Legal mining sites in Brazil store 2.55 gigatonnes of carbon dioxide in vegetation and soil, study estimates

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Open-cast limestone mine in Saltinho, São Paulo state, Brazil. Credit: Francisco Ruiz/ESALQ-USP

As global temperatures continue to reach all-time highs and discussions intensify about ways to mitigate the adverse effects of climate change, researchers at the University of São Paulo's Luiz de Queiroz College of

Agriculture (ESALQ-USP) in Brazil have reported the results of a scientific study showing that if all the country's active legal mining sites continue to operate in the coming decades, emissions will total an estimated 2.55 gigatonnes of equivalent carbon dioxide (Gt CO_2eq) due to loss of vegetation (0.87 Gt CO_2eq) and soil (1.68 Gt CO_2eq).

This total corresponds to about 5% of the world's annual greenhouse gas emissions from human activities.

An article on the study is published in *Communications Earth & Environment*.

According to the researchers, Brazil has 5.4 million hectares of active legal mines. This is a little less than the area of Croatia (5.6m ha). Legal mines are located all over Brazil, but most are in subtropical and tropical areas and have the largest soil organic carbon stocks, estimated at 1.05 Gt CO_2eq.

They advocate a nature-based solution to offset these emissions, consisting of post-mine reclamation involving reconstruction of soils using mine tailings and other residues such as domestic and industrial waste. These anthropic soils, known as Technosols, could potentially offset up to 60% (1.00 Gt CO_2eq) of soil-related CO_2 emissions.

"When we thought about carbon stocks, the first step was to analyze emissions. Although most previous research focused on the impact of ore processing via the burning of fuel and electricity consumption, for example, open-cast mining in pits or borrows is the rule in Brazil and the rest of the world, and the soil is the main terrestrial carbon storage ecosystem. When the soil is removed, organic matter and vegetation change, eliminating CO_2. We estimated potential emissions from removal of soil and vegetation at 2.55 GT CO_2eq," Francisco Ruiz, a Ph.D. candidate at ESALQ-USP, told Agência FAPESP.

For Tiago Osório Ferreira, a professor in ESALQ-USP's Department of Soil Science, corresponding author of the article, and Ruiz's thesis advisor, one of the most important points of the study is the demonstration that Technosols can be a productive path to decarbonization.

"It shows that waste and residues can be used in this innovative manner to construct a fundamental resource, which is soil as a stable form of carbon storage. It serves as a reminder to other countries, especially major miners, such as China and the United States, that there are alternatives in this race to keep up with climate change," said Ferreira, who leads ESALQ-USP's Soil Geochemistry Research Group (GEPGeoq).

The soil is one of the planet's four main stores of carbon, alongside the atmosphere, the ocean and plants. Degraded soil and vegetation releases CO_2, however.

According to a survey by MapBiomas, a collaborative network of non-governmental organizations, universities and tech startups that maps land use and land cover, Brazil has 37 Gt of soil organic carbon (SOC) and almost two-thirds (63%, or 23.4 Gt) is stored in areas under stable native plant cover, mainly in the Amazon. Only 3.7 Gt is stored in areas converted since 1985 to anthropic uses.

Technosols are based on material derived from human activities, including industrial, urban and mining waste. As well as helping to regulate the climate, they can restore essential ecosystem services destroyed by mining, for example, such as food and energy production or protection of biodiversity, water quality and nutrient cycling. Properly treated to neutralize toxic substances, they can also support native plants, crops and forests, capturing carbon as organic matter accumulates.

Brazil is one of the world's ten largest producers of mineral commodities. Mining is an important driver of economic development, but it is also a source of ecosystem degradation, including pollution of soil and water, as well as loss of biodiversity. The mining industry caused two recent disasters in Brazil due to tailings dam collapses in Mariana (2015) and Brumadinho (2019), Minas Gerais state, with high human, economic and environmental costs.

Process

The knowledge used to make Technosols comes from understanding the natural processes by which soil organic matter is formed, weathered and stabilized. To test the hypothesis that Technosol construction mitigates CO_2 emissions from open-cast mining, the researchers estimated carbon stocks in Brazilian mining sites using data available from the literature.

The first step in the process consisted of determining the geolocation and area of all legal mining sites using SIGMINE, an online platform maintained by the National Mining Agency (ANM).

They found that recovery of soil organic stocks with Technosols is climate-dependent, with tropical Technosols showing the greatest potential carbon stock recovery owing to high input of plant-derived carbon and strong potential for carbon stabilization through mineral-organic interactions.

The researchers stress in the article that some types of mine waste contain potentially toxic elements such as arsenic, mercury, cadmium, copper, and lead, and that precautions should be taken to avoid their use or combine it with strategies aimed at preventing pollution and inclusion of heavy metals, including remediation techniques such as phytoremediation (use of plants and associated soil microbes to reduce the levels or toxic effects of contaminants) and soil amendment (addition

of material to improve the soil's physical and chemical properties).

"One of our most important findings is the amount of carbon obtained in Technosols. In some cases, it exceeds the total in natural soils. The studies conducted by Francisco [Ruiz] show that it's possible in a very short time to construct soils that perform even better than natural soils and help mitigate the adverse effects of climate change," Ferreira said.

Ruiz has been studying Technosols since his master's research. In 2020, he was awarded a Prize for Excellence in the Brazilian mining and metallurgy industry by the magazine *Minérios & Minerales*. The study in question focused on the use of tailings by a dolomitic limestone miner in Saltinho, São Paulo state, to construct Technosol and restore the topography and plant cover.

More information: Francisco Ruiz et al, Constructing soils for climate-smart mining, *Communications Earth & Environment* (2023). DOI: 10.1038/s43247-023-00862-x

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