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Carbon economics of LAI drive photosynthesis patterns across an Amazonian precipitation gradient

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The Amazon rainforest is an integral part of the terrestrial carbon cycle, yet whilst the physiological response of its plants to water availability is increasingly well quantified, constraints to photosynthesis through adaptive response to precipitation regime have received little attention. We use the Soil Plant Atmosphere model to apportion variation in photosynthesis to individual drivers for plots with detailed measurements of carbon cycling, leaf traits and canopy properties, along an Amazonian mean annual precipitation (MAP) gradient. We hypothesised that leaf area index (LAI) would be the principal driver of variation in photosynthesis. Differences in LAI are predicted to result from economic factors; plants balance the carbon cost of leaf construction and maintenance with assimilation potential, to maximise canopy carbon export. Model analysis showed that LAI was the primary driver of differences in GPP along the precipitation gradient, accounting for 49% of observed variation. Meteorology accounted for 19%, whilst plant traits accounted for only 5%. To explain the observed spatial trends in LAI we undertook model experiments. For each plot the carbon budget was quantified iteratively using the field measured LAI time-series of the other plots, keeping meteorology, soil and plant traits constant. The mean annual LAI achieving maximum photosynthesis and net canopy carbon export increased with MAP, reflecting observed LAI trends. At the driest site, alternative, higher LAI strategies were unsustainable. The carbon cost of leaf construction and maintenance was disproportional to GPP achieved. At high MAP, increased foliar carbon costs were remunerative and GPP was maximised by high LAI. Our evidence therefore suggests that observed LAI trends across the precipitation gradient are driven by carbon economics. Forests LAI response to temporal changes in precipitation reflects trends observed across spatial gradients, identifying LAI as a key mechanism for plant response to water availability. This research improves our understanding of the constraints on photosynthesis through plants' adaptive response to precipitation, which in light of precipitation projections, has implications for the future Amazon carbon balance.