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Soil moisture stress on plants leads to uncertainty in carbon cycle estimates

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10 January 2019
Issue 519
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Source: Trugman, A.T., Medvigy, D., Mankin, J.S., and Anderegg, W.R.L. (2018). Soil Moisture Stress as a Major Driver of Carbon Cycle Uncertainty. *Geophysical Research Letters*. 45 (13), pp. 6495–6503. DOI:10.1029/2018GL078131.

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A new study paves the way for better projections of the impact of climate change on plants, including agricultural crops and carbon drawdown. The research shows how an equation used in climate models to represent soil moisture levels is responsible for major variations in estimates of the carbon cycle.

Plants are an important resource in mitigating climate change because they draw down atmospheric concentrations of carbon dioxide (CO_2) through photosynthesis. In fact, plants in terrestrial ecosystems currently sequester (store) approximately 25% of human carbon emissions annually. Soil moisture is an important environmental factor which affects the amount of carbon that can be absorbed by land-based ecosystems — because water-stressed ecosystems photosynthesise less.

Vegetation models are used in earth system models to predict how terrestrial ecosystems may respond to changes in atmospheric CO_2 and climate, and the subsequent feedbacks (e.g. subsequent changes to atmospheric CO_2 concentrations and climate) that changes in vegetation photosynthesis may have on the climate. However, vegetation models used in climate-change projections simplify the process of how soil water stress impacts plant productivity by using a correction factor that accounts for soil dryness and represents plant physiological response to this stress. The correction factor ranges from 0 — indicating that the soil is dry and plants have completely closed their pores in response to reduce moisture loss — to 1 — indicating that the soil is wet and the plant pores are open and releasing moisture. In reality, however, there is much more variation and complexity in how plants respond to soil moisture levels.

This correction factor often varies between vegetation models that are used in earth system models for climate change projections. Furthermore, these correction factors have not been rigorously tested using data from water-stressed plants, so they may not accurately represent soil water limited plant photosynthesis. The researchers estimate the variability in photosynthesis in nine earth system models used by the World Climate Research Programme's Coupled Model Intercomparison Project, Phase 5 (CMIP5). The research shows that the representation of soil water stress in vegetation models within the models is one important factor contributing to variations in future estimates of ecosystem photosynthesis, and, therefore, ecosystem carbon sequestration.

In particular, the researchers found that the different soil water correction factors result in different photosynthesis predictions for plants experiencing exactly the same amount of water stress, thus introducing a large and uncertain component into earth system model projections for the terrestrial carbon cycle. Their results suggest that it is responsible for a significant 40–80% of soil water stress-driven uncertainty.

In a climate change context, this plant soil water limitation process is particularly important to understand because soil moisture is expected to become more stressed (i.e. reduced) by forthcoming increases in drought, potentially reducing the extent of the terrestrial plant carbon sink. By highlighting this source of uncertainty, the researchers suggest their results provide a foundation for better projections of climate change's impacts on terrestrial ecosystems, including impacts on vegetation growth, agricultural productivity and carbon sequestration.