Birds)—because of the mounted birds it contained—the museum was originally housed in a building at Avenida Passos, in downtown Rio de Janeiro, as an arm of the Lisbon Museum of Natural History, in Portugal, to which were sent natural specimen and indigenous adornments collected in Brazil.

The museum functioned there for nearly three decades. “With the arrival of the royal family, there was no longer a need for intermediate storage of natural objects bound for Portugal, so the museum became defunct in 1813,” says historian Maria Margaret Lopes, a professor in the Inter-University Graduate Program in Museology at the University of São Paulo’s Museum of Archaeology and Ethnology (MAE-USP). “The collection was moved to the War Arsenal, where it remained until the creation of the Royal Museum.”

The Portuguese crown had long taken an interest in learning about the natural wealth of its colony. The New World also drew interest from European scientists and artists. “After archduchess Maria Leopoldina married crown prince Dom Pedro I, the future emperor



Engineers posing next to the Bendegó meteorite in the streambed of the creek from which it takes its name, in the *sertão* region of Bahia, 1887

## The second half of the nineteenth century saw a proliferation of science museums in Brazil

of Brazil, plans were made for what became known as the Austrian Expedition, which brought naturalists and artists to Brazil to survey and document species and landscapes unique to the country’s biodiversity,” says Lopes. Among them were zoologist Johann Baptist von Spix (1781–1826) and botanist Carl Friedrich von Martius (1794–1868), who in 1817 embarked on a journey inland on an expedition that provided material for *Flora brasiliensis*, a book that revealed the features of Brazilian plants to the Old World.

Having an institution in the country in which to store and study its natural wealth had become indispensable. Modeled after European natural history museums, the Royal Museum had scientific collections, libraries, laboratories, and exhibitions. It was established in an old house in Campo de Sant’Anna, downtown Rio. Besides the collection from the defunct House of Natural History, the museum also housed a collection of rare minerals brought by the royal family and organized and classified by the German mineralogist Abraham Werner (1749–1817). “The Royal Museum was created as a colonial institution, a center for receiving and cataloging the natural treasures brought from Brazil’s provinces,” notes the historian.

In October 1821 the museum was opened to the general public, and thereafter continued to grow. Between 1822 and 1823, José Bonifácio de Andrada e Silva (1763–1838), Minister of the Interior and of Foreigner Affairs under Pedro I, convinced foreign naturalists to part with items collected during their expeditions in exchange for support for their travels. Among these were German naturalist Georg Heinrich von Langsdorff (1774–1852) and French botanist Auguste de Saint-Hilaire (1779–1853).

With the proclamation of independence, in September 1822, the institution was renamed the Imperial and National Museum. Dom Pedro II was a science enthusiast and lent much support to

Polish chemist Marie Curie (seated) and her daughter, Irène Joliot-Curie (standing, wearing a hat), during a visit to the museum in August 1926



2

the museum. One of his most notable contributions was Egyptian priestess Sha-Amun-en-su's sarcophagus, a gift he received from Isma'il Pasha, Khedive (viceroy) of Egypt, during his visit to the country in 1876. Pedro II kept it at his office until 1889, when it became part of the museum's collection.

The museum's natural-history collections were also expanded through donations from private benefactors. One such donation was made by Antônio Luis Patricio da Silva Manso, chief surgeon and inspector of the Military Hospital of the Province of Mato Grosso, who gave about 2,300 specimens of 266 plant species to the museum in 1823. July 1863

saw the creation of the museum's Central Library—one of the largest libraries in Latin America specializing in anthropological and natural sciences. "The museum was seen as an example of excellence by researchers in Argentina, Chile, and Uruguay," says Lopes.

With its subject-matter departments, including botany, zoology, geology, and ethnography, the Imperial and National Museum supported research that helped to develop the natural sciences in Brazil. In the second half of the nineteenth century the museum played an increasingly important role as an advisory body to the Empire on research in geology, mineralogy, and other fields. Its differ-

ent departments and laboratories were used to examine samples brought from across Brazil, including coal, minerals, plants, animals, human skeletons, and the fossilized bones of enormous, unknown mammals.

#### HEYDAY

Under botanist Ladislau de Souza Mello Netto (1838–1894) as director, between 1876 and 1893, the National Museum saw what many researchers regard as its heyday. Mello Netto oversaw an extensive renovation at the museum, reorganizing its already voluminous collections into new sections by discipline, mirroring developments in scientific thought at the time. Other reforms he undertook were based in part on criticisms made by zoologist and geologist Louis Agassiz (1807–1873), director of the Museum of Comparative Zoology at Harvard University, during his time in Brazil leading the Thayer Expedition, from 1865 to 1866.

Agassiz visited the National Museum and reported that the institution suffered from a lack of funding to maintain the collection. In his book, *A Journey in Brazil*, written in 1868, he complains that the collections had been allowed "to remain for years in their present condition, without additions or improvements. The mounted animals, mammalia, and birds are faded; and the fishes, with the



The São Cristóvão Palace in 1862, before it became home to the museum



Alberto Santos Dumont (*center, hat in hand*) visited the museum in July 1928. At his side (*wearing a white coat*) is the then director, anthropologist Edgard Roquette-Pinto

## The National Museum's success and prestige helped to generate interest in the natural sciences in Brazil

exception of a few beautifully stuffed specimens from the Amazons, give no idea of the variety to be found in the Brazilian waters.” In addition to their scientific curatorship of the collections, Mello Netto instructed the directors of each section to teach courses in their fields of research and to publish the results of their work in *Archivos do Museu Nacional* (National Museum archives), a journal that published research findings and news about museum sciences.

Organizing the Brazilian Anthropological Exhibition of 1882, the most important scientific exhibition in nineteenth-century Brazil, gave Mello Netto the experience to participate in another major exhibition, the Exposition Universelle of 1889, in Paris. He actively campaigned for more funding for the museum and invited foreigners visiting the country to attend conferences, participate in field trips, and work at the

institution, including such names as the Canadian-American geologist Charles Hartt (1840–1878), who organized the Geological Commission of the Empire, the American geologist Orville Derby (1851–1915), who headed the geological survey in São Paulo, the Swiss-German naturalist Emílio Goeldi (1859–1917), and the German naturalist Hermann von Ihering (1850–1930); the latter two later headed museums in respectively Belém (Pará State), and São Paulo.

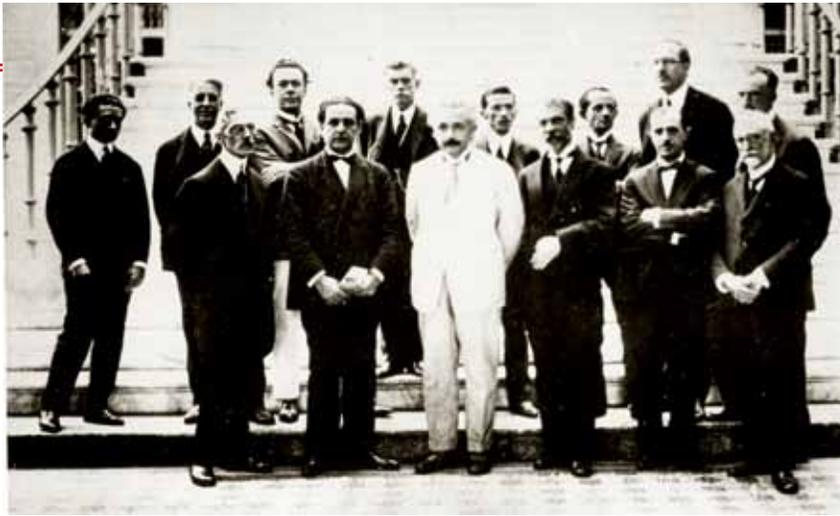
### SCIENCE MUSEUMS IN BRAZIL

“The success and prestige of the National Museum helped to generate interest in the natural sciences in Brazil,” says historian Zita Possamai, a professor in the Graduate Program in Museology and Heritage at the Federal University of Rio Grande do Sul (UFRGS), in Porto Alegre. “The second half of the nineteenth century saw a proliferation of science mu-

seums throughout Brazil.” In 1866, the Philomathic Society of Pará was created in Belém, later becoming the Emílio Goeldi Museum of Pará, in 1871. In 1876, the Paranaense Museum was founded by the Philomathic Society of Curitiba. In 1894 the Museum of the Bahia Institute of Geography and History was opened. That same year, plans were made for the founding of the Paulista Museum.

Following the proclamation of the Republic and the exile of the imperial family, in 1889 the National Museum was relocated to the São Cristóvão Palace at Quinta da Boa Vista. The permanent exhibitions at the museum's new home were opened to the public in May 1900. In the following decades, the institution became increasingly prolific in international scientific collaboration, publishing, and public education. Years later, under the directorship of anthropologist and radio personality Edgar Roquette-Pinto (1884–1954), the museum further enhanced its role in education as a means of building Brazil's science capacity and training future generations. Roquette-Pinto saw education as a way to bring about change and transformation in Brazil.

It was also during his tenure that the museum entertained some of the notable personalities on the global science scene at the time, among them the German physicist Albert Einstein (1879–1955), who visited the museum during a trip



In May 1925, during a trip to South America, the German physicist Albert Einstein (*dressed in white*) used his time in Rio to visit the museum



Juscelino Kubitschek (*dark suit, center*) was one of the last presidents to visit the museum (1958)

to South America. Polish chemist Marie Curie (1867–1934) and her daughter, Irene Joliot-Curie (1897–1956), visited in July the following year, stopping on their way to Belo Horizonte for a conference at the University of Minas Gerais on radioactivity and its potential applications in medicine.

In the 1930s, the newly created Inter-University Graduate Program in Museology at MAE-USP provided an added stimulus to the museum, according to historian Mariana Sombrio. Government concerns over protecting national heritage were increasing, leading in 1933 to the establishment of the Artistic and Scientific Expedition Oversight Board. “The board barred any botanical, zoological, mineralogical or paleontological

specimens from leaving the country unless similar specimens were available at scientific institutions run by the Ministry of Agriculture or the National Museum,” the researcher explains. The board continued to function until 1968. During that period it received 451 applications, mostly from foreigners looking to undertake scientific and artistic expeditions to Brazil.

To enforce these rules, at least one Brazilian researcher, preferably from the National Museum, was required to be on the expedition. “This was so they could report to the authorities on what was being collected,” says Sombrio. This scrutiny was not always effective, however. Many objects were seized at customs offices just before being shipped overseas.

“The museum benefited greatly from this policy, as many items either collected on the expeditions or confiscated in customs were added to its collection.”

The notion that the National Museum should serve the general public gained greater traction between 1937 and 1955 under anthropologist Heloisa Alberto Torres (1895–1977), the first woman to head the institution. She saw it as part of a comprehensive, national cultural framework. Following Torres’s appointment in 1937, she made anthropology into a scientific instrument for preserving Brazilian culture. But scientific museums in Brazil soon began to yield their status as “temples of science” to universities and research institutes. “Scientific knowledge had up until then been developed not in universities, but in museums,” Lopes explains. But as the natural sciences became increasingly specialized, and as experimental studies grew in importance, universities became the place for research, and museums a space for conserving collections.

Their collections, however, were not forgotten. Beginning in the 1930s, museums were gradually incorporated into universities. In January 1946, for example, the National Museum came under the management of the University of Brazil, now the Federal University of Rio de Janeiro (UFRJ). Similarly, the Paulista Museum transferred its collection of zoology to the Museum of Zoology in the late 1930s, and both museums are now administered by USP. In the 1960s the National Museum began training researchers and created Brazil’s first graduate degree program in social anthropology, one of the best in the field, leveraging its extensive collection. In the field of botany, the museum created a master’s degree program in 1972 and a doctoral program—Rio de Janeiro’s first in this field—in 2001. In the years preceding the fire, visitor numbers had remained virtually stagnant. Around 180,000 people visited the institution in 2016, then 192,000 in 2017. As in most museums, only parts of the museum’s collections were exhibited to the public, among them plant and animal specimens of Brazilian biodiversity, mummies from Egypt, indigenous adornments, South American dinosaur skeletons, and the Bendegó meteorite, the largest found in Brazil to date. ■ **Rodrigo de Oliveira Andrade**

# Early-term births on the rise

In 2015, 40% of babies were born before reaching biological maturity, partly because of elective cesarean sections

**Ricardo Zorzetto**

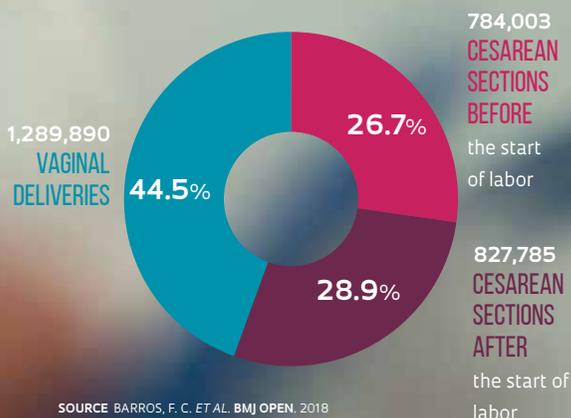
PUBLISHED IN SEPTEMBER 2018

Premature baby in the intensive care unit at the USP teaching hospital



### BIRTHS IN BRAZIL

Approximately 2.9 million children were born in 2015, most by cesarean section (55.5%)



SOURCE BARROS, F. C. ET AL. BMJ OPEN. 2018

For the last decade, Brazil has held the worrisome position of world leader in cesarean sections. The proportion of babies born by cesarean delivery in the country has been growing since the 1970s, surpassing the number of vaginal births in 2009 and remaining the most common method of birth ever since, despite attempts by the government and medical agencies to reverse the trend. Of the 2,903,716 babies born in Brazilian hospitals in 2015, 1,611,788 entered the world via cesarean section (see chart, left). This figure represents 55.5% of all births, an excessively high rate that is topped only by the Dominican Republic, where 56.4% of 172,000 babies are born by cesarean section each year. A high proportion of Brazilian cesareans (48%) may be classed as unnecessary because they are performed before labor begins and therefore before the child is ready to be born. These cesareans, often planned in advance by the obstetrician, may actually endanger the health of the mother and the child rather than protect them.

The largest survey ever performed in Brazil, published online in the journal *BMJ Open* on August 5, confirms the long-held suspicions of epidemiologists, obstetricians, and pediatricians: elective cesareans increase the proportion of babies born before they reach full term. The conclusion arises from a study coordinated by pediatrician and epidemiologist Fernando Barros, a professor at the Federal University of Pelotas (UFPEL) and the Catholic University of Pelotas (UCPEL). Working with colleagues from Uruguay, the UK, and the Brazilian Ministry of Health, Barros cross-referenced the number of births in Brazil in 2015 against information on the type of delivery, gestational age, and education level of the mother.

The data showed that 1,130,676 babies (39.9% of the total) were born at less than 39 weeks, the age at which maternal and infant health specialists consider the baby ready for life outside the uterus. Of this number, 286,000 were born at less than 37 weeks (premature births), probably due to health problems faced by the mother or the baby, and 844,000 were born in the 37th or 38th week of pregnancy. There is a strong indication that in a third of these cases—a total of 370,000 babies—birth occurred earlier than necessary due to elective cesarean sections.

“Those born at 37 or 38 weeks face a small risk of various health complications that could be prevented by postponing delivery,” says Barros. Because these cases represent such a high proportion of births, the researcher explains that such problems can potentially have a significant impact on the public health system. Researchers at the Karolinska Institute and the University of Uppsala in Sweden monitored 550,000 babies born between 1973 and 1979 for a minimum of 23 years. Their findings, pub-

# The skin as a marker of time



The UFMG researcher uses a device that measures the light reflected by skin to estimate the gestational age of a baby

In October, researchers will begin a new study of 790 Brazilian newborns to test the efficiency of a device that estimates the gestational age of a baby at birth based on the light reflected by its skin. The device, which looks like a small flashlight, was developed by researchers at the Federal University of Minas Gerais (UFMG). It uses LEDs to emit low-intensity light and a sensor to capture what is reflected. A mini-processor then uses this information and the baby's weight to calculate how long the infant spent in the womb—the longer the gestation period, the thicker the skin is and the more light it reflects.

Knowing the developmental time (gestational age) of a baby can help doctors provide the best medical care after birth. "Using this information, especially in the case of premature babies, pediatricians decide if the baby needs respiratory support and temperature control or treatment in a neonatal unit," explains gynecologist and obstetrician Zilma Reis, a professor at UFMG who developed the device, called Skin Age, with astrophysicist Rodney Guimarães. "Even in Brazil, which has free and universal access to health services, physicians do not always have reliable information about the gestational age of the infant," says Reis.

She and Guimarães began looking for a noninvasive way to determine the age of newborn babies in 2014, after the Bill & Melinda Gates Foundation issued a call for research

proposals on the subject. They were inspired by the oximeter, a device that estimates the oxygen saturation level of blood using a light that passes through the skin. "The aim was to create a simple device for situations in which prenatal exams have not provided adequate information about the baby's age, or when there is no pediatrician available to calculate it after delivery," she says.

With US \$100,000 from the Gates Foundation and US \$50,000 from the Minas Gerais State Research Foundation (FAPEMIG), Reis and Guimarães analyzed how the skin of the fetus changes and reacts to light during pregnancy, as well as developed initial prototypes and performed clinical tests that provided proof of concept. Applied to the forearm or sole of the foot for just a few seconds, Skin Age estimated the gestational age of 115 babies born in two hospitals in Belo Horizonte with a margin of error of 11 days, according to data published in the journal *PLOS ONE* in 2017.

With funding from the Brazilian Ministry of Health, the group now plans to test the equipment on 790 children from Minas Gerais, Rio Grande do Sul, Maranhão, and Brasília. "We want to use the data to improve the equipment and reduce the error to 7 days," says Reis. A second clinical trial, funded by FIOCRUZ and Grand Challenges Canada, is planned for the next year, involving 400 children from Brazil, Portugal, and Mozambique.

published in *Pediatrics* in 2010, showed that to a lesser extent than premature births, babies born in the 37<sup>th</sup> or 38<sup>th</sup> week of gestation were less likely to complete higher education and more likely to need healthcare services.

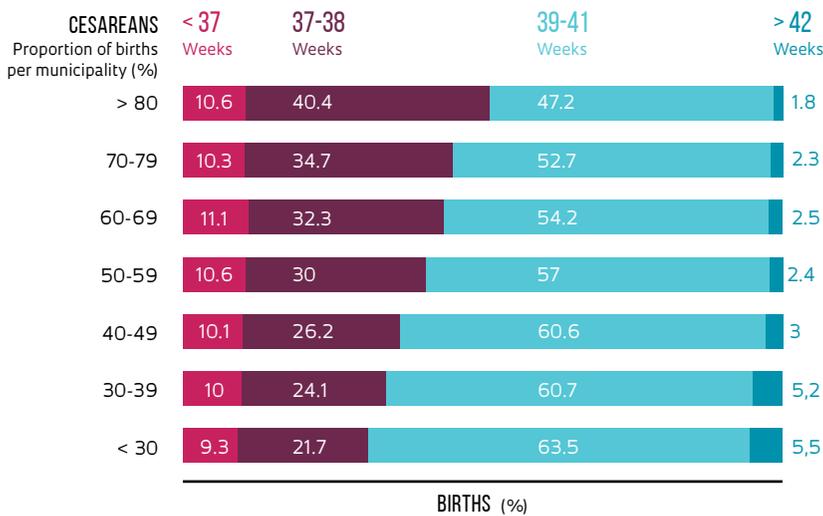
"The results of the study are what we expected," says obstetrician José Guilherme Cecatti, a professor at the University of Campinas (UNICAMP), regarding early-term births in Brazil. Cecatti did not participate in the BMJ Open paper, but, some years ago, he surveyed 33,740 pregnant women in Brazil and identified a high rate of premature births, in part due to the number of cesarean sections being performed. "The merit of the current research is that it shows the extremely high numbers involved in this phenomenon. It shows that a large number of cesareans are being performed too early."

There is one particular finding that reinforces the hypothesis that surgery is often performed with no medical justification. The proportion of cesarean sections conducted before labor begins increased steadily alongside the education level of the mother, which is an indicator of socioeconomic status. Of the 163,000 women with four years of education or less, who are generally poorer and likely face more health problems, 13.2% had a cesarean section before labor. The proportion reached 49.2% among the 528,000 mothers with a university degree, who in theory are more wealthy, healthy, and well informed. "British epidemiologist Julian Tudor Hart called this phenomenon the reversal of care. Those who need the most receive the least," says pediatrician Marco Antonio Barbieri, a professor at the University of São Paulo in Ribeirão Preto (USP-RP).

"Populational studies suggest that early-term birth as a phenomenon will follow the path of cesareans, initially more frequent among the wealthier classes and now also becoming increasingly common among the poorest," says pediatrician Heloísa Bettiol, a colleague of Barbieri and a professor at USP-RP. This effect has been noticed in studies that began in Ribeirão Preto in 1978 in the interior of the state of São Paulo. The proportion of babies born by cesarean section in the 37<sup>th</sup> or 38<sup>th</sup> week of pregnancy rose from 28% in 1978–1979 to 54% in 1994 and 68% in 2010, accord-

# The impact of cesarean sections

The proportion of babies born before 39 weeks increases in direct relation to the number of surgical deliveries, according to 2015 data from 520 municipalities



SOURCE BARROS, F. C. ET AL. *BMJ OPEN*. 2018

ing to data that Barbieri and Bettiol presented to the Ministry of Health in 2017. Barros and his colleagues observed a similar association in the Pelotas studies (see Pesquisa FAPESP issue no. 228).

In the *BMJ Open* study, the relationship between cesarean sections and early births was even more evident when Barros and colleagues analyzed 2.5 million births (82.4% of the total) for which they had the best quality information, grouped by municipality. In towns where surgery accounted for more than 80% of births, the number of babies born in the 37th or 38th week was 62% higher than in municipalities where cesarean sections represented less than 30% of births, which is still twice as many as the number recommended by the World Health Organization. The probability of a baby being born premature was 22% higher in the first group of towns than in the second group (see graph above).

Obstetricians and pediatricians have always been more concerned about premature babies born at less than 37 weeks, who are at the greatest risk of health problems. More recently, however, research has suggested that those born at 37 and 38 weeks, known as early-term births, also face an increased risk of health complications in the first few weeks of life and

moderate cognitive development problems in later years. "Early-term births never received much attention because babies were considered old enough to be born at that age," says Barros. "However, they would benefit from another one or two weeks in the womb."

A common problem for babies born between the 34<sup>th</sup> and 37<sup>th</sup> weeks of pregnancy is that their lungs—one of the last organs to mature—are not yet fully prepared to breathe. Premature babies are thus at greater risk of respiratory distress, often requiring oxygen supplementation and treatment in intensive care away from their mother. According to pediatrician Maria Augusta Gibelli, head of the neonatal ICU at the USP teaching hospital, premature babies may not have developed the ability to properly breastfeed, which can lead to low blood-sugar levels, requiring supplementary formula made from cow's or goat's milk in their first few days of life.

Epidemiologist Maria do Carmo Leal, a professor at the National School of Public Health in Rio de Janeiro, quantified these risks based on information from 12,646 premature babies born in 266 Brazilian hospitals in 2011 and 2012 and monitored for at least 45 days. Published in *BMJ*

*Open* in December 2017, her analysis of the representative sample confirms that an additional week or two in the womb can make a significant difference.

