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Optimal trait theory: an emerging route towards better land ecosystem models

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The last two decades have seen steadily increasing interest in plant functional ecology, and an orders-of-magnitude improvement in the scope and availability of data on plant traits and ecosystem processes. These developments have been propelled in part by a perceived need for a more solid scientific foundation for global vegetation and land-surface models, which are used to explore terrestrial carbon cycling and to represent the interactions of ecosystems and climate. However, this need remains substantially unfulfilled. I will argue that a key reason is the absence of any agreed theoretical framework for the analysis of trait-environment relationships. One consequence of this 'theory gap' is the continued reliance of models on plant functional types (PFTs) with fixed trait values – long after it became clear that most traits vary more within PFTs than between them. Another is the prevalence in the ecological literature of statistical analyses marred by arbitrary choices of environmental predictors, and misattribution of cause and effect in the controls of plant traits. Fortunately, eco-evolutionary optimality hypotheses are now helping to fill the theory gap, and have shown striking success in generating realistic predictions from universal, PFT-independent rules. The emerging 'optimal trait theory' has the potential to underpin a new, unified understanding of photosynthesis, respiration, transpiration, carbon allocation and nutrient acquisition at leaf, plant and ecosystem levels. Such understanding is a pre-requisite for next-generation models that will be more robust and reliable than those currently in use.