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Testing across vegetation types for common environmental dependencies of Gross Primary Production

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Accurate simulations of gross primary production (GPP) are vital for Earth System Models that must inform public policy decisions. The instantaneous controls of leaf-level photosynthesis, which can be measured in manipulative experiments, are well established. At the canopy scale, however, there is no consensus on how GPP depends on (a) light or (b) other aspects of the physical environment such as temperature and CO_2. Models of GPP make a variety of different assumptions when 'scaling-up' the standard model of photosynthesis. As a troublesome consequence, they make a variety of different predictions about how GPP responds to contemporary environmental change.

This problem can be tackled by theoretically based modelling, or by empirical analysis of GPP as reconstructed from eddy-covariance flux measurements. Theoretical modelling has provided an explanation for why 'light-use efficiency' (LUE) models work well at time scales of a week or longer. The same logic provides a justification for the use of LUE as a key metric in an empirical analysis. By focusing on LUE, we can isolate the controls of GPP that are distinct from its over-riding control by absorbed light. We have used open-access eddy covariance data from over 100 sites, collated over 20 years (the number of sites has grown with time). These sites, located in a wide range of biomes and climate zones, form part of the FLUXNET network. We have combined the flux data with a satellite product (FPAR from MODIS) that provides spatial estimates of the fraction of incident light absorbed by green vegetation. Soil moisture at flux sites was estimated using the SPLASH model, with appropriate meteorological inputs, and soil water-holding capacity derived using SoilGrids. LUE was then calculated as the amount of carbon fixed per unit of absorbed light. We then considered additive models (incorporating multiple explanatory factors) that support non-linear responses, including a peaked response to temperature. Recognising that our longitudinal data are not fully independent, we controlled for the hierarchical nature of the dataset through a variance structure that nests measurement year within site location.

In arriving at a final parsimonious model, we show that daytime air temperature and vapour pressure deficit, and soil moisture content, are all salient predictors of LUE. The same explanatory terms are retained in iterations of this analysis run at timescales from weeks to months. Model performance was not significantly improved by inclusion of additional variables such as rainfall,

site elevation or vegetation category (e.g. Plant Functional Type, PFT). This empirical analysis supports the notion that GPP is predictable using a single model structure that is common to different PFTs.