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CO_2 fertilization stimulates vegetation productivity but has little impact on hydrology in tropical rainforests

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Tropical rainforests contribute to ∼52% of the terrestrial biomass carbon and more than one-third of global terrestrial net primary production. Thus, understanding how tropical rainforests respond to elevated atmospheric CO_2 concentration (eCO_2) is essential for predicting Earth's carbon, water and energy budgets under future climate change. While the Free-air CO_2 enrichment (FACE) technique has greatly advanced our understanding of how boreal and temperate ecosystems respond to eCO_2, there are currently no FACE sites available in tropical rainforest ecosystems. Here we firstly examine the trend in long-term (1982-2010) satellite-observed leaf area index and fraction of vegetation light absorption and find only minor changes in these variables in tropical rainforests over years, suggesting that eCO_2 has not increased vegetation leaf area in tropical rainforests and therefore any plant response to eCO_2 occurs at the leaf-level. Following that, we investigate the long-term physiological response (i.e. leaf-level) of tropical rainforests to eCO_2 from three different perspectives by: (1) analyzing long-term runoff and precipitation records in 18 unimpaired tropical rainforest catchments to provide observational evidence on the eCO_2 effect from an eco-hydrological perspective; (2) developing an analytical model using gas-exchange theory to predict the effect of eCO_2 from a top-down perspective; and (3) interpreting outputs from 10 process-oriented ecosystem models to examine the effect of eCO_2 from a bottom-up perspective. Our results show that the observed runoff coefficient (the ratio of runoff over precipitation) and ecosystem evapotranspiration (calculated from catchment water balance) remain relatively constant in 18 unimpaired tropical catchments over 1982-2010, implying an unchanged hydrological partitioning and thus conserved transpiration under eCO_2. For the same period, using 'top-down' model based on gas-exchange theory, we predict an increase in plant assimilation (A) driven directly by an enhanced light use efficiency (ε) at the leaf-level in response to eCO_2, the magnitude of which is about the same as that of eCO_2 (i.e. ∼12% over 1982-2010). Simulations from ten state-of-the-art 'bottom-up' ecosystem models also confirm that in tropical rainforests, direct effect of eCO_2 mainly increases A and ε but does not change E. Our findings add to the current limited pool of knowledge regarding the long-term eCO_2 impacts in tropical rainforests and provide important scientific guidance for future ecophysiology / ecohydrology modelling and field activities conducted in the area.