Brazilian algorithm aims to project future of Amazon rainforest and predict changes in carbon capture

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The computer program was developed at the State University of Campinas to include more vegetation diversity in the analysis of climate change impacts. Credit: Tiago Latesta/Projeto Brasil das Águas

A group of researchers at the State University of Campinas (UNICAMP), in São Paulo state, Brazil, has developed an algorithm that projects the future of vegetation in the Amazon, presenting scenarios for transformation of the forest driven by climate change.

One of the results shows that a drier climate in the region, with a 50% drop in precipitation, could increase diversity but lower the level of carbon storage. Storage of carbon dioxide (CO_2) in roots would increase, but absorption of CO_2 in leaves, stems and trunks, which have more storage capacity, would decrease. Taking different situations into account, the scientists calculate that carbon absorption could drop between 57.48% and 57.75% compared with regular climate conditions.

The algorithm, which is the first of its kind designed exclusively for Brazil, is called CAETÊ, which means "virgin forest" in Tupi-Guarani and is an acronym of CArbon and Ecosystem functional Trait Evaluation model. Its first results are described in an article published in the journal *Ecological Modelling*.

CAETÊ simulates natural phenomena using mathematical equations fed with environmental data such as rainfall, solar radiation and CO_2 levels. It predicts photosynthesis rates under specific conditions, for example, or says which plant parts will store more carbon (roots, leaves, stems or trunks), calculating carbon storage capacity in a given area and the point at which native vegetation can no longer recover.

"The main finding of the study was that including diversity in vegetation models improves their ability to project ecosystem responses to climate change and enhances their credibility. A second point, which was unexpected, was that when a 50% drop in precipitation was applied, plant strategy diversity increased but carbon removal from the atmosphere decreased. This can have a different impact on climate change mitigation. In this case, the increase in diversity isn't necessarily

a good thing," said Bianca Fazio Rius, first author of the article and a Ph.D. candidate at UNICAMP's Institute of Biology (IB).

Rius is a member of the team at the Terrestrial System Science Laboratory, headed by Professor David Montenegro Lapola, last author of the article.

"CAETÊ accurately represents the huge biological diversity of the world's largest tropical forest, while at the same time stimulating field data collection, which is still necessary for this kind of model," Lapola told Agência FAPESP.

Lapola was one of the Brazilians who, with 34 other scientists affiliated with institutions here and abroad, signed an article featured on the cover of *Science* early this year, showing that 38% of the Amazon's current area suffers degradation due to fire, illegal logging, edge effects (fragmentation due to changes in habitats adjacent to deforested areas) and extreme drought. As a result, carbon emissions deriving from gradual loss of vegetation are equivalent to or even greater than emissions due to deforestation.

Pros and cons

Vegetation models are widely used to analyze the carbon balance in the Amazon under projected future climate conditions. Previous research showed that the Amazon's average temperature has risen 1 °C in the last 40 years and that rainfall has decreased 36% in some areas. CO_2 storage capacity has also fallen owing to deforestation, vegetation degradation and global warming.

Moreover, according to a report published on May 17 by the World Meteorological Organization (WMO), global temperatures are likely to surge to record levels in the next five years because of greenhouse gas

emissions and El Niño, and rainfall is set to decrease in the Amazon.

However, most existing algorithms are based on a small number of plant functional types (PFTs), which are adopted by modelers to represent broad groupings of plant species that share similar characteristics and ecosystem functions. As a result, diversity is underrepresented and the combination of traits found in model ecosystems is far simpler than warranted by the complexity of the world's largest tropical forest, leading to scenarios that are limited or overestimate the impact of environmental change.

They include dynamic global vegetation models (DGVMs), which simulate changes in vegetation and the associated biogeochemical and hydrological cycles in response to climate change (e.g. Jena Diversity, or JeDi). If these are the cons, the pros include not depending on logistics and major investments, as do large-scale field experiments.

Tipping point

According to Rius, the study did not focus on species. "We used the idea that every individual, even individuals in the same species, can be considered a type of strategy for dealing with the environment. Computationally created strategies don't necessarily belong to any particular species," she said.

For a plant or any living being, she explained, a strategy represents a set of traits that determine how it responds to or affects the environment. A plant that adapts root depth in order to access water depending on the height of the water table could be a good example. Strategies profoundly influence the ability to survive and reproduce, and they are associated with ecosystem services such as carbon storage or production of moisture for precipitation.

"As the climate becomes drier, we're seeing a change in types of life strategy in the Amazon. Strategies increasingly resemble those of the Cerrado [Brazil's savanna-like biome]. It's as if the Cerrado had begun to penetrate into the forest. Other researchers have noted this as well," Rius said.

The study using CAETÊ provided more evidence that the inclusion of variability and diversity can have implications for modeling the Amazon's tipping point, when natural vegetation will no longer be able to recover, the scientists explained.

One of the first articles to address this topic was signed by Thomas Lovejoy (1941-2021), the biologist who coined the term "biological diversity", and Carlos Nobre, Co-Chair of the Science Panel for the Amazon. The paper highlighted the importance of the forest's water cycle not just for Brazil but for all of South America and other regions.

Through evapotranspiration, the forest guarantees throughout the year the moisture that contributes, for example, to rainfall in parts of the La Plata River basin, especially in southern Paraguay, South Brazil, Uruguay and eastern Argentina.

More diversity

Development of CAETÊ began in 2015. It was based on the potential vegetation model CPTEC-PVM2 developed by Lapola and Nobre, with Marcos D. Oyama.

"Most vegetation models represent the Amazon with two or three types of strategy. We set out to include more diversity. We'll continue to develop our model because good models are never finished," Rius said.

In this direction, Bárbara Cardeli, a Ph.D. candidate at IB-UNICAMP,

joined the group and is working on the model to include a module that will calculate ecosystem services.

"This tool will be easy to use and will show whether specific ecosystem services are assured via processes such as how plant strategies allocate carbon. We want to include numerical values for the provision of these services," Cardeli said.

The researchers envisage CAETÊ as supplying data-based input for decision-making and for the formulation of public policy for the carbon market. At the 2021 UN Climate Change Conference (COP26), Brazil announced a commitment to halve its carbon emissions from the 2005 level by 2030 and achieve carbon neutrality by 2050.

More information: Bianca Fazio Rius et al, Higher functional diversity improves modeling of Amazon forest carbon storage, *Ecological Modelling* (2023). DOI: 10.1016/j.ecolmodel.2023.110323

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