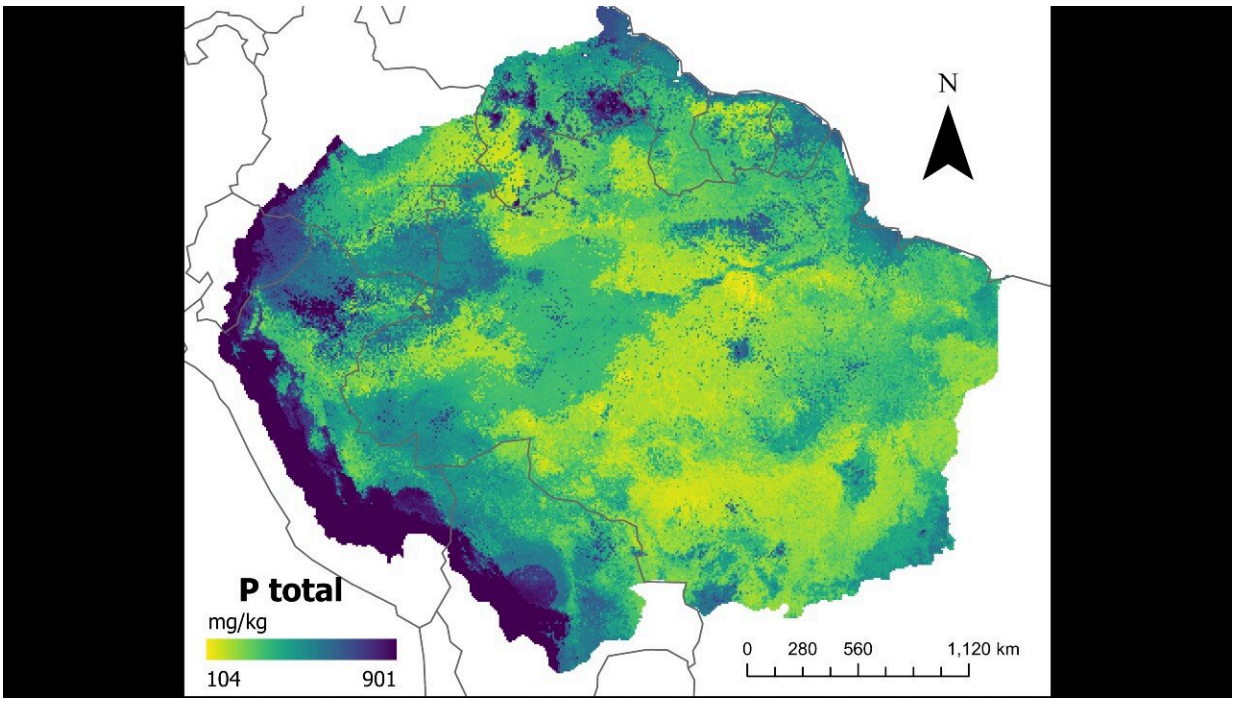
Maps developed with artificial intelligence confirm low levels of phosphorus in Amazonian soil

April 29 2024



Spatial distribution of total phosphorus concentration in Amazonian soils. Credit: image adapted from Darela-Filho et al., 2024

As the impacts of climate change increasingly affect the daily lives of residents in several countries, including Brazil, the resilience of forests, especially tropical ones such as the Amazon, has become a frequent

topic of research. In addition to studying various factors that influence the way vegetation reacts to global warming, scientists are seeking to improve vegetation models—tools that play a crucial role in understanding and managing ecosystems, contributing to biodiversity conservation and sustainable development.

And it is exactly this combination that is described in research published in the journal *Earth System Science Data* by a group associated with Brazilian institutions. The work resulted in a series of maps that more accurately describe the quantity of the different chemical forms of phosphorus in the soil of the Amazon. "Built" using a new methodology based on artificial intelligence, the maps confirm that the region has a very low concentration of the mineral.

The impact of this is that a lack of phosphorus affects the growth cycle of species and can, for example, prevent trees from reacting to the increase in carbon dioxide associated with climate change.

"When we were working on vegetation models to understand climate behavior in the Amazon, we realized that there was specific information about the amounts of phosphorus in the soil. Normally, in previous methods, these maps only used soil types [classes] as predictors of the mineral. We saw that it would be necessary to include other environmental attributes, so we developed a new statistical technique based on machine learning from existing data," explains João Paulo Darela Filho, who is currently a postdoctoral researcher at the Technical University of Munich (Germany).

Darela Filho started working on the project during his doctoral studies, which ended in 2021.

At the time, his focus was on incorporating into the Caetê model data on cycles of nutrients such as nitrogen and phosphorus, which are important

for understanding the behavior of tree growth. Caetê, which means "virgin forest" in the Tupi-Guarani language, is an algorithm capable of projecting the future of Amazonian vegetation by presenting scenarios of forest transformation.

The first of its kind to be exclusively Brazilian, its name comes from the acronym CArbon and Ecosystem functional-Trait Evaluation model.

Caetê was developed by a team from the Earth System Science Laboratory at the State University of Campinas (UNICAMP), coordinated by Professor David Montenegro Lapola, who is also the author of the article with Darela Filho.

"The maps produced under João Darela's leadership are an indispensable step in advancing our understanding of how tropical forests, which are generally phosphorus-limited, will react to climate change and other human disturbances," Lapola told Agência FAPESP.

The researchers used data from 108 sites in the Amazon. They used an approach based on random forest regression models that had been trained and tested to predict different forms of phosphorus—total, available, organic, inorganic, and occluded (when it is bound to other substances). They also used information from the reference soil types and other properties such as geolocation, nitrogen and carbon levels, terrain elevation and slope, soil pH, average annual precipitation, and temperature.

The forest regression models showed average accuracy levels of over 64%, depending on the form of phosphorus. For the total mineral, the accuracy reached 77.3%.

The results of the research showed that the average concentration of total phosphorus found in the analyzed data set was 284.13 milligrams per

kilogram of soil (mg kg^{-1}). This amount is considered low when compared to the global average—570 mg kg^{-1}. When analyzing the maps, it was found that the sites richest in phosphorus are located on the border between the Andes and the Amazon, in contrast to the oldest soils in the Amazonian lowlands, located in the eastern region.

The scientists believe that the new maps could be useful for parameterizing and evaluating terrestrial ecosystem models, and could even provide answers about the relationship between soil and vegetation in the Amazon region.

"Machine learning, with the use of artificial intelligence, will be increasingly applied in science, especially for future projections. Our maps can be used by other researchers to understand how the Amazon will respond to climate change," adds Darela Filho.

An international study led by a team including Lapola and featured on the cover of the February issue of *Nature* showed that nearly half of the Amazon is headed toward a point of no return by 2050, meaning that the forest is likely to lose its resilience to extreme droughts and deforestation.

That study estimated that between 10% and 47% of the region's areas will be exposed to disturbances and threats that could trigger "unexpected" transitions in ecosystems and exacerbate regional climate change. Accumulated deforestation, global warming, the amount of annual rainfall in the biome, the intensity of the rainy season, and the length of the dry season were considered stressful situations. The risk is the conversion of the biome into savanna areas that are unable to fulfill the role of carbon sequestration.

More information: João Paulo Darela-Filho et al, Reference maps of soil phosphorus for the pan-Amazon region, *Earth System Science Data* (2024). DOI: 10.5194/essd-16-715-2024

Provided by FAPESP