Even healthy babies born at 37 or 38 weeks had a low but greater risk of complications in their first few hours and weeks of life than those born at 39 or 40 weeks. From the first group, 3.9% had to receive oxygen after delivery, compared to 2.1% in the second group. A similar proportion required bili light therapy in the first three days of life to neutralize excess bilirubin, a protein that is toxic to the central nervous system. Low glucose levels, known as hypoglycemia, were three times more common among infants born at 37 or 38 weeks (0.9%) than among those born at 39 or 40 weeks (0.3%).

Complications were much more likely when babies in the first group were born due to early obstetrical interference, such as an elective cesarean section when neither mother nor baby were suffering any health problem. This was true in just under half of the cases and tripled the need to receive oxygen (from 1.3% in babies born at 39 or 40 weeks to 4.5% in those born at 37 or 38 weeks), more than doubled the chance of needing treatment in the ICU (from 1.5% to 3.6%), and increased the risk of dying in the first month of life by nine times (from three deaths per 10,000 births in the first group to 26 per 10,000 in the second). "In Brazil, these early interventions are especially common in private hospitals," says Maria do Carmo, who described this phenomenon in a paper published in the journal *PLOS ONE* in 2016.

"The woman's right to choose a cesarean should not trump the child's right to be born at 39 weeks or more," says Fernando Barros, from Pelotas. ■

## Project

Etiological factors of premature birth and consequences of perinatal factors on infant health: Birth cohorts in two Brazilian cities (no. 08/53593-0); **Grant Mechanism** Thematic Project; **Principal Investigator** Marco Antonio Barbieri (USP); **Investment** R\$3,289,922.80.

## Scientific articles

BARROS, F. C. *et al.* Cesarean sections and the prevalence of preterm and early-term births in Brazil: Secondary analyses of national birth registration. *BMJ Open*. Aug. 5, 2018.

LEAL, M. C. *et al.* Burden of early-term birth on adverse infant outcomes: A population-based cohort study in Brazil. *BMJ Open*. Dec. 27, 2017.

# Doubling the effort against cancer

Hospitals such as ICESP and A.C. Camargo combine basic research with applied research in the search for better treatments for tumors

**Suzel Tunes**

PUBLISHED IN DECEMBER 2018



Bringing the laboratory bench closer to the patient's bedside is becoming a key objective for oncology centers and specialized institutes, as well as for general hospitals with sectors dedicated to the study and treatment of cancer. This trend has been verified in both standard public institutions and private establishments. The Cancer Institute of the State of São Paulo (ICESP), which was established 10 years ago and has cared for 95,000 patients, has quickly built bridges between treatment and research. Since the institute was established, its 25 full-time researchers have published close to 1,000 scientific articles. On the eighth

floor of the ICESP facility, which belongs to the government of the state of São Paulo and is located in the state capital, there is a small service elevator to the 13<sup>th</sup> and 14<sup>th</sup> floors, where the hospital's 18 surgical rooms are located. Tumors removed from patients are transported on this elevator to one of the laboratories of the Center for Translational Research in Cancer (CTO), where nearly 500 diagnoses are made each month. From the pathology laboratory, the material used for diagnosis—now divided into hundreds of samples of tumor cells and tissues preserved on glass slides and in paraffin blocks—continues to the biobank. This information is added to the

patient's record, and these samples remain available for research projects that are often born from questions posed by physicians who work in treatment.

The path of the 23,000 samples of biological material in the biobank demonstrates the dynamics and philosophy of the work performed at the CTO. "ICESP is making a significant social impact in its work providing care, and the impact of its research is the generation of knowledge. The combination of care and research allows for desired and possible synergies to arise," comments Roger Chammas, professor of oncology at the University of São Paulo School of Medicine (FM-USP) and coordinator of the CTO.



Storage of a subproduct of samples of biological material from the biobank at ICESP and analysis of melanoma cell imaging (right) in the institute's laboratory



The structure of ICESP itself encourages the consolidation of efforts: the building has 28 floors with dedicated spaces where teaching, research, and medical care coexist.

The biobank is a principal meeting point for researchers from ICESP and other institutions. However, it is not the only one. The laboratories occupy close to 1,500 m<sup>2</sup>, representing 60% of the 8<sup>th</sup> floor, and are shared by researchers from various areas, including cellular and molecular biology, genetics, pathology, virology, biotechnology, and epidemiology. When ICESP was created, dozens of researchers dedicated to the study of cancer were spread out among vari-

ous USP sites. “Our plan was to create a structure that would accommodate the samples required and provide access to advanced technology for all of these research groups, with the docents of the Oncology Department managing the center,” recalls Chammas. That is how the CTO came about.

The biobank, which facilitated the planning carried out by the research groups, made it possible to begin collecting material before funding for the scientific project was received. “The biobank is a treasure,” confirms physician Maria Aparecida Koike Folgueira, head of the department of radiology and oncology at FM-USP, which leads various

studies on genetic and environmental factors in young patients with cancer. “Before, we could only begin to collect samples after the project was initiated.”

#### TRANSLATIONAL MOVEMENT

Since 2010, when the CTO structure was built, more than R\$73 million has been invested in research: R\$2.5 million was donated by the Ermírio de Moraes family and was used to build the laboratories, with the rest coming from ICESP itself, the National Support Program for Oncology Care (PRONON), the Ministry of Health, and from projects funded by FAPESP. The CTO houses 13 projects divided into four research programs:

therapeutic and diagnostic innovation, molecular oncology, epidemiology, and clinical research and prevention. Chammas avoids making distinctions between basic research and applied research. “We want to answer questions. If the question requires basic research, we go in that direction. Translational research transfers the knowledge generated by the basic area for clinical use, a medical application,” confirms the researcher. “Brazil does not have a history of translational medicine, but this is changing. Researchers are beginning to see that work cannot be done in isolation,” notes American molecular biologist Bryan Strauss, who manages the ICESP Viral Vector Laboratory.

Strauss has been in Brazil since 1998 and leads a genetic therapy project that aims to develop a form of immunotherapy for melanoma, the most aggressive form of skin cancer. In this technique, a neutralized virus is inserted into the patient’s cells and used as a carrier of two suppressor genes for the tumor. “They cause the tumor cells to die and release elements that induce an immunological response against these cells,” explains the molecular biologist. “Thus, the genes ‘teach’ the organism how to protect it-

self.” In the laboratory, Strauss has the opportunity to analyze the behavior of cancer cells taken from ICESP patients undergoing treatment, which enables him to assess the heterogeneity of the tumors and the differences in their response to treatment. At the same time, he is seeking to understand, using rodents, the reaction of the immune system to genetic therapy. In the future, Strauss plans to use dogs in his research. “Cancer in dogs is similar to cancer in humans. Studies with rodents have many limitations,” he explains.

The A.C. Camargo Cancer Center, a private nonprofit institution in São Paulo that is funded by the Antônio Prudente Foundation, also invests in efforts to bring treatment closer to research.

## Translational research transfers knowledge generated in basic research to clinical use, says Roger Chammas

According to biochemist Vilma Regina Martins, superintendent of research for the institution, 18 experts are dedicated full-time to research, but there are also professionals on the clinical team who do research and advise postgraduate students funded by the hospital. In total, 60 professionals of the 600 physicians who work for the institution are involved in research. Last year, 77 postgraduate students completed their degrees and published a total of 182 articles in international scientific journals.

The hospital has an exclusive area for scientific activities—the International Center for Research (CIPE), a building that is located near the institution’s headquarters and measures 4,000 m<sup>2</sup>. In this center’s laboratories, translational research is carried out by groups in genomic and molecular biology, bioinformatics, investigative pathology, immunoncology, tumor biology and biomarkers, epidemiology, and biostatistics. “We have participated in clinical trials for the past 10 years,” says Martins. Every year, A.C. Camargo invests close to R\$18 million of its own funds in research, in addition to R\$4 million obtained from funding agencies and other sources.

In October 2017, a new research group was launched led by American immunologist Kenneth Gollob, who has been based in Brazil for 20 years. His team monitors close to 300 patients, primarily those with tumors in the lungs, stomach, head, and neck or with melanoma, who have received some form of immunotherapy recognized by the Brazilian Health Regulatory Agency (ANVISA). The goal of his team is to observe the response of each patient during treatment. “Close to 25% of oncology patients respond well to this therapy. Many suffer from side effects that we are not yet able to control. However, for those who undergo immunotherapy, the response is very good. We have patients who had a



In 2017, the Hospital de Amor in Barretos inaugurated the Molecular Research Center for Prevention



Equipment used in DNA sequencing for oncology studies at the Sírio-Libanês Hospital in São Paulo

prognosis of two months to live and who, after treatment, are still alive more than five years later,” reports Martins. “Each year, immunotherapy is approved for more types of tumors.”

#### PERSONALIZED THERAPY

At the Sírio-Libanês Hospital—a private institution headquartered in São Paulo—the Teaching and Research unit is also focused on research that has the potential to move from the bench to the medical clinic. “The first question we want to answer is how to identify changes that can cause patients with the same kind of tumor to present different responses to treatment,” confirms biochemist Luiz Fernando Lima Reis, director of the unit. He says that 100% of current studies are focused on the identification of biomarkers that can support therapy selection. “We have two lines of research: the search for tumor changes to support treatment decisions and the early diagnosis of resistance to certain drugs,” explains Lima Reis.

Studies are carried out at the Sírio-Libanês Center for Molecular Oncology, which was established in 2011 when the Ludwig Cancer Research Institute left the Oswaldo Cruz German Hospital. “With the shutdown of activities at Ludwig in Brazil, the institute’s oncology group, which was then led by geneticist Anamaria Aranha Camargo, came to Sírio,” notes Lima Reis. Today, Aranha Camargo leads the center, which occupies close to 6,000 m<sup>2</sup> and is located within the hospital complex. She leads a team of approximately 20 researchers.

Also in the state of São Paulo, the newly named Hospital de Amor (formerly the Cancer Hospital of Barretos), has for the past eight years funded the Teaching and Research Institute and maintains ties to its postgraduate program in oncology. There are four lines of research: palliative care and quality of life, epidemiology and prevention, clinical and surgical oncology, and molecular oncology and pathology. According to the molecular biologist Rui Manuel

Reis, scientific director for the Teaching and Research Institute, more than 200 professionals are involved in scientific studies; of these professionals, 30 are postgraduate program advisors, and 10 are full-time researchers. The building offers them a 3,000-m<sup>2</sup> area that includes the Dr. Ricardo Renzo Brentani Tumor Bank. “Today, we have more than 220,000 samples of tumor tissue, blood, and other fluids from more than 40,000 patients, collected between 2006 and 2018. These samples are extremely valuable for translational medicine,” confirms Reis.

Reis explains that the biobank has been fundamental in providing support to genomic research, which aims to map genetic changes to develop personalized cancer therapy. “The majority of the drugs we use were developed for the profile of foreign patients. Few studies explore the genetic profile of the Brazilian population,” notes Reis. The Hospital de Amor is involved in various national and international research consortiums, such as the International Cancer Genome Consortium (ICGC), which includes representatives from 16 countries. In this consortium, a project developed by Brazilian researchers is performing the genetic mapping of melanoma.

The studies carried out by the Hospital de Amor, whose patients are always served by the Brazilian Unified Health System (SUS), depend almost exclusively on grants from funding agencies. Today, close to R\$10 million has been allocated to teaching and research. In 2015, the institution received funds from a large labor settlement in Brazil.

Shell/BASF had to pay damages to employees, in addition to compensation of R\$200 million, as the result of a lawsuit filed by the Brazilian Ministry of Public Service against its Campinas factory for causing occupational illness. The funds were applied to eight nonprofit units that provide services to SUS. The Hospital de Amor received R\$70 million, which was invested in three initiatives: the construction of the Molecular Research Center for Prevention in Barretos and the Institute for Prevention in Campinas, both of which were inaugurated in 2017, and the acquisition of four trucks to operate as mobile clinics to provide free cancer testing and educational programs. ■

# Sources of methane

Two thousand craters releasing the greenhouse gas found off the Brazilian coast

Carlos Fioravanti

PUBLISHED IN SEPTEMBER 2018

Two research groups—one from São Paulo and the other from Rio Grande do Sul—have identified nearly 2,000 craters on the sea floor approximately 200 kilometers (km) off the south and southeast coast of Brazil. Reaching up to 230 meters (m) in diameter and 90 m deep, the holes on the seabed, known as pockmarks, are formed by the expulsion of gas, primarily methane (CH<sub>4</sub>), one of the main greenhouse gases. It is estimated that most of the methane, however, is consumed by bacteria and other ocean organisms before reaching the atmosphere.

There is not yet any data on how much the Brazilian coastal craters contribute to the country's total greenhouse gas emissions, which stood at approximately 2 bil-

lion tons in 2014, representing approximately 5% of the global total, according to the Brazilian Ministry of Science, Technology, Innovation, and Communications (MCTIC). Produced mainly by livestock and waste treatment processes, methane accounts for 24% of global net emissions (the volume of gas remaining in the atmosphere after subtracting the carbon removed by human interventions such as reforestation). Carbon dioxide (CO<sub>2</sub>), which results primarily from the burning of fossil fuels, accounts for 64% of net emissions, and nitrous oxide (N<sub>2</sub>O) from soil fertilization represents 12%. Methane remains in the atmosphere for much less time than CO<sub>2</sub>, but its capacity to retain heat is 21 times greater; N<sub>2</sub>O, in contrast, holds 310 times more heat than CO<sub>2</sub>.

According to estimates published in *Nature Geoscience* by the Max Planck Institute of Marine Microbiology and the Center for Marine Environmental Sciences (MARUM) at the University of Bremen, both in Germany, methane produced at the bottom of the ocean by decomposing organic material, especially in these craters, probably contributes to between 1% and 5% of global methane emissions to the atmosphere. "Recent studies suggest that methane produced at depths greater than 100 m barely reaches the surface of the sea," says geologist Anthony Rathburn, a professor at California State University, USA. "The dissolved methane is often oxidized, forming CO<sub>2</sub>, by microorganisms in the water column." The resulting CO<sub>2</sub>

# under the sea



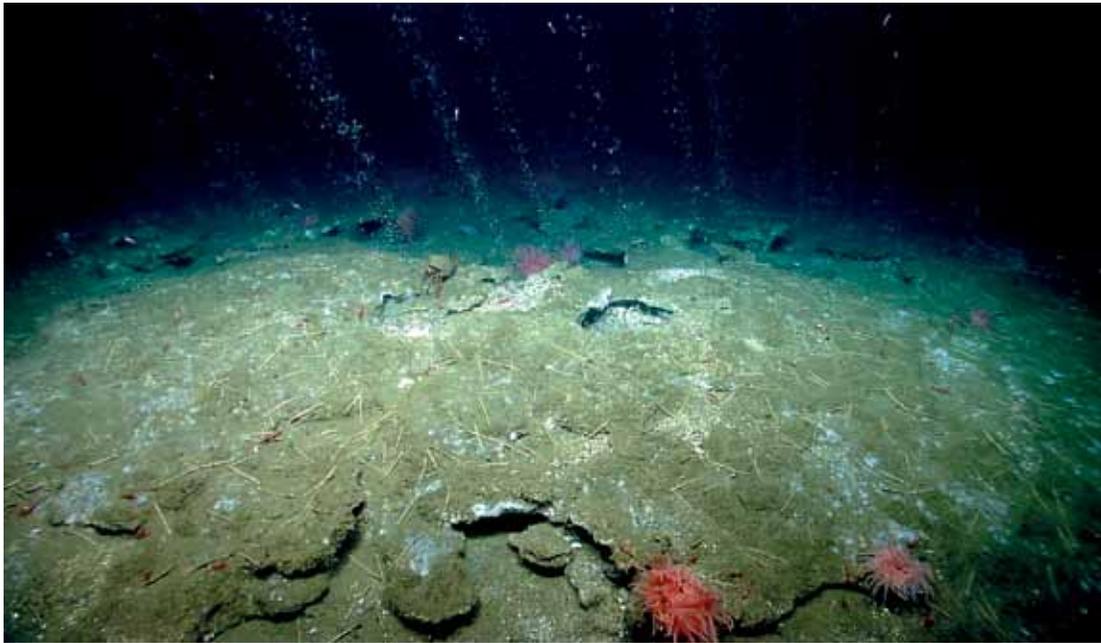
Profile of the seabed off the southeast coast of Brazil, measured using a depth sonar; the depressions are the craters that produce methane

is consumed by marine organisms before it can reach the atmosphere.

These types of underwater craters are economically valuable because they can indicate the presence of natural gas reservoirs. In 2011 and 2013, researchers from the Pontifical Catholic University of Rio Grande do Sul (PUC-RS) and Petrobras mapped approximately 1,000 underwater craters off the coast of Rio Grande do Sul and used them to identify hydrocarbon reserves in the Pelotas basin, a 250 km<sup>2</sup> area in the south of Rio Grande do Sul state. "Based on the initial studies, we believe this area has very large reserves of natural gas that could be exploited in the future," says chemist Luiz Frederico Rodrigues, a researcher at the Institute for Petro-

leum and Natural Resources at PUC-RS. The sediment in this area contains carbohydrates—crystalline solids formed of water and gases—that preserve large volumes of methane, as described in an article published in *Revista Brasileira de Geofísica* (Brazilian journal of geophysics) in September 2017.

In 2016, a team from the Oceanographic Institute at the University of São Paulo (IO-USP) identified 984 craters in an area 130 km long by 30 km wide off the south coast of São Paulo to the north of Rio Grande do Sul. According to a study published in the *Journal of Geochemical Exploration* in September, some of the craters are still emitting methane. "It is difficult to know which ones are releasing gas and which ones



Methane bubbles rise from sediment on the seabed off the coast of Virginia, USA, providing sustenance to anemones, worms, and microorganisms

have already stopped. The only way to find out would be by using a methane sensor, which we don't currently have," says geologist Michel Mahiques, a professor at IO-USP and coordinator of the expedition on the Alpha Crucis that enabled the team to identify the craters. The formations are distributed at marine depths of 300 to 700 m. "In December 2017, we carried out new surveys in the

area and discovered even larger pockmarks in deeper regions," he says.

"Methane was released into the ocean at greater rates in the past, especially during the ice age, when the sea level dropped by about 120 m and the water pressure on seafloor gas reservoirs was lower," says Brazilian biologist Rodrigo Portilho-Ramos, currently a researcher at MARUM in Bremen. In a study conduct-

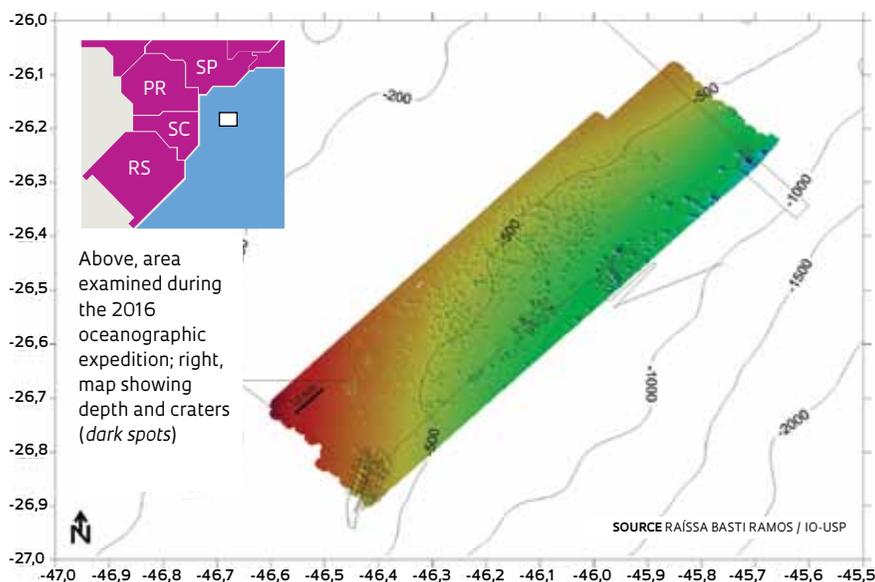
ed at Fluminense Federal University and USP in collaboration with Rathburn and other specialists from Germany and the US, Portilho-Ramos found that fossilized shells collected from a crater at a depth of 475 m off the coast of Florianópolis, Santa Catarina state, had lower carbon levels than samples taken from surrounding areas. The varying carbon contents are the result of an intense but not-yet-quantified release of methane between 40,000 and 20,000 years ago—about the time of the last ice age—according to an article published in *Scientific Reports* in April 2018.

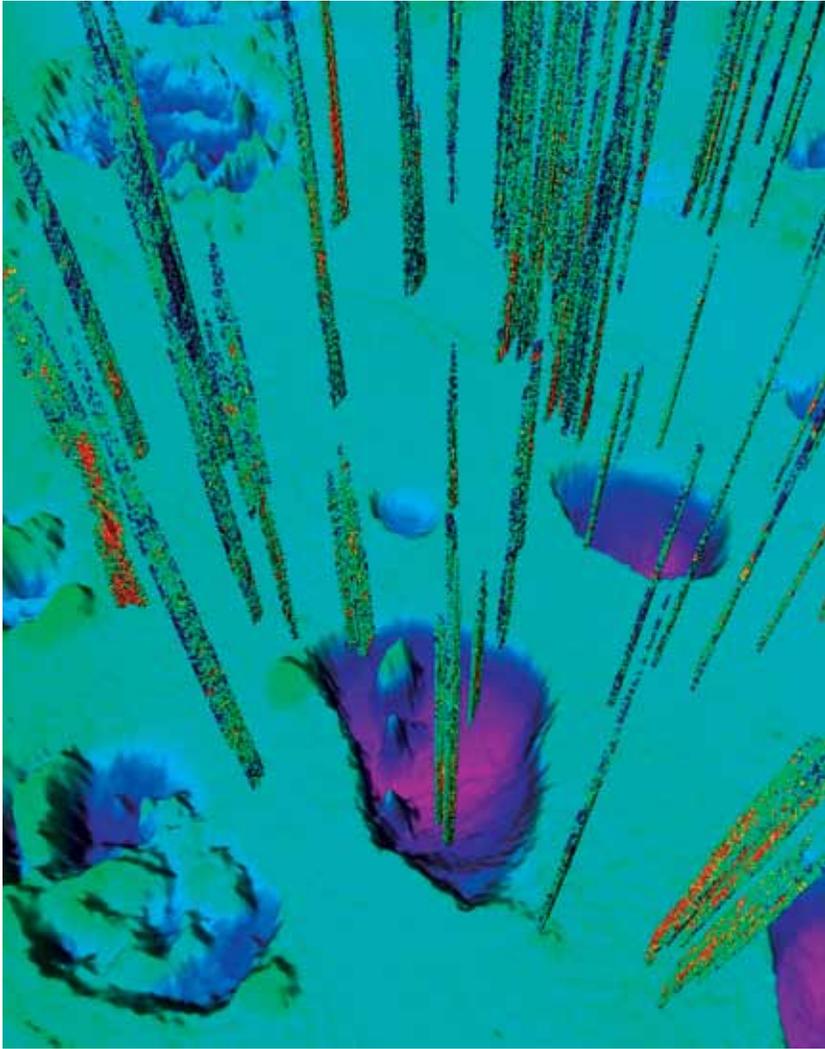
The craters off the São Paulo coast and others near the Abrolhos reefs between the states of Bahia and Espírito Santo were first discovered separately in 2007 by researchers from the Federal University of Rio Grande and were initially believed to be remnants of caves. In 2016, the USP group conducted a comprehensive survey, finding that the craters are abundant and some release methane. However, it is not yet known how many there are off the Brazilian coast and how many are emitting methane. "The Brazilian sea floor has not been mapped in detail by research institutions. Although oil companies and their service providers have a lot of information, they rarely release it for public use because it could contain information on oil and natural gas reserves," says Mahiques.

