

ARCHAEOLOGY

Many geometrical structures are hidden below canopies and are reappearing due to deforestation

HUMAN MARKS IN THE AMAZON



Cutting-edge technology was used to identify geoglyphs beneath the forest, and work with current indigenous peoples suggests the intentional generation of *terra preta* since pre-Columbian times

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It is hard to think of the Amazon rainforest and not imagine a vast expanse of green. It is home, however, to much more than can be seen from the sky. Giant geometrical figures hidden by canopies have been identified using the optical technology LIDAR (laser imaging detection and ranging), as an article published in October in the journal *Science* reported. In September, an article in *Science Advances* also provided more evidence that *terra preta* (literally meaning black soil and known as Amazonian dark earth), generally considered the work of pre-Columbian peoples, was intentional and not the result of chance.

Research carried out in the last three decades indicates that Brazil was already widely inhabited, including the Amazon region, prior to the arrival of Portuguese colonizers in 1500. The scale of this Amazonian occupation is now growing, based on mapping conducted with equipment fitted to drones or onboard aircrafts, which emits thousands of laser pulses per second and, with each pulse, calculates a measurement of distance. “It is almost like a radiography,” explains geographer Vinicius Peripato, a PhD student at the National Institute for Space Research (INPE) and the lead author of the study coauthored by 230 researchers.

In already deforested areas in the western part of the Amazon, enormous geometrical figures, such as geoglyphs, can be observed, which are formed by ditches dug into the ground. With the use of the Google Earth tool and satellite imaging technology, these figures have been visible since the turn of the millennium. “It was possible to identify hundreds of these structures, especially in the west of the Amazon,” says biologist Luiz Aragão, head of the INPE’s Earth Observation and

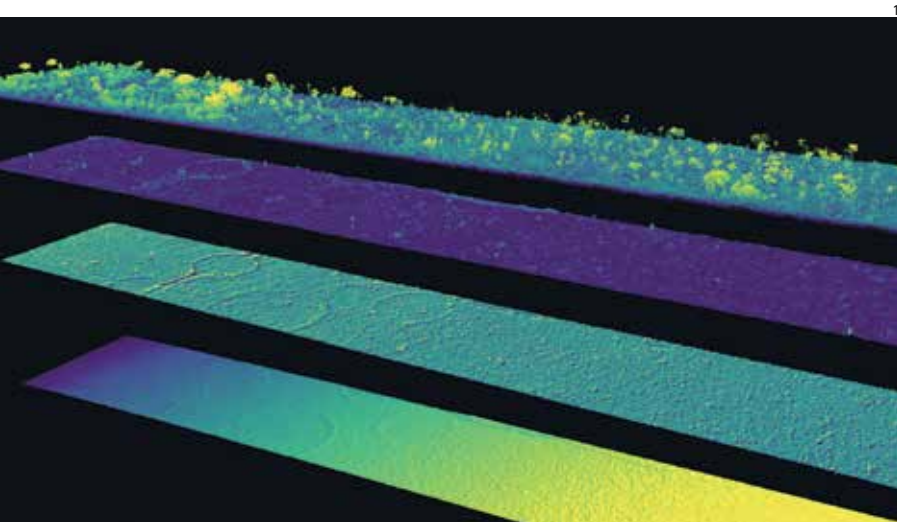
Geoinformatics Division, advisor to Peripato, and coordinator of the article published in *Science*.

In the last 20 years, excavations carried out by archaeologists have shown that the geometric forms are important religious sites (see *Pesquisa FAPESP issue no. 186*). Peripato and his colleagues knew of the existence of these traces of human occupation and thought that more of them may exist beneath the forest canopy. “Previous tests had indicated the possibility of the occurrence of these structures, but nothing precise,” he explains.

These authors developed a method to digitally remove the forest and improve the detection of aspects of relief—the resolution of the LIDAR sensing data was still not suitable for archaeological observations. The equipment covered 5,315 square kilometers (km²) of the Amazon, equivalent to 0.08% of the forest. “It worked, luckily we found 24 previously undiscovered structures,” celebrates Peripato.

With this discovery, the researcher developed a mathematical model to estimate how many other similar geoglyphs would be in the territory and where they would be, taking a series of still-unknown variables into account. He compared the data provided by the LIDAR sensor with information from 937 other known archaeological structures and, using this model, calculated that at least 10,272 still undiscovered pre-Columbian structures exist, possibly 23,648 in the entire forest—a territory of 6,700 km². The distribution of 53 species of domesticated plants used for food was mapped in previous forestry inventories and may serve as an indication of the existence of archaeological structures in the vastness of the Amazon.

The optical technology LIDAR enables layers below the forest, similar to radiography, revealing subtle variations in relief, such as the geoglyphs



“It was a study that required a multidisciplinary team and the use of cutting-edge technology to carry out,” assesses Aragão. The dating of the still-undiscovered geoglyphs was estimated based on the existing archaeological literature but can only be confirmed when excavation work is conducted and material is collected for analysis.

