

Research

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12 COVER

A platform for research on biodiversity, climate change and exploitation of the pre-salt layer, the new oceanographic vessel of the State of São Paulo arrived in may at the port of Santos. The vessel's renovation in a U.S. shipyard and its transfer to Brazil required the overcoming of technical and bureaucratic hurdles

Cover photo

The Alpha Crucis vessel on its way to Brazil

CREDIT NEIL RABINOWITZ
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The Professor from USP recalls his journey from Santiago, Chile to São Paulo, saying that no other country integrates cultures like Brazil

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The Ancient Amazonia in Espírito Santo State

The Atlantic Rainforest in Espírito Santo bears remnants of the Amazon Region from 7.8 thousand years ago

TEXT **Carlos Fioravanti**


PHOTOS **Eduardo Cesar**, desde Linhares (ES)

PUBLISHED IN APRIL 2012

Macuco
Lagoon in the
Sooretama
Reserve:
formerly a
mangrove

P*arkia pendula* is a characteristic tree of the Amazon Region forest that has a height of 24 meters, a red trunk of nearly two meters in diameter and bark that resembles fish scales. However, 30 years ago, this species was discovered in an Atlantic Rainforest reserve in Linhares, in northern Espírito Santo, approximately 2,400 kilometers from the nearest Amazonian rainforest. The origin of this species has been unknown to date. However, in an exciting development, experts from São Paulo are literally unearthing the past: by analyzing soil and pollen from the bottom sediments of a lake, it has been found that Amazonian species have existed in the region for over 7,800 years.

This study identifies species that have persisted or disappeared from Linhares as a result of climate and soil changes over thousands of years. The study also suggests potential interactions between environments that are presently distant and isolated, such as the coastal forest and the Amazon region. The results indicate a transforming landscape as various forms of native vegetation in the country succumb or adapt to changes in climate. “Where there is neither human interference nor climate change, the dense forests tend to expand onto open areas occupied by fields,” says Luiz Carlos Pessenda, a researcher at the University of Sao Paulo (USP) Nuclear Energy Center for Agriculture (CENA) in Piracicaba, who coordinates the surveys that are reconstructing the submerged forest of northern Espírito Santo.



Over the past 20 years, Pessenda, a trained physicist, made approximately 200 holes in the northern, northeastern, midwestern and southeastern regions of Brazil to sample lake and soil sediments in search of pollen. He concluded that open areas tend to become smaller over time, consistent with the trend over the last 4,000 years. However, four years ago, as he was making his way through forested areas and observed native fields for the first time, he suspected that perhaps Linhares was unique, noting that there were approximately 20 circular areas of rather sandy soil with undergrowth and only a few trees that nonetheless, had resisted the advance of the jungle. "There were patches of Amazon rainforest here 8,000 years ago, either because the climate had not changed much over time or the Amazon rainforest had extended this far."

Based on the data obtained thus far, Pessenda and his CENA team concluded that the climate of northern Espírito Santo must have been relatively stable over the past 15,000 years. Thus, the area, composition and structure of rainforests must have changed little over time, whereas the forests were reduced or disappeared in response to strong climate change in the other regions of the country. This difference suggests that the rainforests in Espírito Santo may have acted as biological shelters, preserving plant and animal species that may have become extinct elsewhere or even promoting the formation of new species by isolating populations from one another. Another site where Pessenda conducted field

surveys, the Fernando de Noronha Archipelago, may have also experienced no major changes in vegetation but exhibits clear signs of coastline advancement. "Approximately 5,000 years ago," Pessenda says, "there used to be a beach where there is now mangrove, which is approximately 200 meters from the present beach."

If other studies confirm that these areas have acted as biological shelters for thousands of years, it would increase the recognized biological value of these woods, called Bahian Hiléia due to their similarity to Amazon forests, which half a century ago extended continuously into the south of Bahia State. The forests have shrunk significantly due to the expansion of cities and economic development: Linhares used to be a thriving furniture production center, procuring wood from the native forests. The rainforest in Linhares retains an area of 45,000 hectares, half of which is preserved as a federal public area (the Sooretama Biological Reserve); the other half is preserved by the mining company Vale and is surrounded by coffee and papaya plantations.