The gas released off the southeast coast is caused mainly by rising salt col-

## Where the sea floor is deeper

Survey identifies 984 craters on the seabed between southern São Paulo and northern Rio Grande do Sul





Artist's depiction of craters releasing methane on the Arctic seabed

umns beneath the seabed, according to a study published by the USP researchers in the scientific journal *Heliyon* in February 2017. Because of the intense pressure to which they are subjected, these columns of salt—known as diapirs—break the overlying rocks of the sea floor, which then sink, forming a crater. This process leads to the release of methane trapped in the remains of dead animals and plants that accumulate on the seabed.

#### BIOLOGICAL RICHNESS

These craters form unique environments where communities of microorganisms, mollusks, and other invertebrates are more diverse and abundant than in neighboring regions. In an article published in the journal *Limnology and Oceanography* in October 2007, researchers from Norway and the US found that

in one area of the Arctic Ocean, at 1,200 m deep, there were 2.5 times as many species in methane-rich areas than in surrounding regions. In these areas, the authors of the paper noted that life is sustained by methane, not sunlight, which cannot reach the deep sea.

In her laboratory at IO-USP, biologist Vivian Pellizari grows bacteria and other microorganisms that produce methane during the degradation of organic matter on the sea floor, an environment devoid of oxygen. "The challenge now is to keep these cultivations viable until the microorganisms are isolated," says Vivian, who wants to discover the diversity of microorganisms on the seabed that produce and consume methane. She is on the scientific committee of the São Paulo School of Advanced Methane Science, a conference to be held in Ilhabela, on the coast of São Paulo state, in October,

## Methane is the main source of energy for organisms living on the sea floor where there is no oxygen or sunlight

whose purpose is to discuss the origins and transformations of methane in sea and land environments.

The first underwater craters of this type were discovered off the coast of Nova Scotia in Canada in the late 1960s by a team from the Bedford Institute of Oceanography. Detected by what was a new sonar system at the time, the craters in Nova Scotia were 150 m wide and 10 m deep. They were soon identified all over the world. In 2013, researchers from New Zealand, Germany, and the US discovered the largest underwater craters ever found, 500 km east of Christchurch, New Zealand. The largest craters in this region were 11 km in diameter and 100 m deep, approximately 1 km from the sea surface. They were likely created by gases erupting through the sediments, but they do not seem to have released higher levels of methane than other, smaller craters. ■

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#### Project

Anomalous seafloor features of the Southeastern Brazilian upper slope (no. 16/22194-0); **Grant Mechanism** Regular Research Grant; **Principal Investigator** Michel Michaelovitch de Mahiques (USP); **Investment** R\$231,247.09.

#### Scientific articles

SANTOS, R. F. dos *et al.* Metal/Ca ratios in pockmarks and adjacent sediments on the SW Atlantic slope: Implications for redox potential and modern seepage. **Journal of Geochemical Exploration**. v. 192, p. 163–73. Sept, 2018.  
 PORTILHO-RAMOS, R. C. *et al.* Methane release from the southern Brazilian margin during the last glacial. **Scientific Reports**. v. 8, i. 1, 5948. Apr. 13, 2018.

Other cited articles are listed in the online version of this article.

# Unusual Stars

Researchers puzzled by recent discoveries of stars with variable brightness

PUBLISHED IN DECEMBER 2018

**B**razilian astronomer Roberto Kalbusch Saito was searching for stars that brighten at regular intervals—which helps scientists calculate galactic distances—when he encountered an object behaving strangely that he has been unable to explain. Described in an article published in the journal *Monthly Notices of the Royal Astronomical Society in November*, the enigmatic star was named VVV-WIT-07. WIT stands for “what is this?” The number indicates that the star is the seventh object to display this unexpected behavior from the approximately 800 million that have been observed between 2010 and 2018 by the Vista telescope in Chile, which is creating a three-dimensional, high-resolution map of the center of the Milky Way.

Of the seven objects detected by Vista whose brightness fluctuates abnormally, six showed an initial increase in light emission that then faded. This behavior led the astronomer of the Federal University of Santa Catarina (UFSC) and his colleagues to speculate that these objects are stars that have experienced surface eruptions. The exception was VVV-

WIT-01, which vanished after emitting a burst of light, possibly having suffered an explosive death. However, VVV-WIT-07 behaved differently than the other six objects. Instead of increasing in brightness, this star experienced several dips in luminosity, as if a dense body was passing in front of the star and preventing a portion of its light from reaching Earth.

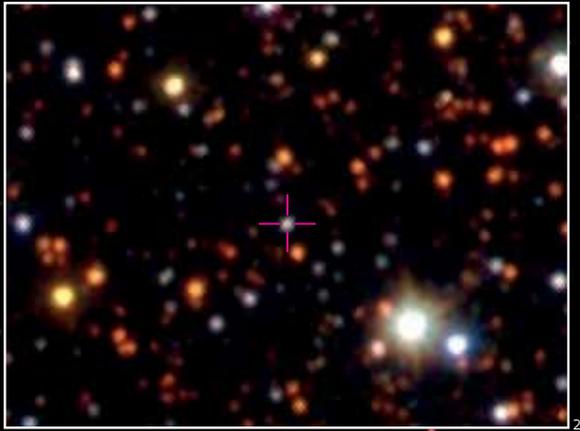
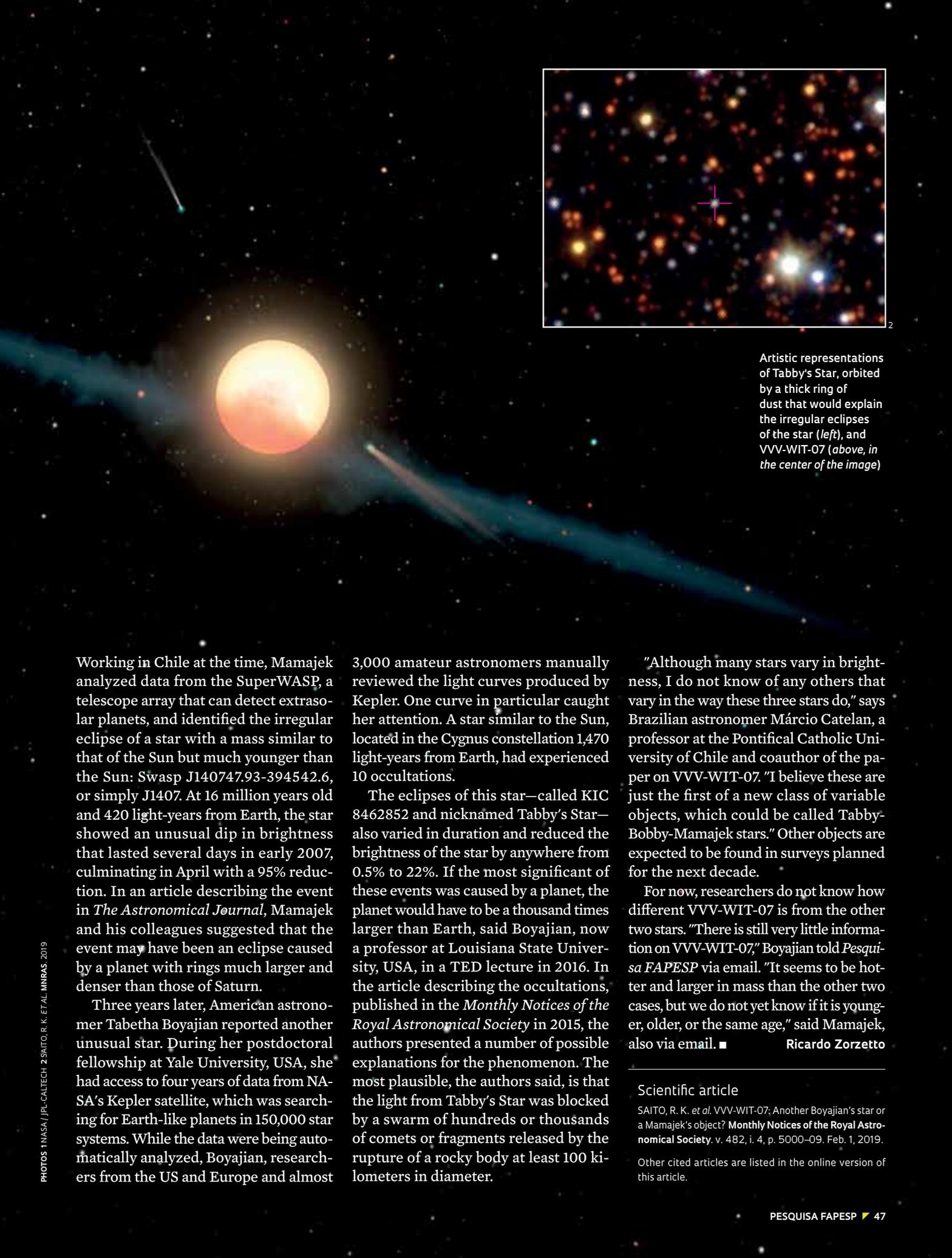
Saito and his colleagues noted that these eclipses were highly irregular. The reductions in brightness were variable, and the frequency of the reductions was inconsistent. Stellar eclipses, caused when the light from a star is obscured by a planet or a smaller star, usually occur at regular intervals and can be mapped on light curve graphs, which show how the brightness varies over time. Each eclipse causes a decrease in the amount of light reaching Earth, followed by an increase in brightness, always with the same duration and intensity. “When a spherical body like a planet passes in front of a star, it generates a U-shaped graph,” explains Saito.

This effect was not the case for VVV-WIT-07. Observed 85 times in the last

eight years, this star—which appears to be older than the Sun and has an unknown mass—suffered at least four major dips in luminosity of varying intensities and durations. The longest reduction in brightness occurred in 2012.

In late May of that year, the star slowly began to lose brightness over a period of 48 days. In July, the luminosity of the star abruptly decreased by 80% in an event that lasted 11 days. At the end of the eclipse, the star returned to its previous brightness within just a few days. “VVV-WIT-07 does not fit into any existing category of variable star,” says Saito. He is still unable to offer a detailed explanation for the eclipses. The variations could be caused by remnants of a newly formed planetary system, clouds of dust released by a low-mass star, or fragments of a planet that suffered a recent collision. “We do not know what we’re seeing,” he says.

To date, only two other stars have exhibited similar behavior. The first star was described in 2012 by American astronomer Eric Mamajek, a professor at the University of Rochester, USA.



Artistic representations of Tabby's Star, orbited by a thick ring of dust that would explain the irregular eclipses of the star (left), and VVV-WIT-07 (above, in the center of the image)

PHOTOS: 1 NASA / JPL-CALTECH 2 SAITO, R. K. ET AL. MNRAS, 2019

Working in Chile at the time, Mamajek analyzed data from the SuperWASP, a telescope array that can detect extrasolar planets, and identified the irregular eclipse of a star with a mass similar to that of the Sun but much younger than the Sun: Swasp J140747.93-394542.6, or simply J1407. At 16 million years old and 420 light-years from Earth, the star showed an unusual dip in brightness that lasted several days in early 2007, culminating in April with a 95% reduction. In an article describing the event in *The Astronomical Journal*, Mamajek and his colleagues suggested that the event may have been an eclipse caused by a planet with rings much larger and denser than those of Saturn.

Three years later, American astronomer Tabetha Boyajian reported another unusual star. During her postdoctoral fellowship at Yale University, USA, she had access to four years of data from NASA's Kepler satellite, which was searching for Earth-like planets in 150,000 star systems. While the data were being automatically analyzed, Boyajian, researchers from the US and Europe and almost

3,000 amateur astronomers manually reviewed the light curves produced by Kepler. One curve in particular caught her attention. A star similar to the Sun, located in the Cygnus constellation 1,470 light-years from Earth, had experienced 10 occultations.

The eclipses of this star—called KIC 8462852 and nicknamed Tabby's Star—also varied in duration and reduced the brightness of the star by anywhere from 0.5% to 22%. If the most significant of these events was caused by a planet, the planet would have to be a thousand times larger than Earth, said Boyajian, now a professor at Louisiana State University, USA, in a TED lecture in 2016. In the article describing the occultations, published in the *Monthly Notices of the Royal Astronomical Society* in 2015, the authors presented a number of possible explanations for the phenomenon. The most plausible, the authors said, is that the light from Tabby's Star was blocked by a swarm of hundreds or thousands of comets or fragments released by the rupture of a rocky body at least 100 kilometers in diameter.

"Although many stars vary in brightness, I do not know of any others that vary in the way these three stars do," says Brazilian astronomer Márcio Catelan, a professor at the Pontifical Catholic University of Chile and coauthor of the paper on VVV-WIT-07. "I believe these are just the first of a new class of variable objects, which could be called Tabby-Bobby-Mamajek stars." Other objects are expected to be found in surveys planned for the next decade.

For now, researchers do not know how different VVV-WIT-07 is from the other two stars. "There is still very little information on VVV-WIT-07," Boyajian told *Pesquisa FAPESP* via email. "It seems to be hotter and larger in mass than the other two cases, but we do not yet know if it is younger, older, or the same age," said Mamajek, also via email. ■ Ricardo Zorzetto

Scientific article

SAITO, R. K. *et al.* VVV-WIT-07: Another Boyajian's star or a Mamajek's object? *Monthly Notices of the Royal Astronomical Society*, v. 482, i. 4, p. 5000–09, Feb. 1, 2019.

Other cited articles are listed in the online version of this article.

# Renewing the fleet

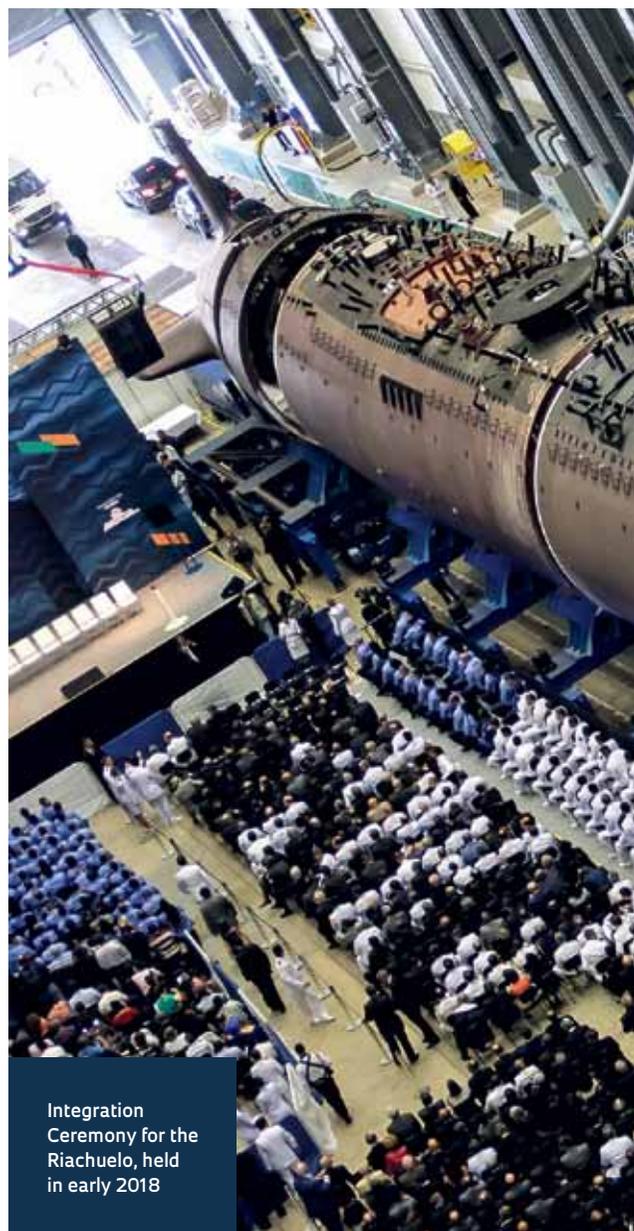
The Brazilian Navy launches the Riachuelo, the first of five submarines that will set a new technological benchmark for the national naval industry

**Domingos Zapparoli**

PUBLISHED IN DECEMBER 2018

**A**fter six years of construction, the Riachuelo is scheduled to be launched in December. The launch will take place in Itaguaí, in the metropolitan region of Rio de Janeiro. The Riachuelo is the first of five submarines—four conventional and one nuclear-powered—that are being manufactured in Brazil as part of the Navy's Submarine Development Program (PROSUB). In addition to patrolling and defending the so-called Blue Amazon, a maritime area of 4.5 million square kilometers rich in biodiversity and resources such as presalt oil reserves, the submarines are giving an important boost to the technological development of the Brazilian naval industry.

The amount invested in PROSUB is estimated at R\$31.85 billion. The program includes the construction of an industrial complex in Itaguaí with two shipyards (one for construction and one for maintenance), a naval base, and the Manufacturing Unit for Metallic Structures. After the Riachuelo, the schedule calls for the completion of the conventional submarines Humaitá in 2020, Tonelero in 2021, and Angostura in 2022. The launch of the nuclear submarine, the SN-BR Álvaro Alberto, is scheduled for 2029 (see inset on page 79). With the completion of that submarine, Brazil intends to join the small group of six countries that possess



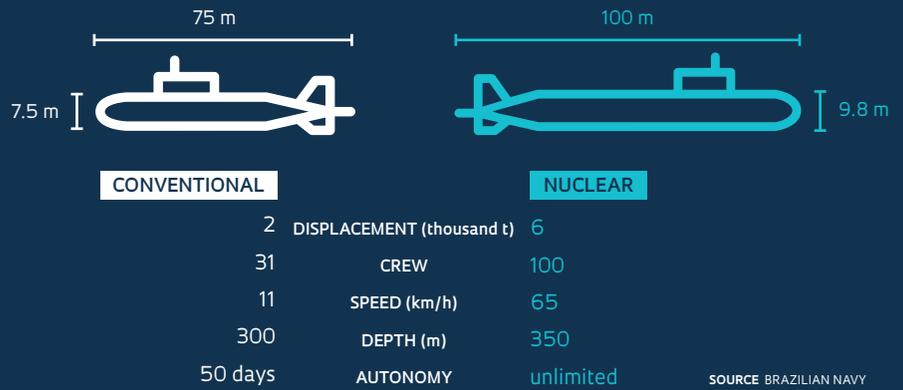
Integration Ceremony for the Riachuelo, held in early 2018

nuclear submarine technology, made up of China, the United States, France, the United Kingdom, Russia, and India.

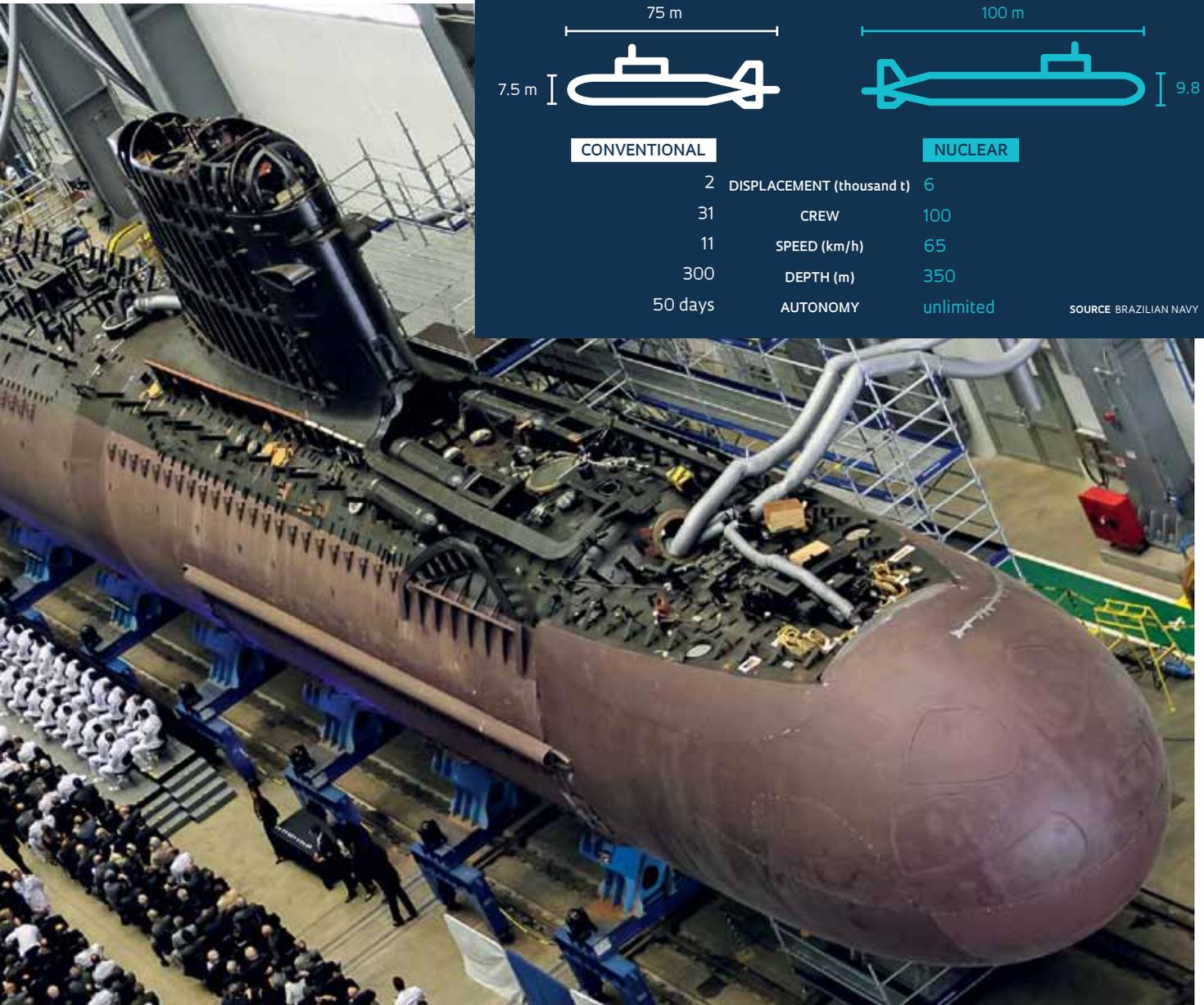
As they come online, the new S-BR Riachuelo-class conventional submarines will replace the current fleet of five Tupi-class vessels, says Admiral Bento Costa Lima Leite de Albuquerque Junior, the Navy's Director-General of Nuclear and Technological Development (who was appointed the Minister of Mines and Energy a few weeks after being interviewed for this story.) The

# Naval force

Principal characteristics of submarines under construction in Brazil



SOURCE: BRAZILIAN NAVY



Tupi submarines were manufactured in the 1980s and 1990s. One was built in Germany and the others in Brazil, in a project carried out by Nuclebrás Heavy Equipment (NUCLEP) in partnership with the Naval Arsenal of Rio de Janeiro.

Modernizing the conventional fleet guarantees increased capabilities to monitor and defend Brazilian waters, as the new Riachuelo-class submarines have greater autonomy than the Tupi-class subs and can stay on mission for 70 days, as opposed to the 45-day limit

of the current vessels. The nuclear sub, however, will raise that capacity to a new level. A conventional submarine is driven by an electric motor fueled by diesel fuel. Because the combustion of diesel fuel depends on oxygen, the vessel needs to emerge twice a day (on average) to capture oxygen from the air, or at least extend a snorkel tube to the surface. It also needs to refuel regularly with diesel. At such times, the vessel is exposed and becomes an easier target for attack during situations of conflict.