“It is an important article that confirms something that archaeologists have said for years: there were lots of people living in the Amazon in the past,” comments archaeologist Eduardo Góes Neves, of the Museum of Archaeology and Eth-

nology of the University of São Paulo (MAE-USP). “These peoples lived there, and they also modified the forest,” he states. Evidence of human presence in the region dates back approximately 12,000 years. For some of the experts, the Amazon is a biocultural heritage site that suffers influences from both nature and from the population that lived and still lives there.

Neves says that a large part of the still-preserved geoglyphs are on environmentally protected lands occupied by indigenous peoples. “It is the indigenous peoples who preserve the structures in the midst of agribusiness advances and the destruction taking place in the Amazon,” he remarks. In his view, the indigenous peoples have been present in the area since ancient times and have contributed to the creation of the country’s biomes. “You cannot separate their history from the history of Brazil.”

The *terra preta* found at various points in the Amazon is another sign of agricultural activity registered around the geoglyphs and has helped to shape the biomes. Made up of leftover foods, such as cassava and fish, ashes, and other organic waste from the forest, it is rich in nutrients such as phosphorous, calcium, magnesium and nitrogen, which are essential for cultivating food.

“When *terra preta* began to be studied, it was a revolution in Amazon archaeology: providing evidence of the existence of large populations on that land, because to form that material, it is necessary to have many people inhabit a place

With LIDAR and mathematical models, researchers have calculated that there are between 10,000 and 24,000 of these structures in the Amazon



for a long time,” states British archaeologist Jennifer Watling of the Museum of Archaeology and Ethnology of the University of São Paulo (MAE-USP) and coauthor of the article. Prior to these studies, the general understanding was that the Amazon rainforest could not support a very dense population due to a lack of fertile soil, she says. “The *terra preta* shows that it is possible to support many people without destroying the forest.”

The team collected more than 3,600 soil samples from four archaeological sites, two historic villages, one modern village in the Alto do Xingu region called Kuikuro II and several samples from the Alto Tapajós region and from the Carajás Mountains. The analyses revealed that the oldest samples were over 5,000 years old.

The dating of *terra preta* is one of the main controversies in recent studies on this type of soil. In 2021, an article in the journal *Nature Communications* questioned the anthropic origins of *terra preta*. “Based on elemental analysis, the data do not match with the presence of human beings in the Amazon,” states agricultural engineer Rodrigo Studart Corrêa, a specialist in the recovery of soils and a researcher from the University of Brasília (UnB). According to Corrêa’s study, the cultivation of Amazonian land dates back at least 4,500 years, although archaeological evidence points to practices of cultivation in the region dating back 9,000 years.

For the agricultural engineer’s group, the *terra preta* they studied originated from sediments from the Andes mountain range. “This material is a river meander,” states Corrêa. According to him, based on the isotope analysis of strontium and other elements, a part of the composition of the samples does not come from organic matter. “The fragments of ceramic in these soils are a great mystery, but this could indicate that they were used to bury the dead, maybe because the soils were easy to excavate,” he speculates.

Watling and geographer and archaeologist Morgan Schmidt, from the Laboratory for Interdisciplinary Studies in Archaeology of the Federal University of Santa Catarina (UFSC), however, believe that their results refute this interpretation of an accidental formation of *terra preta* by local communities. The researchers conducted interviews with inhabitants, observed the daily life of the villages and observed that the residents deposited fish and cassava waste in trash cans as tall as 60 centimeters in height. “The majority of the *terra preta* forms in waste disposal areas, as if it were compost,” says Watling. “They mix the organic material with ash and charcoal to form a fertile soil and spread it on cultivation areas.”



A Kuikuro woman deposits ash from a fire in an area where *terra preta* develops

Terra preta is rich in pyrogenic carbon, also called charcoal or biochar, which originates from the burning of organic material and is a source of nutrients for plants. The *Science Advances* study revealed that concentrations of carbon were two times greater in residential areas than in less occupied areas. This occurs because the indigenous peoples use ash from domestic fires for the production of *terra preta*, according to Schmidt, who has been studying the agricultural practices of Amazonian peoples for more than 20 years.

Another advantage of this type of soil is the sequestration and storage of atmospheric carbon. The measurements indicate that approximately 4,500 tons of this element are present at one of the archaeological sites, while in the modern villages, 110 tons are present. This shows how, over time, the carbon has persisted and accumulated. However, climate change is a concern. “Carbon can decompose quicker due to the warming of the ground,” explains Schmidt. “We also saw that when there is deforestation in an area with *terra preta* and cultivation, the organic material is lost from the soil and the carbon returns to the atmosphere,” he points out.

The climate crisis could also affect the consumption habits of indigenous populations that still prepare *terra preta* on their lands. “This earth is created by means of a very particular way of using and managing the domestic space, which includes the disposal of leftover traditional foods such as cassava,” says Watling. “If they stop planting and consuming such foods, we do not know if the *terra preta* would still form in the same way.” ■

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