"Biodiversity saved the forest in this region," says Gilberto Terra Ribeiro Alves, forest engineer and research coordinator at the Vale Natural Reserve (RNV). The mining company began to form the reserve in 1955 by acquiring farms with native forests. According to the initial plan, trees were to be cut as part of selective exploration, and the wood was to be used to build railway sleepers for the Vitória-Minas railroad, which carries

iron ore from the Iron Quadrangle to the port in Victoria. However, these efforts would have required adapting the production methods and cutting machines for each species of tree that was harvested from the forest. Ultimately, it was easier and cheaper to use local eucalyptus trees to build the sleepers.

The Vale reservation was given another destiny and became a preservation area of this unique Atlantic Rainforest region, a tableland forest. The reservation currently involves approximately 100 projects, many regarding the silviculture of non-traditional species and forest restoration. The reserve is also a site of botanical and ecological research, and, according to Alves, is now home to approximately 60 ongoing research projects conducted by teams from 17 national and 8 foreign institutions. The reserve also hosts a herbarium of nearly 4,000 species and collections of seeds, wood and fruit that have facilitated the identification of forest species.

Siqueira, the curator of the herbarium, was born in Linares but had never been in a forest until he began to work at the reserve in 1995 and describes how he was initially frightened to walk there. "When I would enter the rainforest, the hair on my arms would raise and my heart would begin to race," he recalls. "Gradually, I saw that the forest was not as scary as it looked." Since then, he has collected 800 plants from the forest to enhance the herbarium's collection, and he assists in species identification alongside botanists such as José Rubens Pirani from USP. After Siqueira had sent him material for identification,



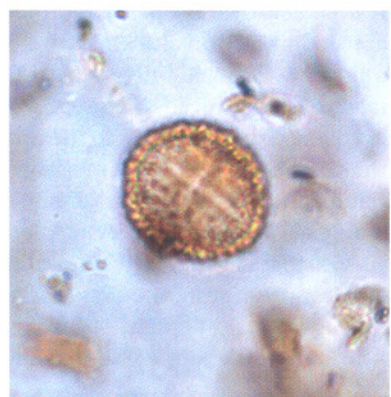
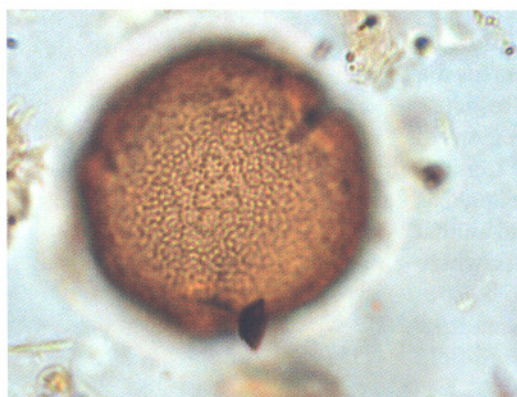
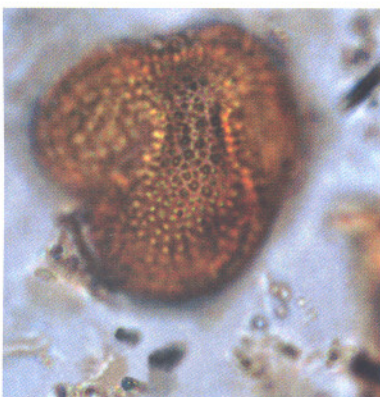
Buso, Alves and Siqueira in front of a massive *Parkia pendula*, enlarged on the side

Pirani visited the reserve in February 2011 to observe in person *Spiranthera atlantica*, a new species representing the first tree type previously known only from the Amazon rainforest and Cerrado savanna.