Nuclear-powered submarines are less vulnerable. Their source of energy is a nuclear reactor, which generates heat to vaporize water, enabling the use of this steam for turbines. Depending on the design of each submarine, the turbines can drive electric generators or the propeller shaft itself. In both cases, they produce all the energy necessary for life on board. "Because they have a virtually inexhaustible source of energy, they can theoretically be submerged for an unlimited amount of time," Admi-

Assembly of two sections of the Riachuelo, at the Itaguaí naval base, in Rio



ral Albuquerque explains. This means that submarine autonomy—understood as time away from port—is limited only by the physical and psychological resistance of the crews, and by food and water supplies. The United States Navy has defined this time limit as six months.

Another advantage of submarines with nuclear propulsion is their speed. While conventional subs move at an average speed of 6 knots (approximately 11 kilometers per hour), those with nuclear propulsion reach 35 knots—almost 65 kilometers per hour. As a result, they can quickly cover longer distances. “The availability of nuclear-powered submarines will significantly increase the operational dynamics of the fleet. The characteristics of these vessels, such as great mobility and stealth, guarantee significant deterrent capabilities in the defense of the Blue Amazon,” the admiral adds.

#### TECHNOLOGY TRANSFER

PROSUB is the result of a cooperation agreement signed in 2008 between the governments of Brazil and France, with the participation of public and private companies under the coordination of the Brazilian Navy. The partnership stipulates that the French not only advise Brazilians on the construction of the submarines but

## PROSUB is the result of a cooperation agreement signed between the governments of Brazil and France in 2008

also help to design the machines. France contributes nonnuclear technology to the projects and construction, and Naval Group, the company known until 2017 as Direction des Constructions Navales et Services (DCNS), is responsible for transferring the French expertise.

The Brazilian company involved in the project is the construction company Norberto Odebrecht (CNO), which has set up a special purpose entity (SPE) with DCNS, called Itaguaí Construções Navais (ICN), in which the Brazilian Navy

holds a “golden share.” ICN is responsible for the construction of the shipyards, the naval base, and the submarines. The Manufacturing Unit for Metallic Structures is one of its operational arms. According to Admiral Albuquerque, the technological challenges of the project are being overcome with technology transfer in a number of areas, including industrial infrastructure, construction of the submarines, and control and combat systems. The nuclear propulsion system is not part of the agreement. The process of technology transfer involves the French supplying information and technical data on the submarines, as well as providing training courses, including specific training carried out in France and technical support.

Another action planned for PROSUB is the nationalization of the equipment and components used for the construction of both the infrastructure and the vessels. The program provides for the transfer of technology to selected Brazilian companies. To date, 52 Brazilian companies have already become involved with PROSUB, such as WEG in Santa Catarina, responsible for supplying the electric motors, the São Paulo company Adelco, a specialist in energy systems, and Newpower, which is in charge of developing suitable batteries for the submarines.

One technology that the Navy considers critical to the project's success is the submarines' combat system, responsible for the control and management of the six torpedo tubes that equip the Riachuelo. This task became the responsibility of the Ezute Foundation, a private nonprofit institution created in 1997, which is accredited as a strategic defense company (EED) by the Ministry of Defense.

The process of nationalizing this system began in 2011, when nine professionals from the foundation were sent to France for training in systems engineering and integration; they also learned to develop Combat Management System (CMS) software. "Our engineers were responsible for creating the modules that allow the submarines to communicate with the tactical data link used by the Navy on its ships," says Andrea Hemerly, director for the defense market at the Ezute Foundation.

#### SYSTEMS INTEGRATION

Returning to Brazil in 2015, the team began to expand on the knowledge they had acquired, training new members for the project and supporting the Navy in the system integration for the Riachuelo-class submarines and in the preliminary design of the SN-BR combat system. "We're confident that Brazil will achieve its goal of obtaining autonomy in submarine engineering and combat systems integration, as well as for the specifications, design, development, and systems integration for the first nuclear-powered submarine in the country," Hemerly states.

Naval engineer Luis De Mattos, president of the Brazilian Society of Naval Engineering (SOBENA), says that Brazil has well-prepared technical personnel and an extensive industrial structure, which facilitates the absorption of technology. "What was missing was the opportunity. And that's what PROSUB is creating," he says. For Mattos, it was important for the Navy to establish clear objectives in the nationalization of the technology; the Riachuelo has 20% Brazilian-made content, and that value will increase with each new vessel. "PROSUB will allow Brazil to enter a select group of countries that are qualified to build their own submarines. In the future we'll even be able to participate in international construction tenders," he says. ■

## The dream of nuclear propulsion

The project to build a submarine with a nuclear reactor started in 1979 and will only be completed by the end of the next decade

The construction of nuclear-powered submarines has been pursued by the government since 1979, when the Brazilian Navy Nuclear Program (PNMB) was created. Its purpose was to acquire the technical capacity to design, construct, operate, and maintain naval propulsion systems using nuclear reactors and to manage the nuclear fuel production cycle. The development of the SN-BR Álvaro Alberto submarine's nuclear propulsion system is the exclusive responsibility of the Navy, which has already begun to deploy the Nuclear-Electric Energy Generation Laboratory (LABGENE) in Iperó, São Paulo. "LABGENE will enable the simulation of the reactor's operation and its integrated electromechanical systems," says Admiral Bento Costa Lima Leite de Albuquerque Junior, the Navy's Director-General of Nuclear and Technological Development.

For the PNMB to achieve its goal, it is vital that the country master nuclear fuel cycle technology as well as the pressurized water reactors (PWR) used in nuclear power plants and submarine propulsion. "Among the fuel cycle stages, isotopic separation is the step that adds the most technological value and is the most complex. Therefore, the Navy prioritized uranium enrichment as the first stage to be mastered," the Admiral says. Among the enrichment technologies, the most promising was ultracentrifugation. The first ultracentrifuges made in Brazil began operation in 1982.

With that technology, the country advanced in its development of new materials, electronic sensors, and new valves for operating with uranium hexafluoride (UF<sub>6</sub>, a compound used in

uranium enrichment), which gave a boost to research centers in industry and at universities.

Despite these advances, construction of the nuclear submarine encountered difficulties, and the schedule had to be revised. In 2008, when Brazil and France signed the partnership that would give rise to the Submarine Development Program, the plan was that a nuclear sub would be ready by 2021. The deadline is now 2029, a half a century after the start of the project.

Defense specialist Bernardo Wahl de Araújo Jorge, of the São Paulo School of Sociology and Politics Foundation, believes that in addition to the federal government's budget constraints, the delay in completing the project has been due to difficulties with mastering the cycle of nuclear propulsion, which includes the process of producing the fuel.

"This is not a type of technology that is usually transferred from one country to another. The Army, Navy, and Air Force have developed technology programs looking for ways to enrich uranium. The Navy program prevailed by being the most efficient," Jorge says. "If this submarine had been a priority for every government that came into office and if there had been no allocation restrictions, the delay would be unusual. As this hasn't happened, the extensive amount of time that it's taking to complete isn't that extraordinary."



Cutaway view of nuclear submarine under construction in Brazil

# Automation in LAW

A new type of startup, known as legaltech, is developing technological systems for the legal field

Janaína Simões

PUBLISHED IN SEPTEMBER 2018

There are more than one million qualified lawyers in Brazil. On average, 12,519 Brazilians out of every 100,000 filed a lawsuit in 2017. At the beginning of 2018, there were 80.1 million open lawsuits in the country according to the latest report by *Justice in Numbers 2018 – Base Year 2017*, a study by the National Justice Council (CNJ) that presents the most up-to-date statistics from the sector. These figures demonstrate the market potential that has led to the formation of a new group of startups in Brazil, which have grown faster than any other over the last two and a half years: legaltechs or lawtechs. These startups focus on the development and use of technologies applied to the law (see details on page 53). In Brazil, there is no distinction between the two terms, but in many countries, legaltech refers to startups that cater to the entire market, while lawtech refers to compa-

nies that develop solutions specifically for lawyers.

There are not yet any official estimates on how many startups there are in this sector in the country. The Brazilian Lawtech & Legaltech Association (AB2L) was formed by a small core of entrepreneurs from a WhatsApp group, which evolved into a formal entity in 2016. Initially the association had approximately 40 members. Based in Rio de Janeiro, today the association represents 180 companies, including early stage startups. “I believe that, within five years, there will be a unicorn in this sector,” says Bruno Feigelson, president of AB2L and CEO of Sem Processo in Rio de Janeiro. A unicorn is the name given to a startup valued at US\$1 billion or more before an initial public offering.

“This is an international phenomenon. In just five years, US\$1 billion of venture capital was invested in technology com-

panies focused on the legal market in the United States,” Feigelson continues. One example of this trend is the work being performed at Stanford University’s Center for Legal Informatics (CodeX). A group from CodeX developed Techindex, which mapped 1,048 legaltech companies in the United States. Another international initiative in this field, which is based in the United Kingdom, is Legal Geek, which has more than 4,000 members from the legaltech ecosystem, and in 2017, it mapped 64 startups. All of these startups were founded in the last seven years.

The Research and Innovation Teaching Group (GEPI), a branch of the Getulio Vargas Foundation in São Paulo (FGV Direito SP), is concluding a study on the use of these new technologies by law firms in Brazil. The results are expected later this year. The use of digital technologies in law is not new, although





## Functions on offer

Products and services provided by legaltech

### ONLINE CONFLICT RESOLUTION

Use of alternatives to lawsuits, such as mediation, arbitration, and negotiation of settlements

### LEGAL CONTENT, EDUCATION, AND CONSULTING

Websites offering information, legislation, news, and consulting, ranging from data security services to tax advice

### COMPLIANCE

A set of controls to enforce legal standards and policies related to the activities of the institution

### TAXTECH

Platforms that offer technologies and solutions for the tax sector

### ANALYTICS AND JURIMETRICS

Platforms used to analyze and compile legal data and metrics; statistics applied to law to predict results

### DOCUMENT MANAGEMENT AND AUTOMATION

Automation software for drafting legal documents and managing contracts and cases

### PUBLIC DATA EXTRACTION AND MONITORING

Monitoring and management of public information, such as publications, ongoing lawsuits, legislation, and documents

### ARTIFICIAL INTELLIGENCE

Artificial intelligence solutions for courts and public authorities

### REGTECH

Development and application of technology to solve problems generated by regulatory requirements

### PROFESSIONAL NETWORKS

Platforms that can help law professionals connect to each other and to potential clients

SOURCE: THE BRAZILIAN LAWTECH & LEGALTECH ASSOCIATION (AB2L)

in the past they were often only applied to internal processes, such as office management. “Now the game has changed: many of the technologies are addressing the end product. For example, databases are being automated to allow lawyers to provide better services. We have technologies such as case management and electronic petitioning that help to better organize court cases,” says Alexandre Pacheco da Silva, a professor at FGV Direito

SP and one of the coordinators of GEPI. “There are also some really pioneering fields in the legal area, such as the reading of judicial decisions by algorithms that categorize and export case data, or that can build a decision profile for a specific judge,” he says. “These are the more sophisticated technological solutions.”

Should legal professionals fear such changes? “Bureaucratic, repetitive functions will be directly affected, while other

activities will continue to be performed by people, such as interpersonal relationships with clients,” says Silva. “Few clients would want to communicate with a law firm using a digital platform.” Silva believes that the market and universities will need to rethink how future lawyers are trained. “Those not prepared for this new landscape will face difficulties finding work,” he says.

Brazilian bodies such as the Superior Court of Justice (STJ), the Superior Electoral Court (TSE), the National Justice Council (CNJ), and others have already automated their petition systems. Contracts go through the same process. “It is difficult to express the advantages of automation in numbers because every firm makes different gains,” says Silva. In the research he coordinates, however, there are testimonials from professionals who were able to reduce the time it took them to draft certain types of contracts from two and a half hours to approximately 20 minutes.

According to the researcher, the FGV study to be published this year shows that the vast majority of the companies that use legaltech solutions are based in the south and southeast of Brazil. One exception he cites is Urbano Vitalino, a law firm in Paraíba that has created an AI program for automatically drafting documents. AB2L also reflects this geographic distribution. Of its 180 associates, including early stage startups, 57 are from São Paulo and 13 are from Rio de Janeiro. The other members are based in the states of Paraná, Santa Catarina, Rio Grande do Sul, Minas Gerais, Espírito Santo, Goiás, the Federal District, Pernambuco, Amazonas, and Amapá.

#### NO PUBLIC FUNDING

There is an interesting characteristic of this generation of startups in Brazil: the absence of public funding. São Paulo-based startup Tikal Tech, for example, was founded in 2014 with investment from Antônio Maia, a lawyer from the city. The company celebrates the fact that some 200,000 lawyers have used or still use their products. “We also have more than 300,000 intermittent customers and individuals who have had contact with our services in some way,” says Derek Oedenkoven, CEO of the company.

Tikal Tech created LegalNote, an AI program that simulates internet brow-



sing to monitor, query, capture, and store information on legal cases and uses machine learning to read, classify, and identify information of interest. Using the lawyer’s Brazilian Bar Association (OAB) registration number, the software tracks all of his or her cases online and alerts him or her to any changes or progress.

LegalNote has begun registering non-lawyers, such as people who have filed lawsuits related to labor disputes or consumer protection, as well as small businesses. The company has also launched a new service called SeuProcesso, which not only allows users to monitor the progress of lawsuits but also translates legal text into a more readable language. The company has also developed an AI-based legal automation program called Eli as well as an application through which lawyers can find and hire colleagues across the country, called Diligeiro.

Founded in São Paulo a year and a half ago, Deep Legal was also funded by private investment from lawyers Vanessa

## Startups focused on law tend to use their own funds to develop technology for the sector

Louzada and Rosely Cruz, advertising professional Isabela Ventura, and engineers Raul Azevedo and Ricardo Rezendé. The system offers three solutions. With the “monitor” solution, users can check their legal performance in real time via several indicators, such as cases opened and closed, progress, judgments, and settlements. With “compare,” users can compare the legal performance of their firm or company with that of their competitors. The “predict” solution, meanwhile, provides statistical information on the chances of winning or losing a case in the user’s portfolio, improving estimated outcomes. With this tool, lawyers can form better legal strategies, such as seeking settlements or changing their defense. The team, which has expertise in the legal area, tests its new technologies in partnership with the law firm Neolaw, whose clients use the products on an experimental basis at no cost. The tool will be available to legal companies and departments in November.

Linte, a startup that aims to combine document automation and workflow, received US\$100,000 from an accelerator based in San Francisco, USA, to create its software, which is named after the company. “We know that activity B follows

activity A. Workflow software helps us organize our work into stages and then automates them,” explains Gabriel Senra, one of the founding partners of Linte, which is based in the Cube, an entrepreneurial space in São Paulo run by Itaú Unibanco and the Redpoint Eventures investment fund.

### SELF-FUNDING

Some developers interested in this market have invested in their own businesses, such as Rio-based startup Sem Processo. Founded in January 2016, the platform facilitates out-of-court settlements by connecting lawyers representing individuals to the legal departments of companies facing legal action. The goal is to save time and money by encouraging an agreement between the parties and preventing the case from going to court—enabling the parties to negotiate and close lawsuits.

In less than a year, cases from more than 500 different companies have been registered on the platform. “We began to develop a module that we call litigation, which is operated by companies, legal departments, or law firms. Some companies have 30 or 40 firms working for them, and they all use Sem Processo,” says Bruno Feigelson, one of the founders.

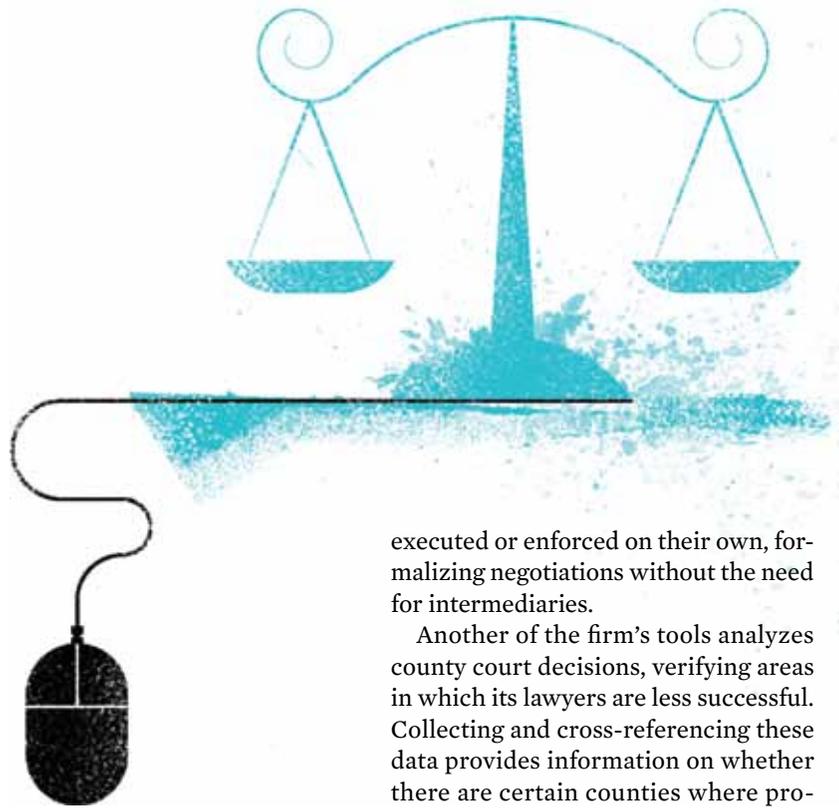
Another startup that chose to take this path was Legaltech from São Paulo. Founded in 2009 by José Antônio Milagre, the company offers services related to online reputation management, focusing on monitoring the personal data and image of individuals, companies, and institutions on the internet. “In 2015, we started thinking about developing AI programs to automate the search for personal data, defamation, news, fake profiles and violations of copyright on social networks,” says Milagre. As a result, Legaltech was able to automate the process of collecting evidence by storing data on offensive texts and images or fake profiles.

“Our tool monitors an average of 600,000 public and private items on social networks per month,” he says. The technology uses artificial intelligence, the semantic web—through which the software interprets information—and machine learning. All of these features are used to identify photo and video posts, determine whether they involve an offense, and assess the potential for legal

repercussions. If an online search finds evidence with forensic value, another tool called Minha Imagem (“My Image”) is automatically triggered to formulate a request for removal by filling out the online forms provided by social networks or drafting a legal letter.

Opice Blum, a law firm in São Paulo, opted to create its own legaltech division in 2013, which is run by seven of the firm’s approximately 100 employees. One example of the software developed by the team is a system for monitoring fake news during elections. “We can detect whether a social media post is fake news, whether it is being viewed and shared in greater numbers than other posts, and whether it should be the subject of special and immediate action, and we can then suggest a response to our customers,” explains the founder and partner of the firm, Renato Opice Blum.

“But, it goes beyond that: algorithms and mathematical models also help lawyers in court to demonstrate coordinated actions across different media, for example, or profiles made for illicit purposes.” The firm is renowned in the detection of fake products in virtual stores as well as other cases involving artificial intelligence and smart contracts — which can be



executed or enforced on their own, formalizing negotiations without the need for intermediaries.

Another of the firm’s tools analyzes county court decisions, verifying areas in which its lawyers are less successful. Collecting and cross-referencing these data provides information on whether there are certain counties where professionals are filing more suits against their clients, where there is a greater or lesser chance of conciliation to avoid prosecution, where there is a greater risk of their clients losing a judgment, and the likelihood that a court will change its decision after an appeal.

### ACCELERATING STARTUPS

In July, Thomson Reuters—a multinational corporation that operates in various sectors, including law—hosted *Accelerator Day for Lawtechs* in Campinas, São Paulo State. Nine of the twenty companies that applied were selected, and all of them already have clients and experience in the market. The mission of the companies was to present technological projects capable of adding value to Legal One, a legal platform developed and marketed by Thomson Reuters.

“It is easier to introduce a solution to a complex market like Brazil and then take it to another market,” says Ralff Tozatti, marketing director for the multinational in Brazil and one of the creators of Accelerator Day. The selected companies will receive mentoring, marketing, development advice, access to events, and certification by Thomson Reuters. The companies will have to complete the development of their technologies by October of this year using Thomson Reuters as their “laboratory”. ■

# Automated farming

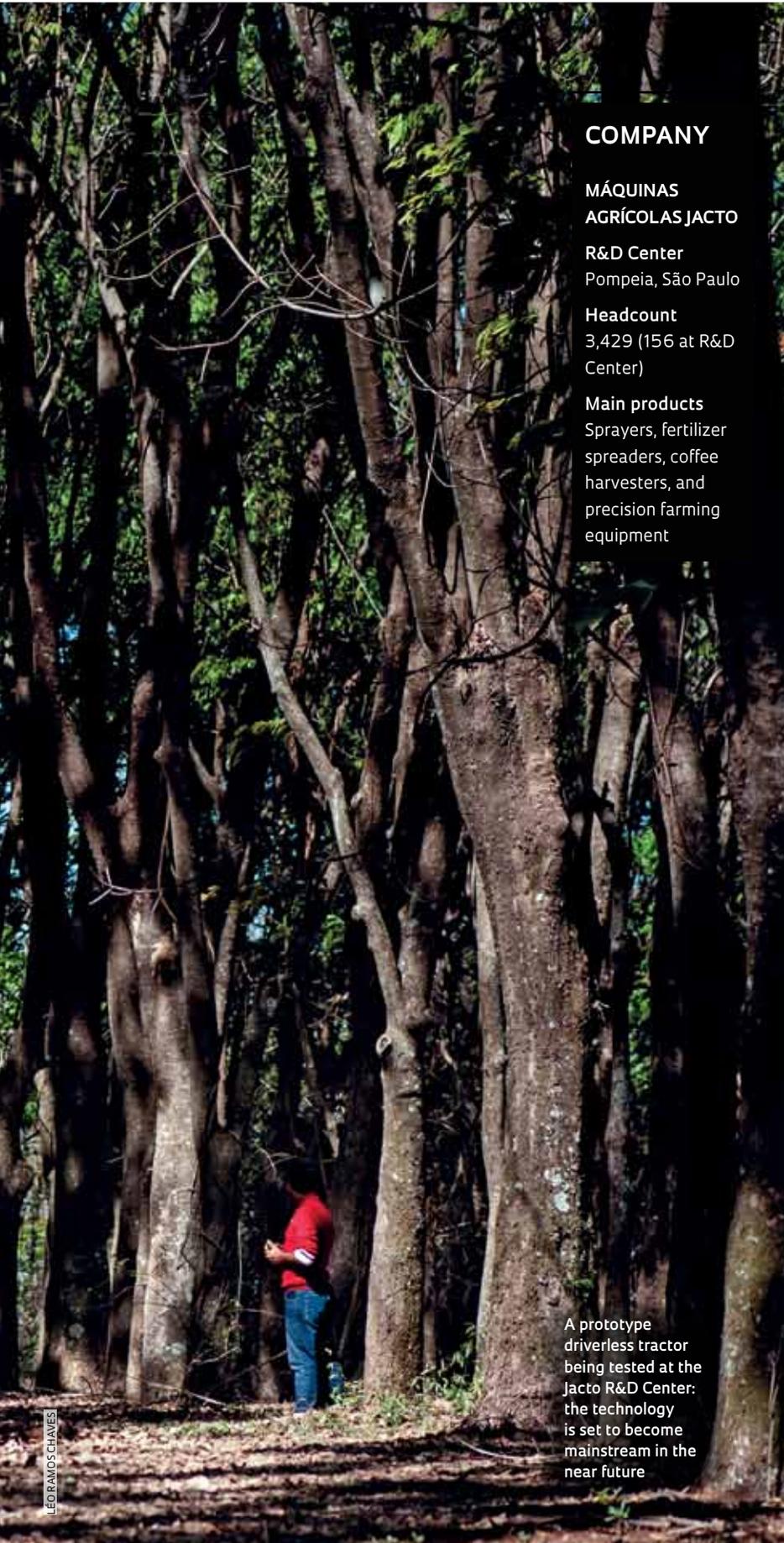
Máquinas Agrícolas Jacto boasts 383 patent applications and is among the global pioneers of driverless farming technology

PUBLISHED IN SEPTEMBER 2018

Visitors to Fazenda Santo Antônio, a property owned by Suzano Papel e Celulose in Anhembi, São Paulo, are likely to chance across a strange-looking vehicle, with no cabin or driver, navigating the alleys between rows of eucalyptus trees. The Jacto Autonomous Vehicle (JAV), as it is called, is a concept robotic pesticide sprayer with which Máquinas Agrícolas Jacto—a 70-year-old company based in Pompeia, a small town 474 kilometers from the city of São Paulo—hopes to make its name among the global pioneers of driverless farming machinery, a technology that is set to become commonplace in the coming years.

