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A simple alternative to the light-use efficiency approach that considers canopy photosynthesis saturation with light

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Abstract

We report eddy covariance CO_2 flux and meteorological observations from a tropical rain forest in Indonesia that clearly show saturation of canopy photosynthesis (P_g) at relatively moderate incident and absorbed photosynthetically active radiation (PAR) (Ibrom et al. 2008). CO_2 fluxes were measured with and open-path fast response IRGA (LI-7500, LI-COR, NE, USA) and a 3D ultrasonic anemometer (USA1, Metek, Elmshorm, Germany). PAR absorption was calculated with a one dimensional model (Oltchev et al. 2007) and complied with measured short wave albedo at the site, the Lore Lindu National Park, Central Sulawesi, Indonesia.

We investigated how this saturation propagated moving from half hourly to larger time scales and found that in the tropical climate, saturation was the dominant phenomenon of the photosynthetic light response both at daily and monthly time scales. From this we conclude that the fundamental assumption of the very often used light-use efficiency approach (Monteith 1972), i.e. that light use efficiency is a constant under non limiting water vapour saturation deficit (D) , temperature and soil water availability,

does not apply at this site. We also revisited studies from other forests and climates and found indications for P_g saturation. These were however masked by combining the light-use efficiency approach with D reduction functions that are used to include certain reduction of ε at dry (and at the same time sunny) weather situations in the simulations.

Apart from the critical evaluation of the light-use efficiency approach we also suggest a similarly simple approach that is able to include both saturation and reduction of P_g at high D levels based on a simple Blackman response approach. This approach uses the light use efficiency approach only for non saturating condition and a constant maximum P_g (P_{max}) when absorbed PAR exceeds saturating levels. As D was found to reduce P_{max}, the PAR level at which P_g saturated became a well described function of D.

We advocate replacing the current version of the light-use efficiency approach by the combined Blackman response when simulating GPP from remote sensing products. Future research should focus to investigate biome characteristic relationships of the additional parameter, P_{max}, with climate and canopy structure.

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