A preliminary survey indicated that approximately 800 species of trees and palm trees – with the most abundant species being typical of Atlantic Rainforest – are found within the Vale reserve, including some species exclusive to these forests, such as two species of trumpet trees. In a recently completed field count, a team from the Federal University of Viçosa (UFV) in Minas Gerais identified 142 species of trees that also occur in the Amazon, some of which are also found in the Caatinga and Cerrado. "The species from other ecosystems are not the most important in terms of their individual numbers, but they show great diversity," says forest engineer Sebastian Venancio Martins, a UFV professor and coordinator of field studies in the forests of Linares. In addition, such species as *Parkia* help form the canopy, the highest part of the forest. Martin's doctoral student, Luiz Fernando Magnago, found that the highest concentrations of Amazonian species are found in the best preserved stretches of forest, far from the edges of the reserve. For Martins, this finding reinforces the need to preserve large areas of native forests in this region of Espírito Santo.



Tree pollen removed from the sediment at the bottom of a lagoon in Linares: *Rinorea* (left), *Glycydendron* (below, left), *Apeiba-Hydrogaster* and *Simarouba*



PHOTOS: A.A. BUSO, JR. / CENIA-USP

The question that comes to mind when seeing these rainforests is: why are these Amazonian tree species here? "There may have been a connection between the Amazon Region and the Atlantic Rainforest, perhaps through the stretches along the rivers," says biologist Antonio Alvaro Buso Junior, who works with Pessenda at CENA. "When? Perhaps 10 or 20 million years ago. Or as recently as 50 or 100 years ago. The connection may have been made through the riparian forests and removed through deforestation."

Pirani agrees: "Several paleobotanical studies have shown that at a time when the climate was more humid and hotter, there were stretches of the rainforest and patches of rainforest where we find Caatinga scrublands and Cerrado savannas today." In addition to the probable, remote links between vegetation types that are very different today but previously formed a continuous green carpet, this forest has a sandy soil, flat terrain and climate marked by constant rainfall, similar to that of the Amazon. For Martins, these similarities help explain the survival of species that occur in forests in the north of the country.

FROM THE BOTTOM OF A LAGOON

Using inflatable boats, Álvaro and Paulo Eduardo de Oliveira, University of San Francisco researcher with experience in this area, collected sediment samples as far as two feet deep into the bottom sediments of the Macuco Lagoon, which extends approximately a mile wide and three meters deep in the Sooretama Reserve. At CENA, Álvaro identified the pollen of 234 genera or families of trees, shrubs, herbs, ferns and aquatic plants (each pollen grain is between 20 to 60 micrometers). «The identification of pollen reliably allows taxonomic identification only to the genus level,» he argues.

Most of the genera identified represented tree species characteristic of the Atlantic Rainforest, some of which, such as *Hydrogaster*, are found only in the tableland forests of southern Bahia and northern Espírito Santo. Other genera are also found in the Amazon Region and Atlantic Rainforest, such as *Glycydendron*, *Rinorea* and *Senefeldera*. "Why do you think they migrated from there to here?" asks Dominic Folli, a botanist who preceded Siqueira at the herbarium. "They could just as well have gone from here to there." Indeed, two-way exchange may have occurred.

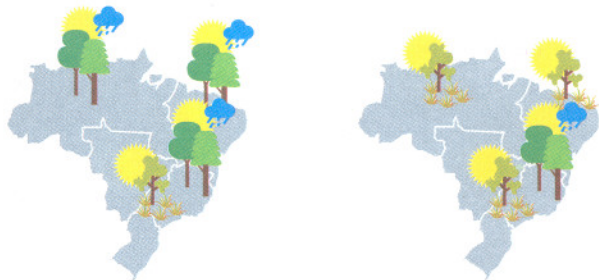
Seeds may have been transported by wind, rain, rivers or animals that ranged between areas of original, perhaps connected, much-broader forests. Jaguars and other rare species, such as harpy eagles and curassows, still live in this area. The Screaming Piha (*Lipaugus vociferans*), one



One day, a surprise amid the forest: a parrot singing Xuxa's song

of 380 identified bird species in these forests, is typical of the Amazon. In both forests, this bird is easily overlooked because of its plumage, which blends in with the vegetation, but it is one of the first birds to sing after detecting the presence of people. While walking through the rainforest one day, Alvaro heard something even more exceptional: parrots singing *Ilariê-ê-ê-ê*, Xuxa's song! He could not believe his ears, but he then learned that a flock of domestic parrots had been released into the forest a few days earlier, and they were still putting on a show with their repertoire obtained in captivity.