The JAV is fitted with cameras and a GPS positioning system for navigation, as well as a plethora of sensors developed by EMBRAPA Instrumentação and the São Carlos School of Engineering of the University of São Paulo (EESC-USP). In addition to fuel, hydraulic oil level, and pesticide tank level sensors, an optical vegetation index sensor provides the ability to sense plant color and identify areas with nutritional deficiencies or that are infected by pests and diseases. A weather monitoring system indicates whether, for example, pesticide spraying could be affected by rain or strong wind.





## COMPANY

**MÁQUINAS  
AGRÍCOLAS JACTO**

**R&D Center**  
Pompeia, São Paulo

**Headcount**  
3,429 (156 at R&D  
Center)

**Main products**  
Sprayers, fertilizer  
spreaders, coffee  
harvesters, and  
precision farming  
equipment

A prototype driverless tractor being tested at the Jacto R&D Center: the technology is set to become mainstream in the near future

LEO RAMOS CHAVES

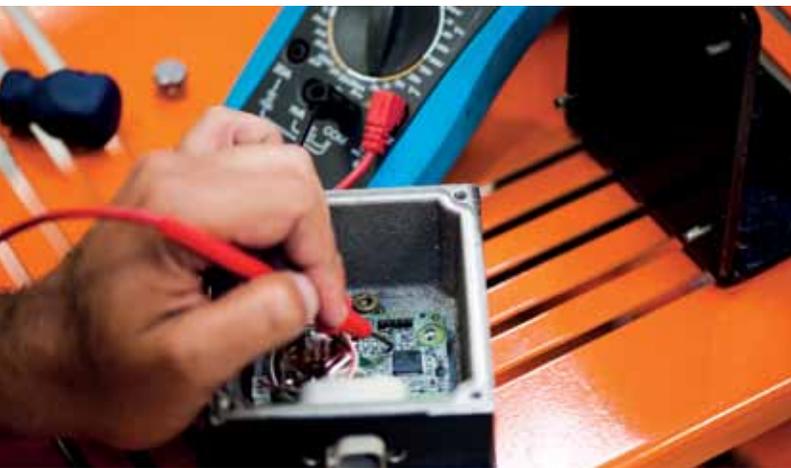
Jacto has been developing its autonomous vehicle platform since 2008 and unveiled the current generation—its second—in 2013 during an agriculture trade show in Ribeirão Preto. Research & Development Director Sergio Sartori Junior says that driverless farming technology is not yet mature enough for commercial applications. “We need to improve the sensors so the technology is more reliable under adverse conditions,” he says. Positioning technologies, such as GPS, also need to be improved to prevent glitches in areas covered by tree canopy, for example.

The concept is that autonomous vehicles will work together as a fleet on the same field, exchanging information with each other about farm tasks and being monitored at a distance by a single operator. Driverless farming will also require better rural connectivity, with a denser distribution of telecommunications antennas.

Despite these constraints, Jacto plans to produce an experimental batch of three to five JAVs in 2019, equipped with a new generation of sensors for an additional season of controlled testing with other customers. If this second round of testing is successful, the company will consider a commercial launch of the vehicle, but only for applications in which it has been proven to perform well.

Sergio Sartori Júnior says that work on developing the JAV is also helping Jacto to improve products already on the market, such as its Uniport sprayer platform. In 2017, the company launched Omni 700, a new version of its suite of solutions for precision agriculture—a concept that describes the use of technology to manage crop production with greater precision and accuracy. The system is the first in the world to offer an operation repeater with which the operator can record the parameters used for spraying on each section of a field.

The previous version already incorporated functionality such as autopilot and lightbar systems, which help operators apply pesticides in parallel strips with no gaps or overlaps. The system allows pesticide spray nozzles, which are spaced 35 centimeters apart on a boom



up to 36 meters wide, to be individually actuated to target infected plants. Diseased plants are identified by a vegetative index sensor.

Jacto's automation expertise also supported the development and 2017 launch of its Uniport 5030 NPK fertilizer spreader. The new product features functionality such as Precision Way, a system for precisely dosing fertilizer at each application point; border control, which prevents fertilizer from being thrown beyond the boundary of the field; and automatic section control, which lays out adjacent application sections to avoid overlaps. Automated systems can reduce fertilizer consumption by up to 15%.

CEO Fernando Gonçalves Neto says that technological development in the farming machinery industry is currently

A navigation mechanism being tested (*left*) and professor José Vitor Salvi delivering a lecture at the Precision Agriculture Laboratory at ATEC Pompeia (*right*)

being driven by two fundamental principles: eco-efficiency and productivity. The more precise the machinery, the less farmers spend on farm inputs, and the lesser the environmental impacts and health effects on farm workers, who suffer less chemical exposure.

#### AGRIBUSINESS PROFESSIONALS

Cultivating professionals with the skills to manage technology and an interest in working in agriculture has become

a challenge, one that Jacto has worked to address. Company executives convinced Centro Paula Souza (CPS), the organization managing Brazil's School of Technology (FATEC) network, to set up a campus in Pompeia, a small town with a population of just 21,000, despite the network's policy of opening schools only in cities with a population greater than 120,000. The school was created under a private-public partnership agreement—the first to be concluded by CPS—with Fundação Shunji Nishimura de Tecnologia, a trust established to manage the estate of Jacto's founder.

FATEC Pompeia has 30 professors and two major programs. The first, mechanization in precision farming, trains professionals (agricultural production engineers) to work with emerging technologies in agriculture. Electrical engineer Tsen Chung Kang, a professor who codeveloped the program, explains that students learn both theory and practice at a facility with equipment worth R\$3.5 million, supplied by 93 partner companies. "Students learn about the entire value chain, from seeds and fertilizers, through planting and harvesting equipment, to ERP software and distribution logistics," he says. The three-year program has trained more than 500 engineers so far. "Almost all students are employed by the time they complete the program and will work at companies or farms using these technologies in their production processes," he says.

When the program was created in 2012, only one other school—in Oklahoma, USA—offered a comparable program, which was subsequently discontinued. Two years ago, another equivalent program was created in South

## RESEARCH TEAM

Below are the names of some of Jacto's R&D staff and their *alma maters*

Sergio Sartori Junior, mechanical engineer, R&D director	University of Campinas (UNICAMP): bachelor's degree São Paulo State University (UNESP), Bauru campus: master's degree
Gustavo Barbosa Micheli, mechanical engineer, project manager	UNESP/Bauru: graduate degree, master's degree in mechanical engineering, currently pursuing doctoral research in the same field
Édson Lúcio Domingues, systems analyst, innovation and technology manager	University of Marília (UNIMAR): bachelor's degree Fundação de Ensino Eurípides Soares da Rocha: master's degree in computer science UNESP/Bauru: master's degree in electrical engineering
Daniel Alves B. de Oliveira Vaz, electrical engineer, senior R&D engineer	Federal University of Uberlândia: bachelor's degree São Carlos School of Engineering of the University of São Paulo (EESC-USP): master's in sciences
Bruno Fernando Mendonça Callegaro, electrical engineer, R&D engineer	EESC-USP: bachelor's degree EESC-USP: master's in electrical engineering
Adilson Fábio Bazucco, mechanical engineer, project manager	UNESP/Bauru: bachelor's degree, pursuing master's in mechanical engineering



Jacto assembly line: the agricultural division generates approximately 70% of revenues

Dakota. FATEC was recently visited by delegates from Mexico and China keen to learn about the teaching methodology. Kang is also part of the group that developed the Big Data in Agribusiness program in 2017, the only program of its kind anywhere in the world. The goal, according to Kang, is to meet market demand for professionals with the skills to handle the vast amount of information generated by onboard technologies and integrate that information with the data used by processing companies downstream. The three-year program is currently educating its third class.

#### LONG-STANDING INNOVATION

Jacto was founded in Pompeia by sheer circumstance. In 1939, Japanese immigrant Shunji Nishimura (1910–2010) left São Paulo City for the interior in search of work. He went as far as he could go by train. At the time, Pompeia was the last station on the westbound main line of the São Paulo rail network. Nishimura rented a house and posted a sign-out front reading “We Fix Anything”. He soon had a thriving business repairing

all sorts of machinery for farmers in the area, including imported dusters—pesticides were then sold as powder. In 1948, Nishimura developed his own duster, the first to be produced in Brazil, with the advantage that it could be carried as a backpack, whereas competing dusters had to be held in front of the user, limiting movement. This invention led to the founding of Máquinas Agrícolas Jacto.

Sixty-nine years later, in 2017, the Jacto Group posted net revenue of R\$1.22 billion and net income of R\$94.4 million. The agricultural division accounts for approximately 70% of revenues. The group also includes a plastic manufacturing company, a medical equipment business, a cleaning equipment division, and a trucking company. The group has a total workforce of 3,429 employees. Jacto markets its products in 110 countries and has a facility producing portable equipment in Thailand and another site producing heavy equipment in Argentina. The agricultural division derives 25% of its revenues from foreign markets.

Fernando Gonçalves Neto says the company’s advisory board, consisting of five of the founder’s seven children, has set a goal of doubling the company’s size by 2025. How this will be achieved is part of the company’s business strategy and is kept confidential. Neto could only comment that new products and services

are at the core of the company’s plans. Last year, 25% of revenues came from products placed on the market in the three previous years, and the company hopes to sustain new-product revenue levels between 20% and 30%.

To this end, the company has invested between 4% and 5% of its annual revenues in a research and development center with 156 staff, including 25 employees with master’s and doctoral degrees, 13 with other graduate degrees, 50 with undergraduate degrees, 17 trainees with undergraduate degrees, 49 staff with associate degrees and 2 apprentices. Since 1963, Jacto has filed 383 patent applications.

One of its first breakthrough products was the world’s first coffee harvester, launched in 1979. In 2015, the company launched another highly innovative product on the coffee-farming market—the K 3500—a modular vehicle accommodating harvesting, spraying, pruning, and fertilizer spreading systems that can be changed out in just a few hours. The platform sits more than three meters off the ground and above the plantation rows, with only the wheelbase touching the ground between rows, allowing it to be used in higher-density coffee plantations. The development of the K 3500 resulted in six patent applications. ■

Domingos Zapparolli

# Brazilian technology at the PENTAGON

Brazilian identification systems company Griaule has won two contracts in the United States worth a total of US\$82.5 million—one with the Department of Defense

**Yuri Vasconcelos**

PUBLISHED IN DECEMBER 2018

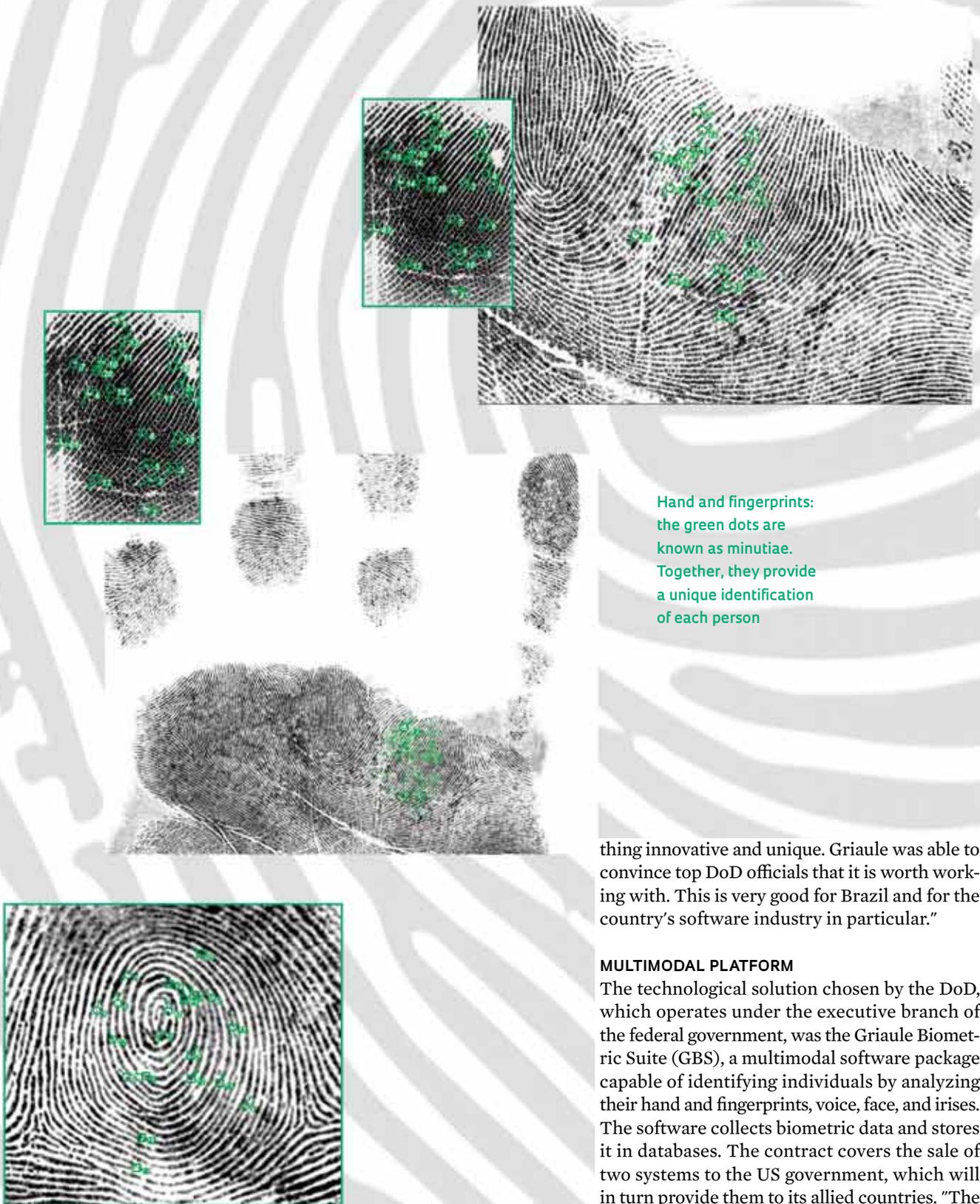
**G**riaule, a company based in Campinas, São Paulo State, provides biometric solutions for ensuring the fidelity of electoral data. In recent months, the firm has won two major contracts in the USA. In September, the company, which was founded at the University of Campinas (UNICAMP) and received funding from FAPESP, was chosen by the US Department of Defense (DoD) to provide an identification system for the storage and certification of biometric data for 55 million Iraqi citizens as well as another 30 million people in Afghanistan. The following month, the Arizona State Department of Public Safety chose Griaule's biometric technology to assist police investigations and perform criminal background checks for public officials.

Biometric systems such as those developed by Griaule recognize people by the unique characteristics of their body, such as fingerprints, facial features, or irises (see Pesquisa FAPESP *issue no. 255*). The contract with the DoD, which is based at the Pentagon, is worth US\$75 million and will

be executed over five years, with an extension option. Having participated in wars in Iraq and Afghanistan, the US is now working with local authorities to rebuild, which explains why Washington is contracting the services.

One of the biggest developers of biometric solutions in Brazil, Griaule, participated in the Pentagon bidding process as part of a team with six other companies, all of which are from the US. The technology to be provided, however, is 100% Brazilian according to the company. The consortium was led by a joint venture called RS3, which is run by EIS, a company that already provides engineering services and technology solutions to the US federal government.

"Seeing a company with Brazilian DNA win international contracts for state-of-the-art solutions is a source of great pride. It puts Brazil on the map in terms of major providers of global biometrics solutions," says computer scientist Anderson Rocha, a professor at the UNICAMP Computing Institute. "Being selected by the Pentagon shows that the company is offering some-



Hand and fingerprints:  
the green dots are  
known as minutiae.  
Together, they provide  
a unique identification  
of each person

thing innovative and unique. Griaule was able to convince top DoD officials that it is worth working with. This is very good for Brazil and for the country's software industry in particular."

#### MULTIMODAL PLATFORM

The technological solution chosen by the DoD, which operates under the executive branch of the federal government, was the Griaule Biometric Suite (GBS), a multimodal software package capable of identifying individuals by analyzing their hand and fingerprints, voice, face, and irises. The software collects biometric data and stores it in databases. The contract covers the sale of two systems to the US government, which will in turn provide them to its allied countries. "The biometric identification systems currently used in Iraq and Afghanistan are out of date. We are going to replace them and extend their functionality," says Renato Burdin, operations manager at Griaule.

According to Burdin, the system will be used for border control and for issuing documents to Iraqi and Afghan citizens, as well as in criminal

Handprint reader, one of the biometric solutions developed by the company

investigations. The software will be capable of recognizing hand and fingerprints found at crime scenes, known as latent prints. "GBS is designed to be multimodal. I believe this project will use more biometric factors at the same time than most," says Burdin.

Under the Pentagon contract, Griaule will use existing national databases from both countries, allowing for the continuous aggregation of new biometric information. "In the first year, we will migrate from the current system to GBS. From then on, we will provide technical support and maintenance services," explains Burdin, pointing out that the Griaule system has already obtained dozens of national and international certifications, 20 of which were issued by the Federal Bureau of Investigation (FBI).

In the US\$7.5 million deal with Arizona, the technology will also be used for civil and criminal purposes. "It is important to note that the GBS platform can be used by multiple state organizations and can communicate with federal systems," said Burdin. Michigan state police already use the company's biometric technology.

#### FOSTERING RESEARCH

Founded in 2002 by the electrical engineer Iron Calil Daher, Griaule was part of the UNICAMP incubator for its first three years. Working so closely with the university helped the company recruit bright young talent. The initial staff of five has multiplied sevenfold, and today, Griaule has approximately 35 employees, 20 of which are graduates and four of which have PhDs or specialist postgraduate qualifications. The research and development (R&D) team behind the solutions developed by the company consists of 20 people, most with backgrounds in engineering and computer science.

The company's revenue in 2017 was R\$16 million, a significant jump from the R\$100,000 it achieved in 2005, which was its final year in the UNICAMP incubator. Support from funding agencies such as FAPESP and the Brazilian Funding Authority for Studies and Projects (FINEP) was fundamental to the business's growth. The company's main product is a fingerprint identification system. The Campinas-based company also makes recognition software for voices, irises, faces, and hands as well as latent prints.



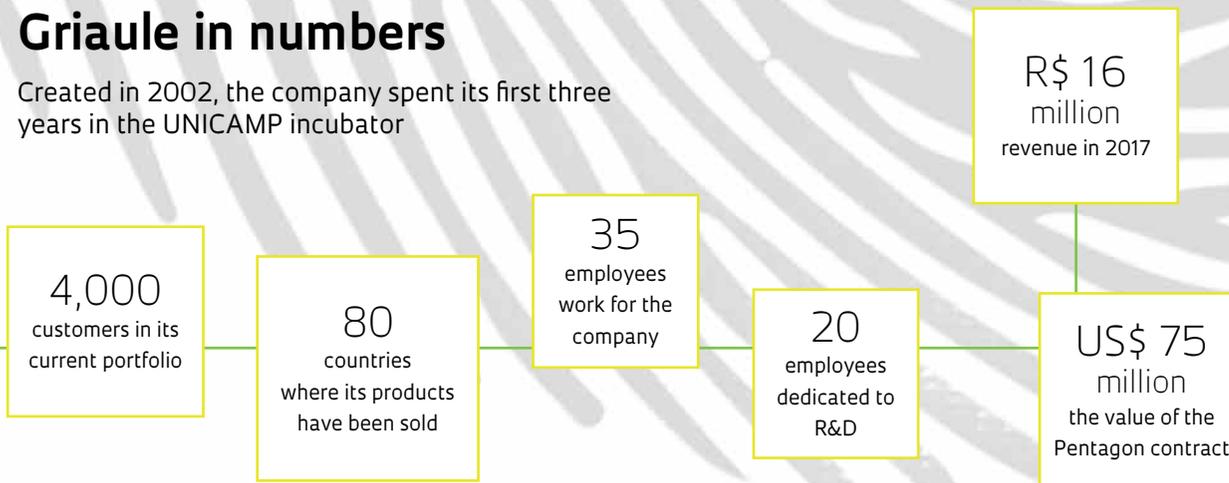
## Griaule created the software used for storing, validating, and authenticating the biometric data of Brazilian voters

Over the course of its history, Griaule has received three grants from the FAPESP Technological Innovation in Small Businesses (PIPE) program, the first in 2003 to help it improve its automatic fingerprint identification system. In 2005, further funds were granted to support the development of facial recognition technology, and in 2007, funds were granted to support the creation of a new voice identification system. "Without the financial support of FAPESP, we would not have reached this point," says Iron Daher, the company's CEO.

The quality of Griaule's products was quickly recognized. In 2005, the company won the FINEP Award for Technological Innovation in the Small Businesses from the Southeast category, and the following year, it earned international prestige by coming first in the Fingerprint Verification Competition (FVC 2006) after its fingerprint identification algorithm had the lowest error rate in a field of 150 competitors. After winning the award, Griaule opened a commercial office in Mountain View, California, in 2007, and began

# Griaule in numbers

Created in 2002, the company spent its first three years in the UNICAMP incubator



SOURCE GRIAULE

exporting its products to the US. The company recently moved its operations to Morgantown, West Virginia, to improve sales and support for the local market.

Despite receiving such recognition, the company only observed a significant increase in revenue in 2014, when it signed a contract with the Brazilian Superior Electoral Court (TSE). The contract involved creating a bespoke software package to store, validate, and authenticate the biometric data of voters, allowing them to identify themselves using a fingerprint reader connected to an electronic voting machine. The system is more secure and less open to fraud. In this year's presidential election, more than 2,800 counties used biometrics to identify voters. According to the TSE, more than 87 million Brazilians registered their fingerprints.

Creating a database of this size poses a number of challenges; the more fingerprints that are

stored in the system, the greater the processing requirement for adding new ones. This is because recording a new fingerprint involves performing a full scan of the database to avoid duplicate registrations. The task is even more complex because fingerprints are collected for all 10 fingers of each voter, meaning the recognition software has to process a huge amount of data.

