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Commentary

Optimizing Carbon and Water Cycles: A Plant-Based Approach

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DESCRIPTION

The global carbon and water cycles are governed by the coupling of CO_2 and water vapour exchanges through terrestrial plant leaves. This coupling is controlled by plant adaptations to balance carbon gains with hydrological hazards. They provide a trait-based optimality theory that combines the study of plant biochemical adaptation to changing environmental conditions over a range of timescales with stomata reaction analysis. Tested with actual data from eighteen species, their model correctly predicts the simultaneous decline in photosynthetic ability, stomata conductance, and carbon absorption rate during progressive soil drought. Furthermore, it forecasts temperature, CO_2, and air vapour pressure deficit and their effects on gas exchange with accuracy.

For instance, the distribution of hydraulic strategies is an established empirical trend that agrees with model predictions. Their thorough theory opens up new possibilities for precisely modeling the intricate relationships between transpiration, soil dryness, and growing CO_2 levels in the atmosphere.

Water is lost through transpiration when stomata, the tiny "valves" on the surface of leaves, open to absorb carbon dioxide for carbon absorption. For plants that use the C3 photosynthetic pathway, this is the primary issue. The transpiration stream is maintained by negative water potentials in the roots, transport networks, and leaves of the plant. Hydraulic failure can occur in the xylem due to extreme water potentials. The tissues of the stem, leaf, and root must be altered in order to survive negative water potentials.

Hydraulic failure is more likely when there is a decrease in water availability over a plant's rooting zone or when the vapour pressure deficit at a leaf surface increases. Plants can avoid hydraulic failure by controlling their stomata openings in response to dry soil and atmospheric conditions. Water loss and carbon uptake are closely correlated when stomata are closed because it decreases carbon assimilation. At the ecosystem level, this link between the carbon and water cycles regulates the rates of Gross Primary Production (GPP) and evapotranspiration in response to water stress. On the one hand, increased precipitation and atmospheric CO_2 levels are increasing water usage efficiency and may even be speeding up the development of trees.

Conversely, when droughts happen more frequently and strongly, stomata conductance decreases and mortality rates rise due to increased atmospheric vapour pressure deficits. It has been suggested that a persistent increase in tree mortality rates and a saturation spike in growth rates have a substantial effect on the carbon sink of tropical forests. Therefore, to address the limiting influence of soil moisture stress and atmospheric water demand on plant photosynthesis, vegetation models that explicitly account for plant hydraulic processes are required.

Important restrictions on a plant's capacity to transpire water and, consequently, on the conductance of its stomata are imposed by the hydraulic mechanism of the plant. It has taken a great deal of work to develop stomata control models that explicitly describe plant hydraulics. Because hydraulically explicit stomata models have been successful in replicating short-term stomata reactions to drying soil and air on sub-daily and daily timescales, Earth system models currently use these models. However, they are still unsure of how plant physiology adjusts on a daily to weekly basis to the onset of a soil-moisture drought or how this longer-term acclimation affects stomata's susceptibility to abrupt water stress.

This understanding is especially important for predicting stomata and biochemical responses to new environments, as well as for sparsely characterizing well-known patterns related to plant hydraulic strategies. The conventional stomata optimization model suggests that plants adjust their stomata conductance to maximize total carbon uptake for a given amount of water loss, based on the assumption that transpired water has a constant unit cost. This study states that plants have the ability to store water for later use. On the other hand, current stomata models recognize that plants fight for the scarce water supply. From an alternative viewpoint, the risks associated with hydraulic failure and the energy and structural needs to endure high suction pressures are what drive transpiration costs.

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