The yoyo motion of fields and forests



15 TO 9.5 THOUSAND YEARS AGO

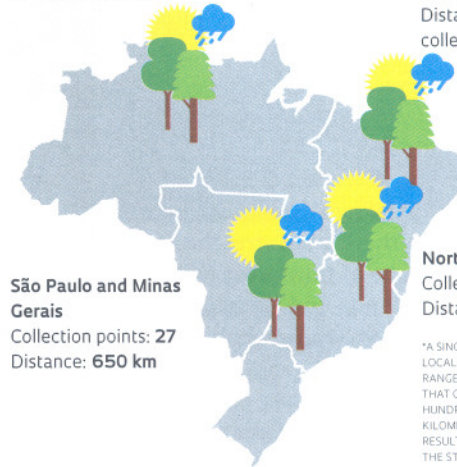
Most likely in a hot and humid climate, forests dominate in the northeast and the north



9.5 TO 4 THOUSAND YEARS AGO

Aided by the predominantly dry climate, fields and savannas expand to the north and northeast

Rondônia, Amazonas and Mato Grosso
Collection points: 30
Distance: 1,250 km



São Paulo and Minas Gerais
Collection points: 27
Distance: 650 km

Northeast
Collection points of plants, sediments, soil and turf: 36*
Distance between the farthest collection points: 1,500 km

North of Espírito Santo
Collection points: 9
Distance: 20 km

*A SINGLE COLLECTION POINT INDICATES A LOCAL ENVIRONMENTAL CHANGE (THE RANGE EXTENDS TENS OF KILOMETERS) THAT CAN BECOME REGIONAL (REACHING HUNDREDS OR THOUSANDS OF KILOMETERS) IF IT IS ASSOCIATED WITH THE RESULTS OBTAINED IN OTHER POINTS IN THE STUDIED REGION

4 THOUSAND YEARS AGO TO DATE

The predominantly humid climate favored forest growth in fields and savannas

SOURCE: LUIZ PESSENDA/CENA-USP

REMNANTS OF THE SEA

In the samples collected from the bottom of the lagoon, Álvaro found pollen from three genera of trees typical of mangroves, indicating that approximately 8,000 years earlier, a dense mangrove forest must have occupied the banks of the lagoon and adjoining rivers. Under the watchful eye of Pessenda, carbon-14 analysis confirmed this interpretation.

“This area used to be an estuary, and the seawater probably reached this spot 8,000 years ago or more,” says Álvaro near the top of the lagoon bank, at a height of almost 30 meters. Calcified skeletons of algae and marine sponges from the bottom of the lagoon, much larger than pollen grains (up to half a millimeter in diameter), confirm that 10,000 years ago, the water from the nearby rivers mixed with seawater that is presently 23 kilometers away. «The mangroves, which today can only be found in the north, on the border with Bahia, must have disappeared before human occupation when the sea level dropped,» says Pessenda. In cooperation with Marcelo Cohen of the Federal University of Pará, an expert on the evolution of paleomangroves, the CENA group aims to discover the geographical limits and the possible causes of the loss of this vegetation. In a previous study, Pessenda

observed that the coastline of Cardoso Island, off the southern coast of São Paulo, is 100 kilometers from where it was approximately 40,000 years ago. He concluded that a forest occupied an area on the island that is currently covered by mangroves.

Approximately 6,000 years ago, the sea level along the coast of Espírito Santo should have been approximately 4 meters higher than where it is now, according to geologist Paul Giannini and his team from the USP Biosciences Institute. This conclusion is based on the analysis of fossil gastropod mollusks known as vermetids (*Petalococonchus varians*), which form colonies on rocks along the water line.