Griaule currently has 4,000 customers in 80 countries. Brazil is its primary market, accounting for 95% of its revenue in 2017, followed by the USA. In addition to the TSE, the company also provides biometric services to the Brazilian state bank Caixa Econômica Federal, which has implemented Griaule technologies in its bank branches, in the federal government's Bolsa Família welfare program, and at Fundação Casa, an autonomous government agency in São Paulo that uses the technology to identify children who arrive at the institution with no identity documents. GBS is also used in Israel for the issuance of national documents and by Sure Bank in South Africa, which uses the fingerprint recognition system in its ATM network. The company hopes that the contracts signed in the USA in recent months will help spread the word and open new markets, helping to increase overseas sales. ■

Electronic voting machine with fingerprint reader used in some Brazilian electorates



## Projects

1. Improvement to the recognition quality and availability (SpeedCluster) of Griaule AFIS (no. 03/07972-6); **Grant Mechanism** Technological Innovation in Small Businesses (PIPE) program; **Principal Investigator** Iron Calil Daher (Griaule); **Investment** R\$352,605.89.
2. Detection and digital recognition of the human face (no. 05/59952-4); **Grant Mechanism** Technological Innovation in Small Businesses (PIPE) program; **Principal Investigator** Luís Mariano del Val Cura (Griaule); **Investment** R\$445,850.19.
3. Voice recognition: speaker verification (no. 07/03843-8); **Grant Mechanism** Technological Innovation in Small Businesses (PIPE) program; **Principal Investigator** Marcos Renato Rodrigues Araújo (Griaule); **Investment** R\$219,646.30.

# Local with a GLOBAL MINDSET

The president of Movile speaks about the future of iFood, which received funding totaling US\$500 million, and encourages the internationalization of innovative companies

**Neldson Marcolin**

PUBLISHED IN DECEMBER 2018

In mid-November, the president of Movile, Fabrício Bloisi, announced that the food delivery app iFood had received support from investors totaling US\$500 million, the highest amount received by a Latin American startup. With these funds in the bank, the expectation was that both the app and Movile, its primary investor, were on their way to becoming unicorns—companies valued at US\$1 billion or greater. Bloisi created shock waves when he revealed that both Movile and iFood had already reached this status back in the early months of 2017, even though this had not been made known previously. For the businessman, this landmark represents yet another number that has been surpassed—his efforts are now concentrated on multiplying the value of the company by 10 in the next few years, an achievable goal due to the international potential represented by the online market for ordering food.

The US\$500 million invested in iFood came from various sources. Movile made an initial investment of US\$100 million in mid-2018. The remaining US\$400 million came at the end of 2018 from the South African group Naspers; from Innova Capital — led by the Swiss-Brazilian investor Jorge Paulo Lemann; from Just Eat, which is the largest digital market in the online food delivery world and is headquartered in London; and once again, from Movile. The funds will be invested to accelerate the growth of the brand in Brazil and abroad, as well as to significantly increase the number of registered restaurants (today there are 50,000), delivery persons, cities, and, consequently, orders. The same app is also available in Mexico and Colombia. Overall, a total of 12 million orders are completed each month. It is one of the largest service companies of its kind in the world.



According to Bloisi, many other young Brazilian companies will be worth more than US\$1 billion in the near future

Movile began to invest in iFood in 2013, and today, it owns 60% of iFood's capital. The company, which is led by Bloisi, includes various startups such as PlayKids, which offers educational content; Wavy, which brings IT companies together; the online ticketing service Sympla; and Zoop, a payment and service platform.

As often happens with technology companies, Movile was created at a university (the University of Campinas, UNICAMP) under another name and underwent various transformations through which it evolved. Bloisi and Fábio Póvoa, who were colleagues during their undergraduate education, created Intraweb, which offered software and IT solutions, in 1998. The company had its beginnings at the Company

for the Development of the Campinas High Technology Center (CIETEC), and in 2001, it was bought by GoWapCorp.

The following year, Intraweb's name was changed to Compera. In 2007, it joined with Movile and adopted the latter's name. From this point forward, the company was run by Bloisi and went through various other stages, including new mergers with and acquisitions of companies in Brazil and other Latin American countries. Within this decade, the company became a capital risk group with 2,200 employees, headquarters in Campinas, and 16 branch offices in Latin America, France, and the United States.

Bloisi is from Bahia and is 41 years old. He decided to leave Salvador for the interior of São Paulo to study computer science at UNICAMP in 1995. He graduated in 1998 and began his master's program at the Getúlio Vargas Foundation in São Paulo (FGV-SP) between 2005 and 2008, during which time he studied models and growth strategies for startups. During this interview, he talked

about the plans for expanding iFood, about the two Movile Group facilities, and about his vision for how Brazilian companies should be innovative and always looking to the international market.

**Recently, you said that iFood and Movile have been unicorns since the beginning of 2017. Until now, only Nubank, 99, and PagSeguro have announced reaching this status. Why have you not done the same? Is this not good marketing?**

We are not used to revealing numbers. Furthermore, we are more focused on being a company worth more than US\$10 billion, so we think and dream very big. China has hundreds of companies worth US\$300 billion, and the United States, worth US\$1 trillion. But in Brazil, we are used to dreaming of only US\$1 billion. There is room to do much more in our market. It became trendy to talk about being a unicorn. But I think that this nomenclature creates a distraction — I'm certain that, starting now, we will not only see unicorns

in Brazil, but also companies that are worth much more than this. We are just beginning. We want to pass along this optimism to Brazilian companies. This region is a benchmark for investment in tech companies.

***iFood makes 12 million food deliveries each month throughout Brazil, in addition to Colombia and Mexico. In which areas will the US\$500 million be invested?***

We are growing more than 100% per year, and there is considerable room and desire to grow. We want to double the number of delivery persons and cities served, as well as triple the number of restaurants registered in the app—today close to 50,000—and also the number of orders. This investment will increase the growth, product development, and geographic expansion of iFood. We want to invest more in artificial intelligence and payments, reducing costs and increasing quality, in order to improve the experience of our key partners and customers: restaurants, delivery persons, and users. Our goal is to grow exponentially.

***The American industry leader, Grubhub, does 410,000 meal orders per day, which is a little more than iFood, at 390,000. Will you reach first place?***

We are growing two times faster than Grubhub in the number of orders per day as an annual percentage. We went from 187,000 orders per day in October 2017 to more than 390,000 per day in October 2018. Online food delivery is experiencing incredible growth on a global scale, and we believe that, in comparing our recent numbers with the key global players, we are putting Brazil on the food delivery map more and more every day.

***Is there a possibility that iFood will receive new financial support next year?*** I believe so, but there is nothing yet forecasted. It is excellent that Movile has long-term investors that have supported us over the last decade. This has ensured that our group will continue to support iFood to ensure that it remains a market leader.

***Do you see an IPO on the horizon—an initial public offering or public listing—for iFood or for Movile?***

We are not planning this because we



**We need to believe in the disruptive potential of technology and understand that trillions of dollars will go to innovative companies in the coming years**

are not in need of [additional] capital at the moment. iFood could easily do an IPO today. But we have better access to capital as a private company with the advantage of not having to tell the world what we are doing. We do not have an exact projection for iFood, but we want to grow 10 times bigger.

***What is the market value of Movile today?***

We can't say. In the beginning of 2017, we surpassed US\$1 billion.

***What is the second largest company controlled by your group today?***

iFood is the largest. In second place is PlayKids, a global leader in educational content platforms for families. PlayKids, which is the most downloaded educational children's app in the world, includes Leiturrinha, the largest membership club for children's books in Brazil; PlayKids Explorer, a membership club of educational activities; and Loja Leiturrinha, a marketplace with the best children's products on the market. There are also other companies that are part of the group, such as Wavy, which brings

together messengers, content, and other mobile phone operators and television companies. They are a leader in Latin America and one of the largest companies in their industry in the world, with an average annual income of R\$100 million, 100 million active users, and 400 partner companies. We have Sympla, a complete platform for ticket sales and management, as well as registrations for all kinds of events. The company has already sold more than 4 million tickets in 2,000 cities for more than 50,000 events carried out by 10,000 producers. On average, seven tickets are sold every minute. In the beginning of the year, we also invested in Zoop, an open platform for payments and financial services, with financial technology focused on enabling other companies to develop their own payment and financial services solutions.

***There is a clear movement toward more research and the use of AI—artificial intelligence—around the world, including in Brazil. Are the companies of the Movile Group that are based in technology already using this resource on a regular basis?***

Yes, our companies are already using it, but we want to increasingly invest in AI within the group, as we consider this to be a huge opportunity. We want to be a world benchmark for AI, with the deepest understanding of our customers in order to personalize their experience. No one is investing in AI in Brazil as they should. As a country, we are behind in this game, and we have to change this scenario to ensure our ability to compete. As a company, we are doing a lot in this regard, and we want to become regional leaders in the development of solutions based on artificial intelligence.

***You have already stated that technology companies in Brazil think small and should look to the longer term. In your opinion, why is this happening?***

It's necessary to be local with a global mindset. Learning with the market leaders is essential. What we're doing at iFood is a world benchmark in food delivery, comparable with the big players in North America and Europe. I believe we have enormous potential as a country and that we can have many US\$10 billion companies. At Movile, we are working to reach this goal, enabling companies with



Food delivery persons for the iFood app in São Paulo: the company wants to achieve exponential growth

global potential to broaden the Brazilian ecosystem. Becoming global is no longer an option—it's a necessity. Therefore, looking only at the internal market and not creating strategies to impact lives at a global level has led to many Brazilian companies becoming hostage to their own limitations.

***How do we get out of this trap and create a truly productive ecosystem of innovation for the country?***

It requires thinking big and focusing on building global companies. We don't need to have an inferiority complex. I see people blaming the economic crisis and the problems our country is facing. These issues don't contribute to life, but I'm certain that some of the blame can be placed on entrepreneurs. We have to do our part — it's necessary to believe in the disruptive potential of technology and know that trillions of dollars will

change hands, going to new innovative companies in the next few years, supporting innovation and investing more and more in initiatives that accelerate change through technology. We have seen considerable growth in this area in recent years; large investors have begun to look to Latin America, and I believe the trend will be towards big growth. Examples of this are the large investments by China, the PagSeguro IPO, and the emergence of unicorns such as 99 and Nubank, among others.

***Even with their limitations, Brazilian universities, particularly those that are publicly funded, grant degrees to professionals who have the ability to solve technological problems. Does Movile recruit people directly from universities?***

Yes, we have partnerships with various junior companies and universities throughout the country, such as UFS-

CAR [Federal University of São Carlos], USP [University of São Paulo], UNICAMP, and UFPE [Federal University of Pernambuco], among others. We believe in the knowledge that is produced in academia, and we have various internship programs.

***The topic of your master's at FGV was creating a model for the process of accelerated growth for startups. How much did your postgraduate studies help you professionally?***

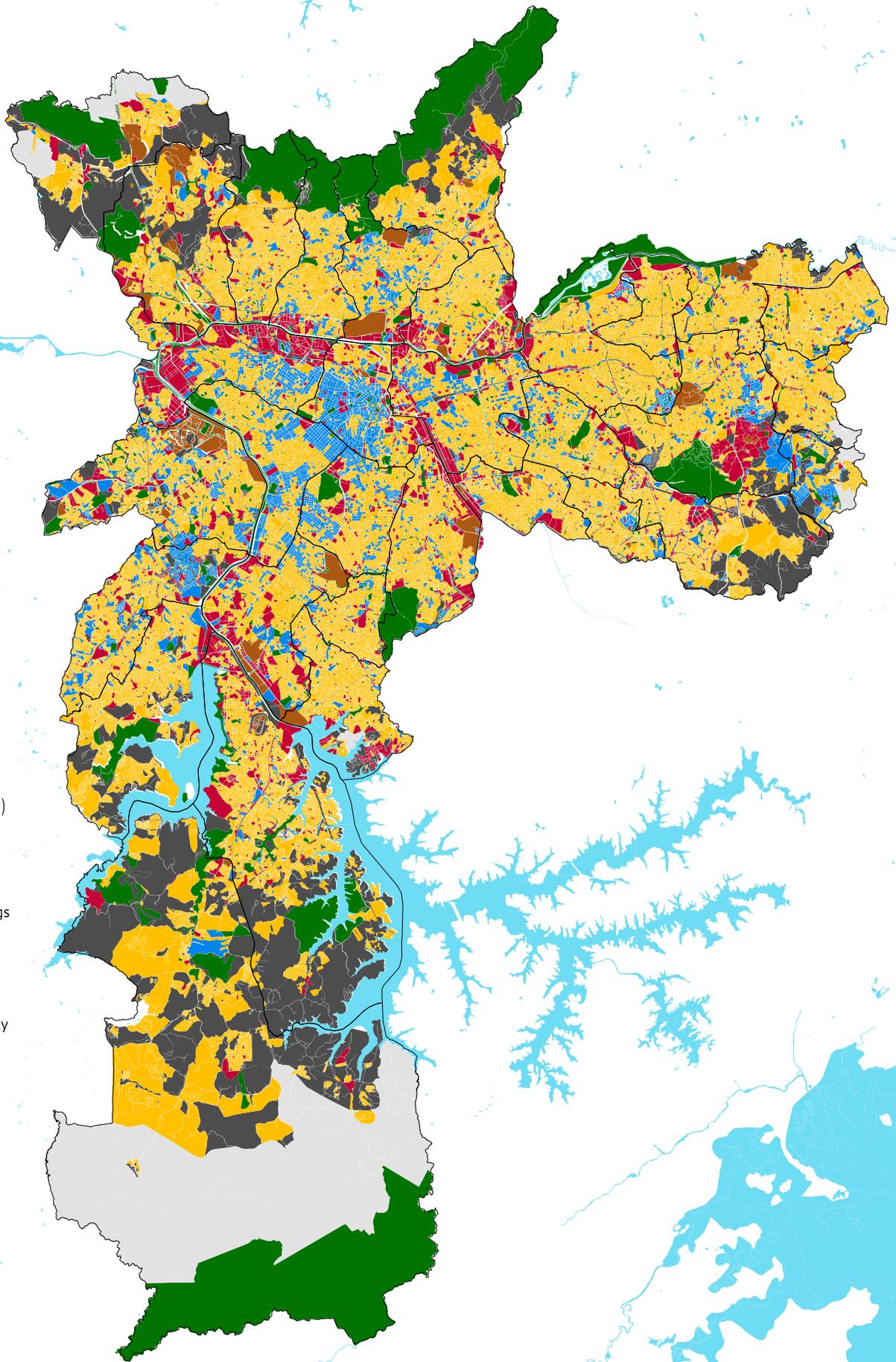
I believe that my postgraduate studies were fundamental for my growth at Movile. I studied how international companies grow and innovate, what consolidation strategies are most effective, and how to apply all of this to improve the group I lead. And, without a doubt, I put my master's into practice changing the strategy of the company. I believe a lot in studying and I don't support the separation of academics from practice—I believe in both. It's necessary to be a student to learn and put this into practice, and this was my experience. I encourage people to continue studying all the time. After my postgraduate studies at FGV, I completed courses at Stanford University, and now I'm starting another at Harvard in the United States. The ability to learn continuously enables me to sustain a company that is always changing and innovating.

***During your undergraduate studies at UNICAMP, you participated in a thematic project by researcher Secundino Soares Filho about electrical energy systems through a scientific research scholarship from FAPESP. Did this experience help you in any way when you became a technological business entrepreneur?***

My initial scientific research was my first contact with innovation, academia, and the first step toward thinking about doing a master's. It helped me develop a deeper connection with UNICAMP, interact more with my colleagues and professors, and expose me to new experiences and knowledge about technology. At the time when I was doing my initial scientific research, something very interesting happened: I started to develop the idea of launching a business. I ended up putting theory into practice. ■

## OCCUPIED AREA IN SÃO PAULO (SP)

- Small, horizontal buildings (up to 1,000 m<sup>2</sup>)
- Medium-sized horizontal buildings (over 1,000 m<sup>2</sup>)
- Vertical buildings (more than four stories)
- Urban enclaves (airports, university campuses, etc.)
- Open spaces with public access
- Non-constructed areas
- Hydrography



# The search for open spaces

Recent urban development has been marked by contradictions around the use of open areas

Christina Queiroz | PUBLISHED IN SEPTEMBER 2018

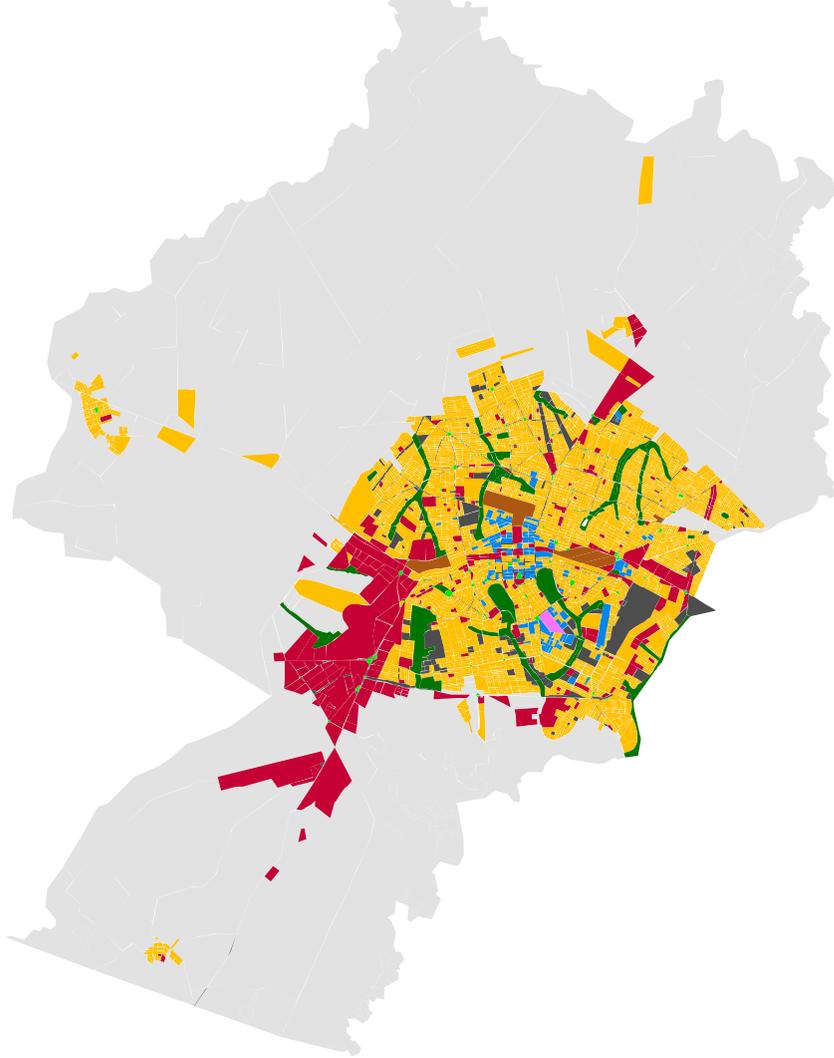
**D**uring the last 30 years, both large and medium-sized Brazilian cities have undergone significant transformations, breaking with the standards of form and usage that prevailed in the twentieth century. Studies conducted in 70 municipalities from all regions of the country show that during this period, there was a proliferation of subdivisions and gated communities, while the appropriation of public space also increased. Since 2006, the Landscaping Lab (Lab QUAPÁ) of the School of Architecture and Urbanism at the University of São Paulo (FAU-USP)

has conducted national surveys to analyze how urban open spaces develop, proposing practical guidelines to municipalities on how to improve their use. “One of our findings is that populations in different cities end up occupying these spaces in different ways, from political and religious purposes to leisure and physical activities,” says Eugênio Fernandes Queiroga, a professor at FAU-USP and coordinator of a research project on the subject.

The research works with a concept of open space that includes not only areas of environmental conservation but also terrain without buildings

City of São Paulo: buildings with more than four stories are predominant in fewer than 15% of city blocks





MARINGÁ,  
PARANÁ STATE

- Nonurbanized areas
- Unoccupied areas
- Squares and parks
- Cemeteries
- Small horizontal buildings (up to 1,000 m<sup>2</sup>)
- Medium-sized horizontal buildings (over 1,000 m<sup>2</sup>)
- Vertical buildings (more than four stories)
- Urban enclaves (airports, university campuses, etc.)

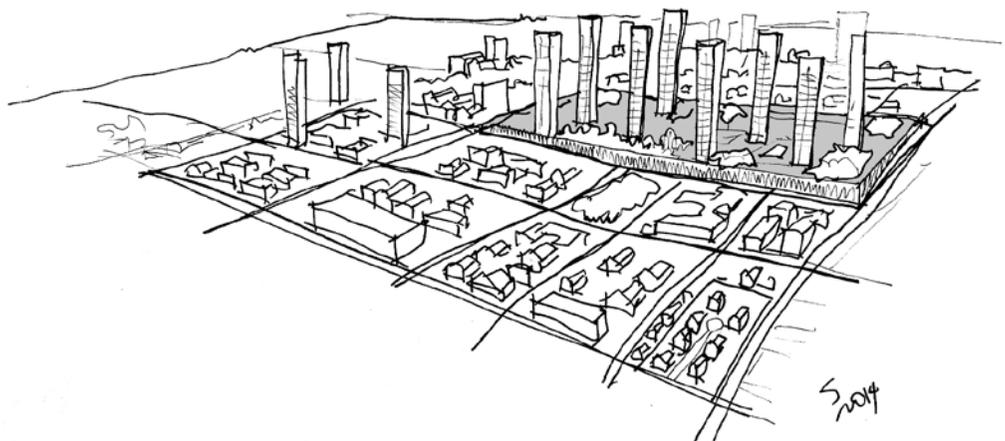
such as certain backyard spaces, airport runways, water and sewage treatment plants, and streets and avenues. According to the Brazilian Institute of Geography and Statistics (IBGE), in the 1970s, the Brazilian urban population surpassed the rural population, with 56% of the inhabitants living in cities. At that time, Queiroga explains, the highest-quality open spaces were found mainly in elite neighborhoods, such as Casa Forte, in Recife, Graça, in Salvador, and Jardim América, in São Paulo. Road systems were designed exclusively for the circulation of automotive vehicles, with

no provisions for pedestrians and bicycles. “In the 21<sup>st</sup> century, there is a search for a more equitable distribution of public open spaces around the country,” the researcher summarizes, noting that some guidelines developed by the project regarding the use of open spaces were incorporated into São Paulo’s master plan in 2014.

Queiroga notes that in contrast to the previous era, today, open spaces are beginning to spread to other parts of the cities. Some characteristics are common to almost every municipality analyzed, regardless of size, and are found in all the capital cities. One of these is that the streets function as the principal elements of the urban open space system in the public sphere, except for in Florianópolis and Rio, where ample green areas exist. Along with private open spaces, streets constitute the majority of the unobstructed spaces in cities. “Although still a minority feature of the urban landscape, we have seen a proliferation of other categories of public open spaces across various parts of cities, which see common and shared use by the entire population, such as parks, squares, gardens, promenades, and margins,” the researcher observes.

According to Queiroga, although verticalization is a growing part of the urban landscape, with the construction of buildings over four stories becoming increasingly frequent, municipalities are still mainly horizontal. Buildings with up to three floors prevail in the studied regions. “Unlike one would imagine, in São Paulo, for example, fewer than 15% of city blocks are predominantly made up of buildings with more than four floors,” he says.

