Rainfall patterns determine geomorphology and carbon fluxes in tropical peatlands

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Video Abstract

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Abstract

Peat is a soil-like material made up of decomposed plant matter found in water-saturated environments around the world. From the arctic to the tropics, these peatlands act as giant carbon sinks, storing enormous amounts of organic matter. In the tropics, peat accumulates in dome-shaped mounds that can reach kilometers across and ten or more meters high. Removed from the atmosphere via photosynthesis in trees, this carbon can be preserved for thousands of years. But human disturbance by fire and drainage for agriculture is now causing re-emission at an unprecedented rate. This is especially true in tropical Asia. Because peat accumulation occurs via waterlogging of plant remains, which quickly degrade in the presence of oxygen, its deposition is determined, in part, by the proportion of time exposed to air. And this, in turn, is driven by the depth of the water table which rises and falls with rainfall and discharge from the peatland into rivers. When the water table is high, degradation is inhibited by a lack of oxygen and peat accumulates. When the water table is low, oxygen enters the peat, enabling microbial oxidation and the organic material is converted to carbon dioxide. To better understand how tropical peatland growth and loss (and the carbon fluxes that accompany these changes) are controlled by climate, sea level, and drainage networks, an international team of researchers set out to develop a quantitative model of these dynamic processes. Traveling to Brunei Darussalam, on the island of Borneo, the team identified a field site within a pristine peat swamp – one of the last protected tropical peatlands in Southeast Asia – where current processes affecting peat accumulation approximate long-term developmental processes. Taking numerous measurements, they characterized fine- and large-scale morphology, groundwater flow, and carbon balance in this area. These data were combined to create a mathematical model which was then used to investigate carbon storage in the peatland. The model showed that the pattern of rainfall and permeability of peat together determine a particular curvature of the peat mounds that defines the amount of naturally sequestered carbon stored over time. Using this principle, the research team calculated the long-term carbon dioxide emissions in tropical peatlands driven by changes in climate and drainage. The results suggest that fluctuations in net precipitation reduce long-term accumulation of peat in these systems. This means that the greater seasonality projected by climate models could lead to increased carbon dioxide emissions, instead of sequestration, from otherwise undisturbed peat swamps. Though natural carbon sinks, peatlands around the world may become sources of carbon dioxide if current trends continue.