Giannini also works in Linhares: “Approximately two years ago, Pessenda asked me: ‘Paul, discover why grasslands are there.’ The vegetation is not only a result of the climate. We also have to consider the influence of the sediment – whether, for example, thousands of years ago, there were lagoons in the region, which later silted up, forming areas in which specific groups of plants grow.” The forest fields in northern Espírito Santo are circular, 100 to 500 meters in diameter, and resemble the landing spot of a spacecraft. They also exhibit differences: in one field, the sand layer extends

THE PROJECT

Interdisciplinary paleoenvironmental studies off the Espírito Santo coast – no. 11/00995-7

MODALITY
Thematic Project

COORDINATOR
Luiz Carlos Ruiz Pessenda – CENA-USP

INVESTMENT
R\$ 1,027,868.62 (FAPESP)



Fields surrounded by forest and a block of compact layer in the sand: resistance

for nearly one meter deep before reaching a compact black layer of soil rich in metal and organic material; in another, the sand layer is nearly two meters deep.

Different species of grass grow in this nutrient-poor soil, spreading over fields, taller in some than in others and sometimes in fields with single trees, reminiscent of the open types of the Cerrado. In one field, a white-flowered orchid, *Sobralia liliastrum*, grows on an isolated tree; this orchid is common in Chapada Diamantina forests in the south of Bahia and has already been found in the Serra dos Carajás rainforests in Pará.

Experts believe that the forest trees surrounding the fields are adapted to a more fertile soil and would struggle in nutrient-poor fields, which, moreover, are submerged under 10 to 15 centimeters of water during the rainy season. Vegetation of intermediate height occupies the areas closest to the forest, but it is still unclear whether the fields are expanding into the woods, retreating or both, in a seasonal oscillation. "If the seasonal climate continues," says Pessenda, "it is likely that the firm-soil trees that are in the vicinity of the fields will not colonize the other area, which is often covered by water. It is not their environment!"

When left without intervention, forests advance into fields throughout Brazil

Siqueira suspects that the fields are shrinking and has already seen many disappear. The sand is easily removed and has been widely used in the construction of homes and buildings for many years. "If there are no major interventions," says Martins, from Viçosa University, "the fields will tend to remain because the soil type blocks the advance of forest species." Pessenda believes that the fields have occupied the same areas "for at least 15,000 years."

In 20 years of fieldwork, Pessenda has often witnessed forests invading fields. He observed this process over five years Humaitá, in the south of the state of Amazonas. In the early years, Pessenda left a string marking the border between the forest and the fields. Upon his return the following year, it was difficult to find the string, which had been swallowed by the forest during its encroachment (by one or two meters) into the field (see map).

Pessenda tells us that he had to have shoulder surgery because of the effort required to make the holes (today, the students help, of course), but he does not consider quitting. "We are going to the south of Bahia to look for signs of mangrove forests, fields and old rainforests," he announces, while planning the next trips and the expansion of the laboratory from 240 to 400 square meters (it occupied 90 square meters in 1990). This field of study is also proving very

fertile, as teams from Rio de Janeiro, Rio Grande do Sul and elsewhere are reconstructing the landscape of thousands of years ago based on the analyses of soil and pollen and wondering how the current landscape will change in the future.

Another indication of the favorable situation for this field of research is the fact that the German oceanographic ship *Maria Merian* left the port of Recife on February 11 to collect sediments from the mouth of the Parnaíba and Amazon Rivers and off the coast of French Guiana. In addition, researchers aim to reconstruct the change in climate in the Amazon over the last 2,000 years. "Right now [early March], we are at the mouth of the Amazon and have already collected sediment of excellent quality and samples of the water column, and we were able to map the underwater delta of the Amazon River with an amazing spatial resolution," reports Cristiano Chiessi from the ship. Chiessi is a geologist from USP and one of the Brazilian researchers onboard. "Our final destination is Bridgetown in Barbados where we expect to arrive on March 11." ■