Afforestation within cities does not generally exceed 10% of the empty space within city blocks, and large expanses of vegetative cover are common only in parks, squares, vacant lots, and environmental preservation areas. “Some exceptions can be found in elite neighborhoods that have wider sidewalks and, therefore, extended space for tree planting, such as the Jardim districts in





São Paulo, the Jardim Oceânico district in Rio de Janeiro, and the Jurerê district in Florianópolis,” he points out. On the other hand, in peripheral districts occupied mainly by the low-income population, the open spaces tend to be limited to streets, small park squares, and soccer fields.

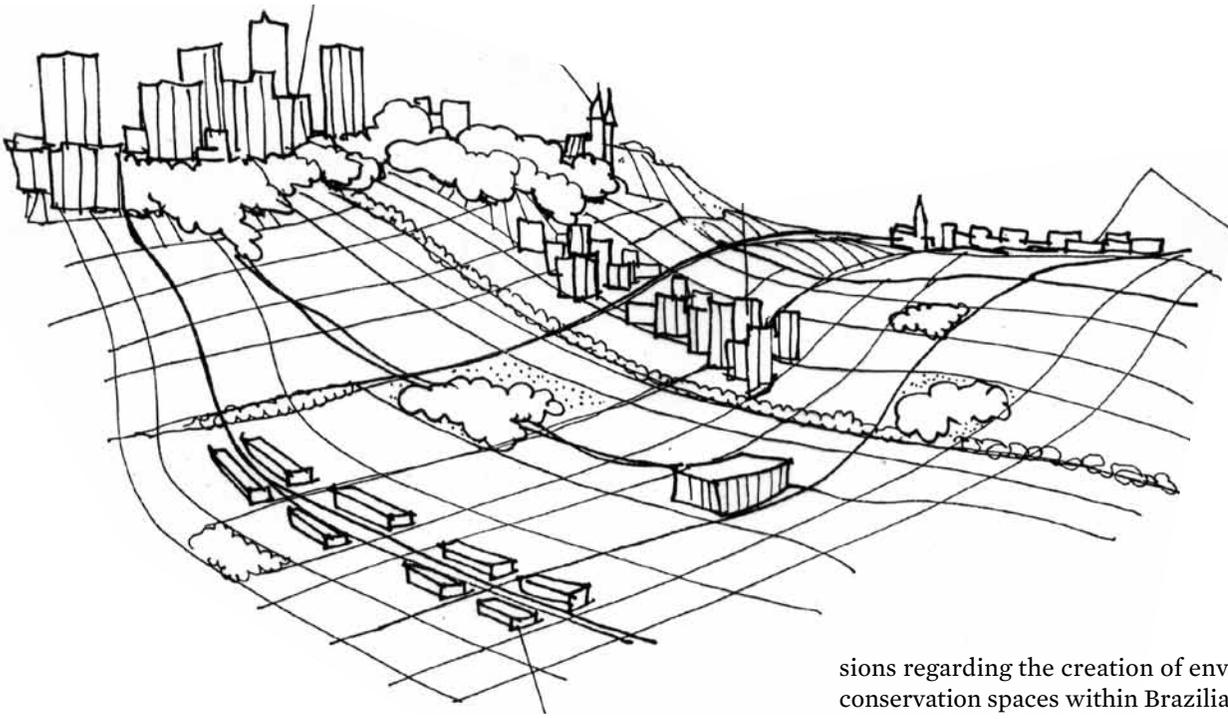
Another common trend identified by the project involves the increase in the number of subdivisions (division of property into lots intended for construction), gated communities and condominiums, which meet the demands of the middle- and upper-income strata of the population. “However, this dynamic does not necessarily mean that people have stopped frequenting public spaces. In contrast, we found that it was accompanied by a greater appropriation of these spaces, for example, as occurred after June 2013, when political demonstrations took place in the streets and squares of cities of all sizes,” Queiroga adds. In this respect, the study detected the creation of new spaces intended for public meetings and socializing, in addition to conventional areas such as city squares and parks.

In São Paulo, for example, Municipal Law No. 16,833 from February of this year transformed the elevated João Goulart avenue, the Minhocão, into a municipal park, increasing the already existing restriction on auto traffic and expanding the hours dedicated to recreational use. Prior to this, in June 2016, the city of São Paulo had created

the Open Streets program, based on Federal Law No. 2,587, which was enacted in January 2012 with the objective of promoting the sustainable development of the city and ensuring equity in the use of public space. Through this program, streets and avenues, such as Avenida Paulista, began to prohibit motorized traffic on some Sundays and holidays, a practice that is now in effect weekly, encouraging pedestrian traffic, physical activities, and leisure. “Viaducts or avenues that are turned into parks without losing their initial role, intended for the circulation of vehicles, exhibit levels of multifunctionality that were not foreseen in their initial design,” notes Queiroga.

These examples are repeated in other locales, says Eneida Maria Souza Mendonça, a professor in the Department of Architecture and Urbanism at the Federal University of Espírito Santo (UFES). Since 2012, the city of Vitória, for example, has restricted car access to only one side of an important avenue along Camburi beach, with the objective of stimulating sports and leisure pursuits. In Rio de Janeiro, squares, promenades, wide avenues, and especially viaducts, which offer protection against the sun, have also been used as locations for fairs, events, and classes, explains Vera Tangari, a professor in the Department of Architecture Projects at the Federal University of Rio de Janeiro (UFRJ). The

Manaus, Amazonas State, maintains parks to avoid floods and clean up streams



researcher notes that in Rio, the peripheral and hillside districts, where the low-income population is concentrated, have grown more than the central districts. However, this growth has not been accompanied by the creation of new open spaces.

In Florianópolis, beaches also perform an important role as open spaces geared towards leisure, says Alina Gonçalves Santiago, a professor in the postgraduate program in architecture and urbanism at the Federal University of Santa Catarina (UFSC). According to her, open areas such as squares and parks do not constitute even 1% of the total municipality. “And the city government justifies the low investments in such spaces because of the existence of beaches, which can fulfill the function of providing leisure spaces to the population,” she says. Despite this, Florianópolis, which is the capital of Santa Catarina State, has an extensive area of environmental preservation, up to approximately 50% of its land. Much of it, however, is disconnected from the urban grid and does not have infrastructure that can provide access, such as streets for automobiles, parking lots, or hiking trails.

#### THE CENTURY OF PARKS

Although the nineteenth century in Europe may be known as a period when urban parks were proliferating, in Brazil, the development of these areas did not gain momentum until the second half of the twentieth century. Queiroga points to the creation of parks as another recent trend in the country and adds that this dynamic arises from the Federal Constitution of 1988, with its provi-

sions regarding the creation of environmental conservation spaces within Brazilian cities. He observes that Goiânia is the capital that dedicated the most areas for parks in that century. “The abundance of parks occurred mainly in the state capitals, which then spread this culture of urban planning and landscaping to smaller cities,” he observes, noting that the study identified the existence of parks even in small municipalities such as Engenheiro Coelho, in the metropolitan region of Campinas, São Paulo State, which has approximately 20,000 inhabitants.

In Queiroga’s estimation, the creation of urban green areas generates, among other consequences, an appreciation for the idea of environmental conservation in society. However, for conservation to take place effectively, it is essential for green spaces to have infrastructure that facilitates access. “It is no use creating green areas and leaving them inaccessible, as is the case with the largest municipal park in São Paulo, Anhanguera Park, which has nine million square meters, but with a visiting area that is less than one-third the size of Ibirapuera Park. No one can experience it like that,” he says.

The creation of public gardens has different motivations according to the city. Thus, municipalities such as Curitiba (Paraná), Manaus (Amazonas), Rio Branco (Acre), and Sorocaba (São Paulo) developed their parks to avoid flooding and clean up streams, explains Queiroga, while in Campo Grande (Mato Grosso do Sul) and Maringá (Paraná), these elements are the result of urban planning measures, which have set aside open spaces in anticipation of future endeavors. Maringá, for example, has had its open spaces planned since its foundation in 1947, when it determined that the sidewalks would be three to five meters wide, and it reserved areas

Avenues in Campo Grande, Mato Grosso do Sul State: median strips up to 20 meters wide permit the inclusion of bicycle paths



## The proliferation of gated communities was accompanied by increased occupation of public space

for afforestation, in addition to parks established as a conservation strategy for groundwater springs. Queiroga recalls that the Forest Code, updated by Federal Law No. 12.727 in 2012, stipulates that 30-meter margins should be left along the edges of rivers less than 10 meters wide. “The planning of Maringá goes beyond this and designates a reserve of 60 meters, which, over the years, allows for the construction of linear parks along the sides of its rivers,” the researcher observes, indicating Campo Grande as another city that planned its open spaces well. Since the 1960s, in addition to the areas reserved for

the creation of parks, the municipality has also designed extensive avenues, with median strips up to 20 meters wide, which, over time, made possible the construction of bicycle paths and pedestrian-only areas.

As a counterpoint, Queiroga observes that these two cities are a far cry from the situation in Brasília. In the federal capital, he notes, only the district included in the pilot plan was well planned. In the satellite city of Águas Claras, for example, most of the production of new urban spaces involved the construction of buildings with more than 20 stories, which offer internal recreation areas and narrow sidewalks inadequate for pedestrian circulation. Along the same lines, Belo Horizonte also has its planned

open spaces mainly in its downtown area, notes Staël de Alvarenga Pereira Costa, a professor at the School of Architecture of the Federal University of Minas Gerais (UFMG). “However, in peripheral districts, the only unobstructed areas are the streets and soccer fields.”

Silvio Soares Macedo of FAU-USP, the investigator responsible for coordinating the research project until 2016, says that to map out the open spaces, the team used satellite images available on the internet, which were incorporated into a geo-referencing system. It was the responsibility of the project team—which in São Paulo alone comprised approximately 25 people, including professors, undergraduates, and graduate students—to identify the characteristics of each block in every city that was analyzed, including their levels of afforestation and the presence of buildings, gardens, or broad sidewalks.

With the cartography ready, the FAU lab organized more than 40 workshops at partner universities, as well as with managers of municipal governments. As part of the activities, flyovers were performed in the regions studied to allow a closer analysis of the zones initially mapped by satellite. Coordination with city governments involved four cities in the state of São Paulo: Santos, São José dos Campos, Sorocaba, and São Paulo. “In these meetings, we showed the administrators responsible for urban development how they can use the data collected by the project to improve the open space systems in their cities, by developing master plans and using municipal legislation to regulate the



**Macapá  
(Amapá State)  
has extensive  
open spaces,  
encouraging the  
future creation  
of parks and  
recreation areas**

operations of the principal agents of transformation in their regions,” Queiroga says.

One of the major accomplishments resulting from the meetings with municipal governments came to fruition in 2014, with the inclusion of concepts related to open-space systems into the master plan of São Paulo, ideas that go beyond simply creating green areas. “For example, we were able to stipulate that the São Paulo plan, a basic instrument of urban development policy, would determine the creation of spaces for public enjoyment on private properties. Today, real estate developers are required to reserve part of their projects for public use, creating, for example, pedestrian walkways and rest areas within the development projects they have undertaken,” he reports. This type of measure, explains Queiroga, takes into consideration increasing population densities, allowing new developments to accommodate growing pedestrian traffic in urban areas.

#### **OFF THE CHARTS**

Macapá cannot easily be accessed by land, only by means of a few airlines or ferries, which is why the city has experienced the transformations identified in other regions of the country to a far lesser degree. Founded in the eighteenth century using a master plan drawn up in the colonial period, the capital of Amapá is considered a strategic site due to its location at the entrance of the Amazon River, offering inland waterway connections to Belém and Manaus and access to the Atlantic Ocean. Pedro Mergulhão, a professor of architecture and urbanism at the Federal University of Amapá (UNIFAP), states that the city’s master plans were designed in harmony with the original, maintaining the width standards of the streets and blocks perpendicular to the Amazon River.

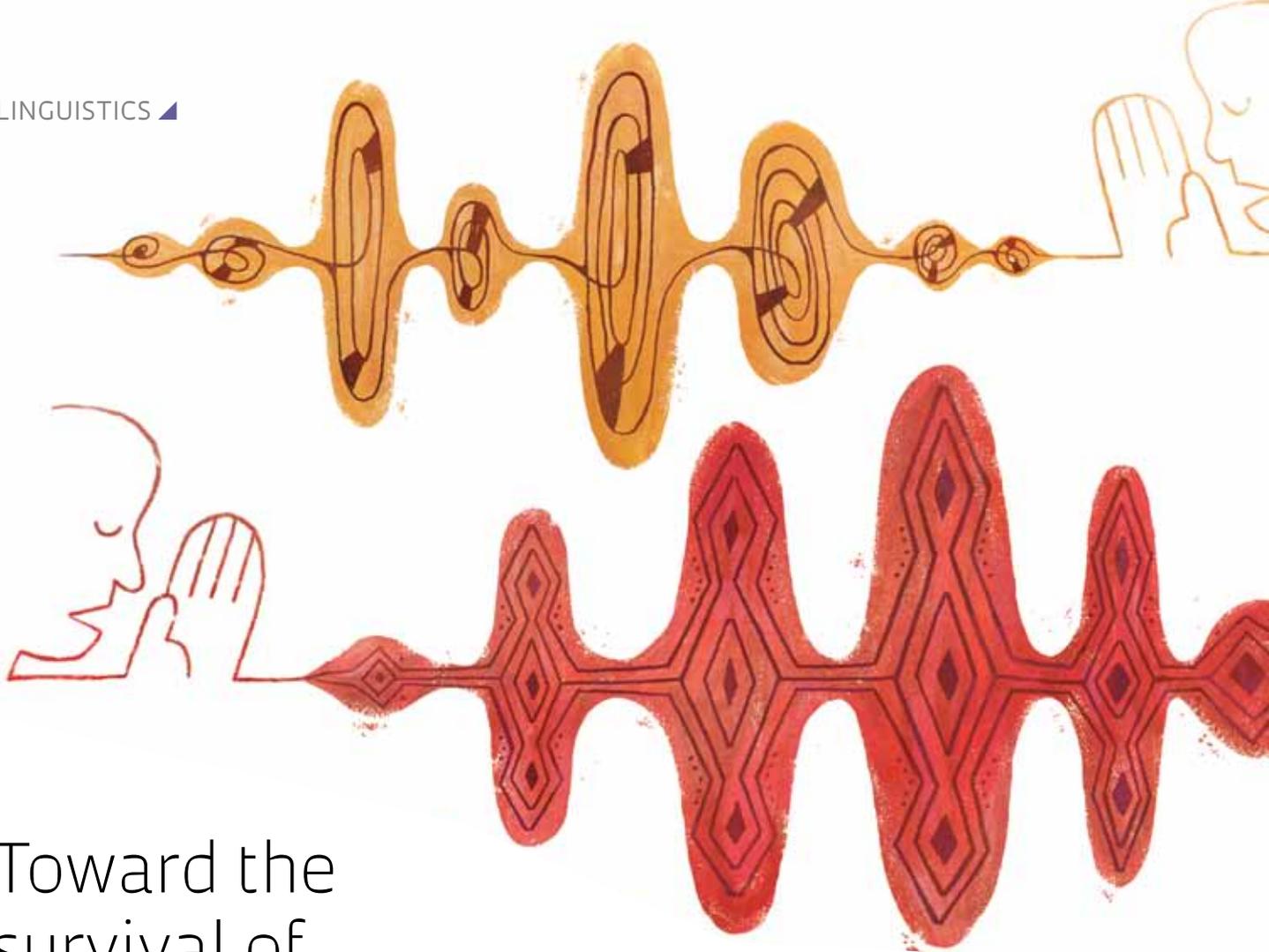
“Thus, part of the urban landscape from the colonial period has been preserved, including the squares and riverbanks that allow open access by the populace, unlike Belém, in Pará, which is built right up to the river’s edge,” he explains. As in most of the state, and unlike in other capitals, Macapá still has extensive unoccupied areas, which encourages the planning of open spaces capable of ensuring a better quality of life for its inhabitants.

Macedo, who began researching the subject in the mid-1990s, explains that until then, urban development projects tended to value the creation of green areas. However, he argues that thinking about urban development from the standpoint of open spaces makes more sense because these spaces are responsible for structuring the quality of life within cities, determining the availability of natural light and air circulation. When analyzing cities from the standpoint of developing open spaces, Vera Tangari notes that the studies conducted by Lab QUAPÁ helped to create a Brazilian school of urban morphology. “Before, this field of study was interpreted through historical analyses of architecture, using the development of European cities as a parameter,” she says. In her view, analyses based on the evolution of open spaces provide a better understanding of the configuration of Brazilian cities, closer to Latin American municipalities. Based on these findings, the project’s researchers intend to create a Latin American observatory of the urban landscape. ■

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#### **Project**

Systems of open space in the constitution of the contemporary urban form in Brazil: Production and appropriation—QUAPA-SEL II (2012–2018) (no. 11/51260-7); **Grant Mechanism** Thematic Project; **Principal Investigator** Eugênio Fernandes Queiroga (USP); **Investment** R\$585,123.33.



Toward the  
survival of

# indigenous languages

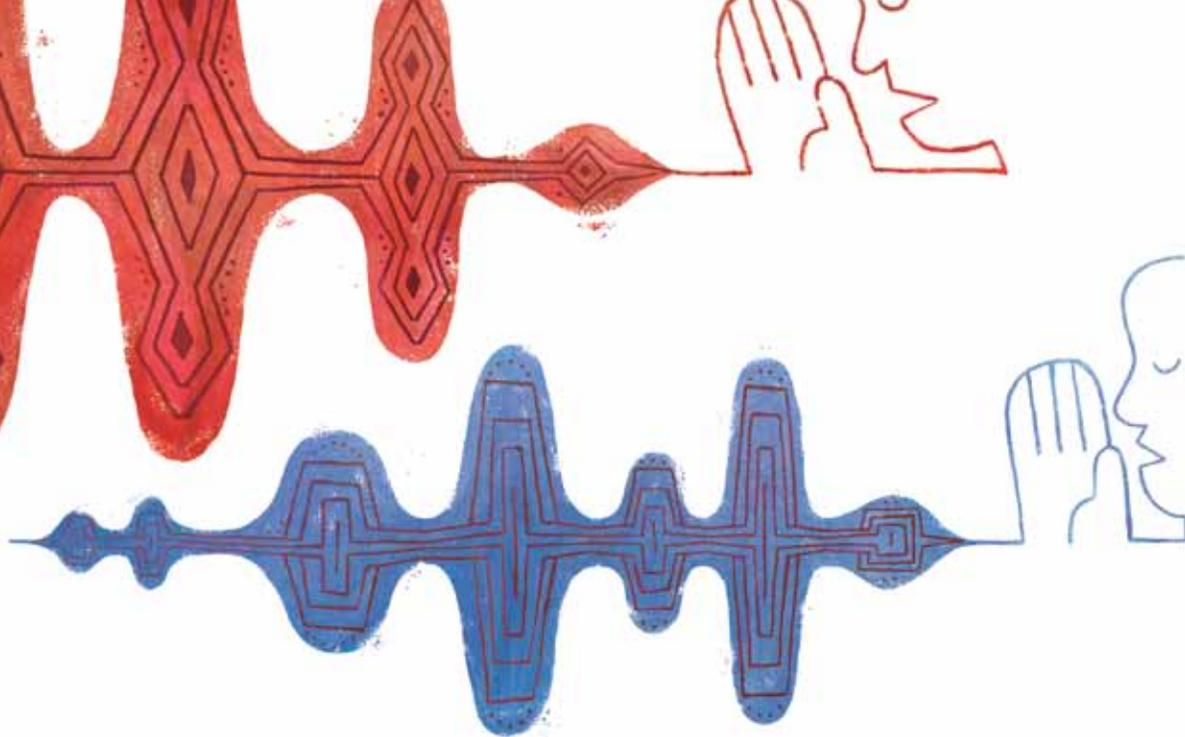
With the help of  
technology, researchers  
work to prevent the  
disappearance of native  
languages in Brazil

**Luisa Destri**

PUBLISHED IN NOVEMBER 2018

**T**he approximately 170 indigenous languages spoken in Brazil are an important subject of research in the linguistic field today. It's a fight against time. Faced with estimates that these languages could disappear within 50 to 100 years, linguists are dedicated not only to recording them but also to working toward their survival. From textbooks to dictionaries, from sites in indigenous languages to digital linguistic corpora, a generation of researchers who began their studies with these communities in the 1990s are offering contributions that simultaneously deal with the subject's scientific demands and meet social aims.

"We've lost a lot of diversity and we're going to lose even more," says Luciana Storto, a



professor in the Department of Linguistics at the School of Philosophy, Languages and Literature, and Humanities at the University of São Paulo (FFLCH-USP). She refers to an estimate that there were more than a thousand native languages spoken in the country before colonization. Nevertheless, Brazil is recognized worldwide for its many languages: there are 37 families or linguistic subfamilies (Macro-Jê and Tupi are the largest groupings), as well as eight other isolated languages—that is, languages unrelated to any other known language.

The indigenous population in the country has grown to 896,917, according to data from the Brazilian Institute of Geography and Statistics (IBGE), but the number of people who speak these languages is continually declining—today, only 434,664 people are able to speak them. Although many of these native peoples don't live on indigenous lands, most indigenous language speakers are concentrated in the demarcated areas that occupy 13% of the Brazilian territory and favor the preservation of the language and culture of these ethnic groups. In the book *Línguas indígenas*:

## The production of material for use in communities is one way of repaying the contributions of indigenous people

*Tradição, universais e diversidade* (Indigenous languages: Tradition, universality, and diversity), scheduled for release in 2019, Storto explains that while health care and nutrition have improved among indigenous peoples, “historical prejudice” causes many to abandon their own languages, believing this is the most suitable way to obtain fluency in the Portuguese language.

For languages with an oral tradition, the consequences of this process are disastrous. “Knowledge is passed down from generation to generation, mainly through narratives told by the oldest

and most experienced to the community's youngest members,” explains Storto. When older people stop using a certain language and children stop learning it, the result is the disappearance of that language. Schools, which could intervene in this process, aren't always able to do so. Although indigenous education has had its autonomy legally guaranteed since 1999, there is no structured educational system—each ethnic group must take responsibility for conceiving its own plan. As there are few native professionals with the training to do this, communities rely on specialized collaboration to develop specific teaching materials for their own language.

The linguist's work with indigenous communities is extensive and almost always begins with the description of the language in its many aspects—sounds and their combinations, words and their composition, sentences and their formation, and the language in actual use. An initial synthesis of this knowledge results in theoretical works that can take the form, for example, of a grammar text. Such was the case for Storto, whose doctoral thesis, defended at the Massachusetts Institute of Technology (MIT) in the United States, was dedicated to Karitiana, the language of a community living in an area located in Porto Velho, Rondônia.

“It's common that this is the first approach, because every language has a logic, and linguists have techniques to



extract this logic and write down a grammar,” explains Filomena Sandalo, a professor in the Department of Linguistics of the Institute of Language Studies at the University of Campinas (IEL-UNICAMP). Sandalo has been a researcher on the subject for more than 25 years. As part of her doctoral thesis, defended at the University of Pittsburgh in the United States, she created a grammar for the Kadiwéu language, which is spoken by the eponymous indigenous community whose territory is located in Mato Grosso do Sul.

Starting from the description, which is also a way of understanding and mastering the language, the work can develop in different directions. Sandalo’s work has an unusual trajectory because it is subordinated to theoretical discussions in the field of generative linguistics. Presented by the American linguist and philosopher Noam Chomsky in the late 1950s, this field abstractly describes and explains language, which is understood to be an innate capacity of the human brain. “I created a grammar which was atypical among those working on

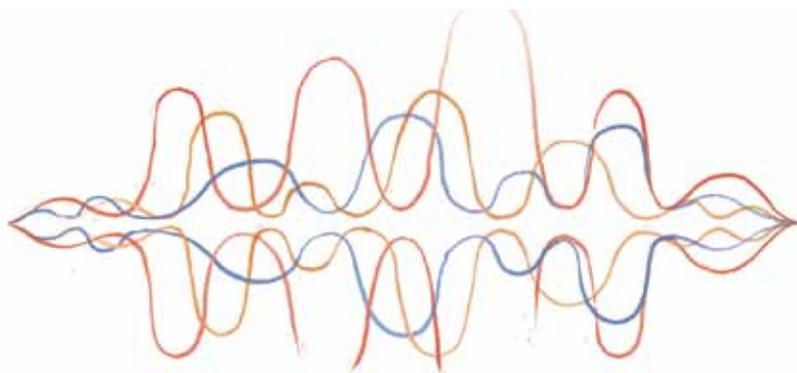
documenting indigenous languages,” the UNICAMP researcher explains. She adds, “The themes I’m looking for are the universals of the language, that which characterizes human language regardless of culture and society.”

#### DIGITAL CORPUS AND WEBSITE

As part of the project “Frontiers and asymmetries in phonology and morphology,” which proposed experiments with Portuguese and Kadiwéu in order to discuss linguistic theory, Sandalo coordinated the creation of a digital corpus of this indigenous language. Available for consultation at UNICAMP’s Tycho Brahe Project website, this corpus brings together some of the Kadiwéu people’s narratives in sound and text files, with a translation of each of the words (annotations to a text to explain the meaning of a word, for example, are called “glosses” by linguists), as well as morphological analysis. The aim is twofold: to serve both for linguistic research and for educational use. “A corpus is also a mechanism for preserving languages,” the project coordinator adds.

In the field of theoretical research, the production of material for use in communities is seen as a way of repaying the contributions of the indigenous people. “We do a lot of work documenting texts and sentences, and we need them to help us the entire time with translations. In exchange, we produce didactic material: a spelling reference, a documentation project,” says Storto. Such projects, she explains, have significant value to these communities: “If exhibited at school, a video of ancestors speaking the language, for example, is useful as a record of traditional knowledge.”

Given the importance of writing in Western culture, the preliterate nature of that indigenous languages contributes to their vulnerability. For this reason, the orthographic part of the project is often part of the work of the linguist, who establishes the alphabet and the rules for its use. This was what Wilmar D’Angelis did in the early 2000s in a joint effort with the Kaingang in the western region of the state of São Paulo, where he worked for almost four decades, initially as an indigenist and later as a linguist. In a participatory process, the community and researcher adapted an orthography developed in the 1960s for the Kaingang



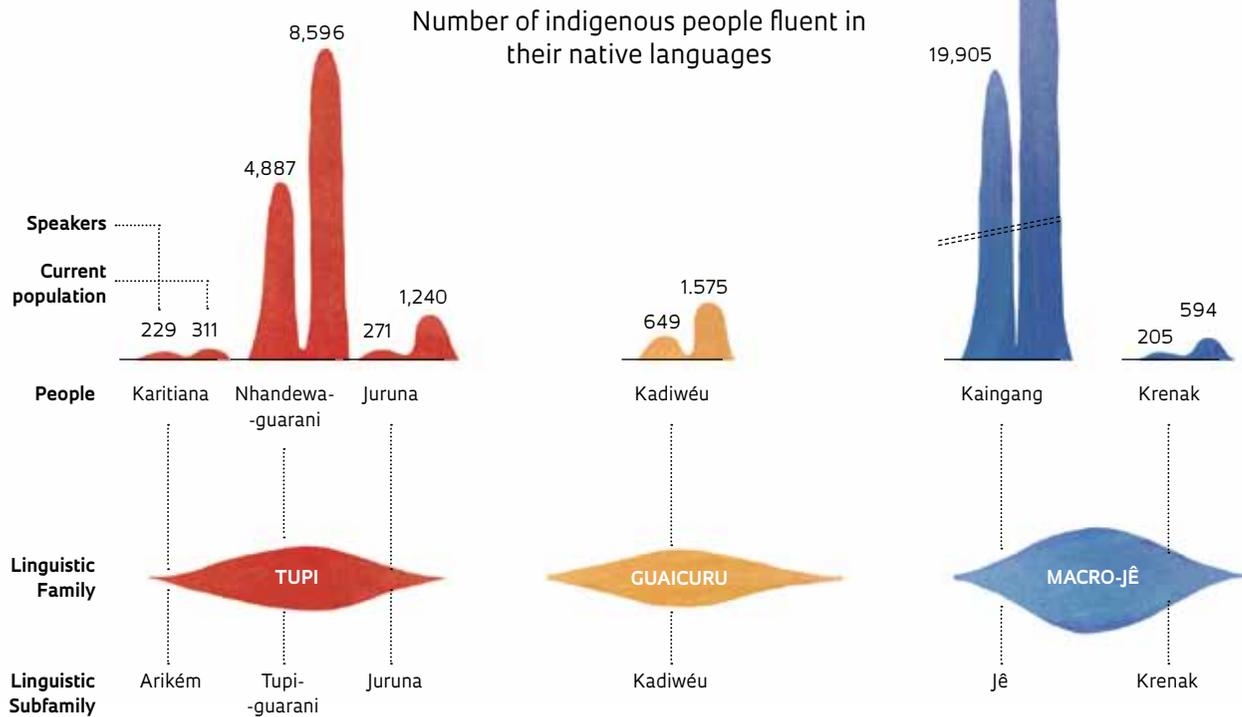
## Preserved from childhood

When she was invited by the Juruna to record their lullabies, Cristina Fargetti was surprised. A few years earlier, she had asked members of the community if there was a tradition of women singing at night for their children. There wasn’t. “If you ask the wrong question, you’ll get the wrong answer,” she says today, after discovering that the tradition does exist but that lullabies can be sung only during the day, until around 4:00 p.m. The Juruna believe that sleep temporarily takes people’s souls away from their bodies. If they were sung at night, these songs would quickly push the soul away. Pulled into the darkness, it wouldn’t be able to return. This would lead to illness or even to the child’s death.

The result of the research, which had as its goal the revitalization of this indigenous tradition, can be found in *Fala de*

*bicho, fala de gente – Cantigas de ninar do povo juruna* (Animals speak, people speak—Lullabies of the Juruna people; Edições SESC). The book provides a complete study of the genre, comparing it to Portuguese and Brazilian songs, discussing their meaning among the Juruna, and presenting transcriptions and contextualized translations of 49 songs. The rich musical repertoire of this ethnic group is also the object of a study by researcher and composer Marlui Miranda, who wrote the transcriptions of the songs Fargetti collected, which are reproduced on a CD that accompanies the book. There are also discussions about humor among the Juruna and how they view the differences between humans and animals— aspects that are important for understanding the songs and that evoke specific understanding of linguistics and anthropology.

# The languages and their speakers



**SOURCES** LUCIANA STORTO AND FELIPE FERREIRA VANDER VELDEN (KARITIANA), MÔNICA THEREZA SOARES PECHINCHA (KADIWÉU), KIMIYE TOMMASINO AND RICARDO CID FERNANDES (KAINGANG), RUBEM FERREIRA THOMAZ DE ALMEIDA AND FABIO MURA (NHANDEWA-GUARANI), MARIA HILDA BAQUEIRO PARAISO (KRENAK), TÂNIA STOLZE LIMA (JURUNA) – INDIGENOUS PEOPLES IN BRAZIL, INSTITUTO SOCIOAMBIENTAL; CENSO DEMOGRÁFICO 2010: CARACTERÍSTICAS GERAIS DOS INDÍGENAS (DEMOGRAPHIC CENSUS 2010: GENERAL CHARACTERISTICS OF THE INDIGENOUS POPULATION), BRAZILIAN INSTITUTE OF GEOGRAPHY AND STATISTICS.

of southern Brazil. Both a defender and a creator of inclusive projects, D'Angelis also highlights the importance of the indigenous language being visible in communities with access to technology; not seeing their own language on the internet, “in what to indigenous people will appear to be the largest space for dissemination and circulation of ideas and information,” can generate the belief that native languages have value only as folklore, without function in the real world. Therefore, the researcher considers it essential to create contexts in which the language is actually used.

It was this thinking that guided the 2008 creation of Kanhgág Jógo, the first website entirely in an indigenous language in Brazil. The result of the collaboration of D'Angelis's research group with members of the Kaingang communities of Rio Grande do Sul, the project was then repeated with other ethnic groups. For D'Angelis, preventing the use of technology would be akin to taking a refrigerator to the village and only allowing the storage of food brought from the city, leaving out anything produced locally.

## The production of literature indicates the language's vitality and gives cause for celebration

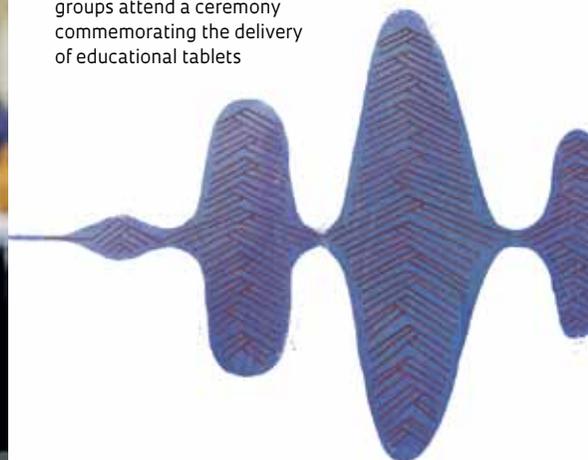
### INFORMATION RETRIEVAL

Together with his students who meet in the INDIOMAS research group, the UNICAMP professor carries out projects with the participation of members of several indigenous communities. By engaging languages that were about to go out of use, such as the Nhandewa-

Guarani, the Krenak, and the Kaingang of São Paulo, researchers are working on retrieving linguistic information, as well as conducting teacher training workshops and producing materials for teaching the languages. The group is finalizing the second volume of the book *Lições de gramática nhandewa-guarani* (Nhandewa-Guarani grammar lessons) and, by request from the community itself, will publish a scholastic dictionary of the São Paulo Kaingang language in 2019. Unlike works that point out corresponding terms in both Portuguese and the respective native language—works that, according to D'Angelis's estimate, would consult one indigenous speaker for every 100 nonnative consultants—the dictionary proposes to show what the terms mean within the Kaingang culture. Among the challenges the research group faces is the task of stimulating, in the language's few remaining speakers, the memory of terms they don't use today because they refer to situations or elements that no longer exist, such as animals that are no longer seen or customs that are no longer practiced.



Natives in Cacoal, Roraima state, from the Surui, Cinta-Larga, and Karitiana ethnic groups attend a ceremony commemorating the delivery of educational tablets



Another researcher working against the current of proposals that present indigenous culture from a Western viewpoint is Cristina Fargetti. A professor of linguistics at the College of Letters and Sciences at São Paulo State University (FCL-UNESP), Araraquara campus, Fargetti has been developing a vocabulary of the Juruna language since 2010. She explains that instead of translating terms like “snow” into a culture that doesn’t even have this concept, her goal is to ask how the Juruna see reality itself. For an entry on a certain bird, for example, in addition to the translation into Portuguese, it’s important to understand aspects such as its association with a myth or song and the connotations of its birdsong.

#### LITERARY PRODUCTION

Fargetti’s work with the Xingu Indigenous Park community in Mato Grosso began about 30 years ago during her master’s research, which was dedicated to the Juruna language. At that time, the language had no written record, with the exception of lists of words designated by travelers and a few scientists. Several years later, participation in a training project for indigenous teachers led to the proposal of a Juruna orthography, in which members of the actual community discussed solutions for a written version that facilitated its

use. “Today, there are many young people typing in their own language and typing very fast. This is a sign that the language makes sense, has a function, and that they prefer to use Juruna to Portuguese,” observes Fargetti, now the coordinator of LINBRA (the Brazilian Indigenous Languages Research Group), which gathers students around the study of indigenous languages.

Appreciating their own culture is, among the Juruna, a reality based on the importance given to the language itself [see inset]. Although in the late 1960s there were around 50 Juruna, there are currently more than 500, and all are speakers of their native language. Portuguese is used only with nonindigenous people or visitors of other ethnicities. According to the UNESP professor, with the learning of written Juruna, the younger members of the group began to show more interest in the stories and myths told by their elders. “They discovered that the written stories were always reductions or adaptations of what is alive and dynamic in the spoken versions, so that the spoken stories came to be valued more,” explains Fargetti. There is also literature being produced in Juruna, especially in verse. This fact is, for the researcher, a cause for celebration: “Poets never announce the death of their language, but, rather, its full vitality,” she adds.

Among the Karitiana, the last decades have also been marked by valuing their own culture, with a gradual rise of leadership formed within the community, notes Luciana Storto. In her view, since at least 1991, outside leaders and teachers have been replaced by members of the community, which has become self-managed and is striving to offer complete elementary education within their own village. “The trend is that they are becoming self-sufficient, but without isolation,” she observes. “People are on the internet, they’re studying, they’re seeking employment. It’s not possible to stop time. The ideal scenario is that they bring the diversity and specificities of their cultures to the professions they will be pursuing,” she says. ■

#### Projects

1. Contact and linguistic change in Alto Rio Negro (no. 14 / 50764-0). **Grant Mechanism** Regular Research Grant; **Principal Investigator** Luciana Raccanello Storto (USP); **Investment** R\$66,326.29.
2. Frontiers and asymmetries in phonology and morphology (no. 12/17869-7). **Grant Mechanism** Thematic Project; **Principal Investigator** Maria Filomena Spatti Sandalo (Unicamp); **Investment** R\$422,423.59.

#### Scientific articles

- D’ANGELIS, W. da R. Do índio na web à web indígena. In: D’ANGELIS, W. da R.; VASCONCELOS, E. A. (Org.). **Conflito linguístico e direitos das minorias indígenas**. Campinas: Editora Curt Nimuendajú, p. 111–21. 2011. Available at: [bit.ly/webindio](http://bit.ly/webindio).
- FARGETTI, C. M. Breve história da ortografia da língua juruna. **Estudos da Língua(gem)**, v. June, p. 123–42. 2006. Available at: [bit.ly/OrtoJuruna](http://bit.ly/OrtoJuruna).

## Sagui

From *ça-coi*, restless eyes. The smallest of them all, which inhabits the upper Amazon, measures 16 cm, not including its tail—which measures the same in length. American explorer Victor Wolfgang von Hagen (1908–1985) wrote about it: “The *saguis* are classified among the most beautiful animals in the world. Some of them are black, with fingers seemingly inside orange gloves. There are the *leonardos*, as they are called (a name such as this for such a small animal!) for possessing a mane of sorts, similar to a lion. There is also the golden *sagui*.”



# Secrets of the forest

Using a multidisciplinary approach, a book recovers legends and records of naturalists to reveal little-known aspects of the Amazon

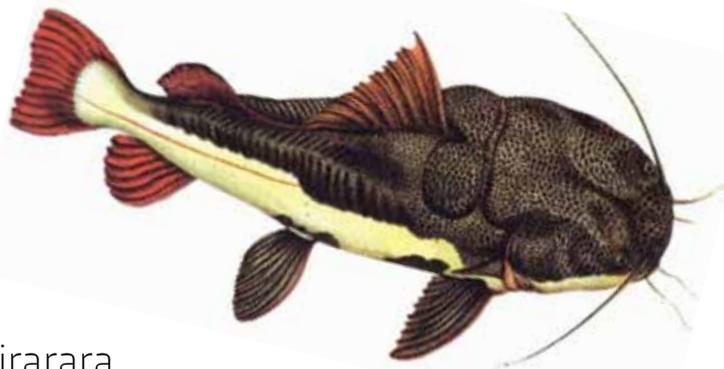
**Glenda Mezarobba**

PUBLISHED IN DECEMBER 2018

**D**espite the first “scientific” expedition to the largest tropical forest in the world having been recorded in the 18<sup>th</sup> century, the Amazon is shrouded in mystery. However, if we consider its size, this could not be any different. It measures approximately 7,000,000 km<sup>2</sup>, covering land that belongs to nine countries. With 60% of the forest occurring in Brazilian territory, the biome is located in the North, Northeast and Central-West regions of the country. While science is still not able to describe or explain a significant part of what exists there, there is considerable accumu-

lated knowledge about the forest, as indicated by the library collection at the Emílio Goeldi Museum of Pará. This is where library technician Olímpia Reis Resque hunted for treasures that comprise *Amazônia exótica: Curiosidades da floresta* (Exotic Amazon: Rarities of the forest; Empíreo), which allows for a somewhat better understanding of the region that in 2000 was named a Natural Heritage Site by the United Nations for Education, Science and Culture (UNESCO).

According to a book from a trilogy initiated in 2011, the 57 entries that comprise the book are the result of the efforts of the researcher of Ama-



## Pirarara

The pairing of *pi'ra* (fish) + *a'rara* (macaw). An Amazonian fish that can reach 1.3 m in length. "Pirarara means thief of the fish, or fish thief, suggesting that the name comes from the many fish it eats as its prey," as the Portuguese Jesuit priest João Daniel (1722–1776) defined, dedicating the last years of his life, while in prison, to recording his memories and reflections on the 16 years he lived in the Amazon. The material was published in 2004 in the book *Tesouro descoberto no máximo rio Amazonas* (Treasure discovered in the great Amazon River).

## Paricá

Taken from *pari'ka*, a species of tobacco. Also known as *angico* and *niopó*, the tree of the family of leguminous plants has good wood. Its fruit, if prepared appropriately, can be used as snuff. In the above image, from the work *Viagem filosófica pelas capitânicas do Grão-Pará, Rio Negro, Mato Grosso e Cuiabá (1783-1792)* (Philosophical travels by the captaincies of Grão-Pará, Rio Negro, Mato Grosso, and Cuiabá [1783–1792]), by Alexandre Rodrigues Ferreira (1756–1815), a Mura Indian inhales the *Paricá*.



zonian history to reveal details about the species most used by the local population. "It was a way I could communicate not only about our fauna and flora but also our collection," she says. As the librarian of the institution for 35 years, Resque began her professional career in the museum itself, as an intern, when she was still studying at the Federal University of Pará. It did not take her long to realize that there was no lack of information for her there. With 300,000 volumes, including magazines and books available to the public, and more than 3,000 rare works, the Domingo Soares Ferreira Penna Library, founded in the 19th century, holds the country's largest collection on the Amazon. "After 40 years of visiting the museum on a daily basis, I am still surprised by the collection, which is extremely diverse. I go into the library looking for a book, and I find another that I have never seen before," she recounts.

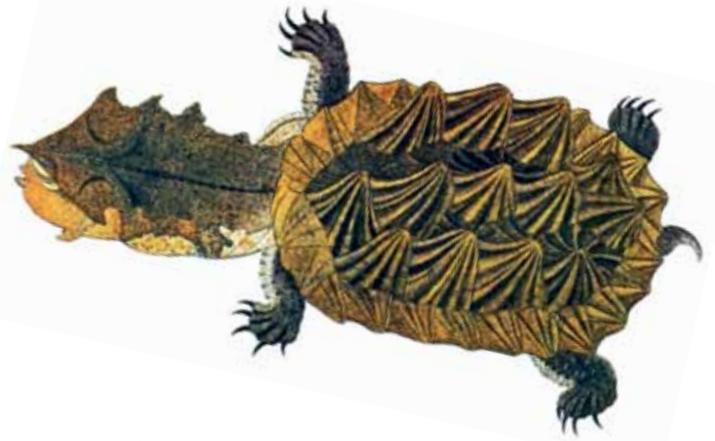
### MULTIPLE VIEWS

As indicated by the brief records provided in this report, there is information from varying perspectives in the book. With the selected species organized in alphabetical order, they reveal the etymology of the words, prioritize naturalist reports, and share legends and treasures of the forest inhabitants. In addition to a literature review, which includes rarities such as *Pátria selvagem, a floresta e a vida, mythos amazônicos: Os escravos vermelhos* (Wild homeland, the forest and life, Amazon myths: The red slaves), published at the beginning of the 19<sup>th</sup> century by Alexandre de Mello Moraes Filho (1844–1919), the book includes a glossary of regional terms, such as *caruana* (good character) and *paul* (bog), and a short biography of approximately 50 travelers who have passed through the region, with a focus on a particular woman. Reading the book, one discovers that the English botanical artist Margaret Mee (1909–1988) started her first expedition to the Amazon at age 47 and maintained contact with the local population for the following three decades.

Some of the images that illustrate the book were taken from the museum's archive and from its own collection of rare works. Some of the watercolors were painted by local contemporary artists, and there are illustrations from websites, such as plant illustrations. Thrilled with the space reserved for the feminine in the minds of the indigenous peoples and riverside communities, in the last volume of the trilogy, Resque attempts to explore the mother figure. "In the Amazon, there is a mother for everything," she says. "Jaci is the mother of the moon, Coaraci, the mother of the sun. For the people of the forest, the jungle is the mother of the animals and must not be disrespected." ■

## Pacova

Coming from *pac-oba*, a leaf that can be rolled or that rolls itself. Banana, *figueira-de-adão* and pacobuçu are a few of its varieties. "Banana trees are found in great abundance throughout the Amazon valley. In the municipality of Vila Bela, I saw bananas or *pacovas*, as they are called there, colossal in size," wrote Father Francisco Bernardino de Souza (1834–?) in *Lembranças e curiosidades do Vale do Amazonas* (Remembrances and rarities of the Valley of the Amazon) before numbering at least 10 varieties of the fruit, among them the big pacova "whose length varies from one to two palms, being 3 inches in diameter.



## Matá-matá

In *O nome do jabuty matá-matá* (The name of the *jabuty matá-matá*), Goeldi wrote about the etymology of the word used to describe the tortoise that lives in still waters and feeds on small fish: "Meaning '*matá*' in Aruan, the word for 'leather, skin,' the repetition of the word simply gives more strength to the idea. Such repetitions are a characteristic of the childlike language on one hand, and of the many languages of the primitive peoples on the other."



## Jenipapo

A variation of *yanipaba* or *nhandipab*, a fruit used for scrubbing and painting. The peel of the *jenipapo* has medicinal properties. Naturalist João Barbosa Rodrigues (1842–1909) recorded in 1894 that its roots are purgative and that "bathing with its peels can be used for ulcers and diarrhea." Its wood can be used to make canoes and furniture. Anthropologist Luís da Câmara Cascudo (1898–1986) said that the "*janipapeiro* houses ghosts within its branches and, for this reason, on some cattle farms, the herd does not reproduce."

An artistic illustration of three Araponga birds perched on a tree branch. The tree has large, vibrant leaves in shades of yellow, green, and red. One bird is blue with a black face and white belly, perched on a thin branch. Another is white with a black face and green throat, perched on a thicker branch and looking upwards. A third bird, brown with a pinkish-red throat, is partially visible on the left. The background is plain white.

## Araponga

The combination of the terms *ará* + *ponga* = resonant bird. Found in the states of Pará and Amazonas, the bird is known for producing sounds similar to a bell, and for this reason, it is also called ferrier and blacksmith. It can also be found in the Guianas and Venezuela. The male (see image to right) is completely white. Naturalist Emilio Goeldi (1859–1917) wrote about the bird in 1894: "There the Araponga also chants its blacksmith nursery rhyme, resembling a hammer handled violently countless times, but with decreasing intensity, repelled and attracted by the anvil."

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