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Phosphorus feedbacks on the tropical CO_2 fertilization effect: Deriving model-based hypotheses for the AmazonFACE experiment.

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Increasing atmospheric carbon dioxide (CO_2) concentration is assumed to have a stimulating effect ("CO_2 fertilization effect") on forest growth and resilience. The implications of the tropical CO_2 fertilization effect are far-reaching, as it strongly influences the global carbon and water cycle, and hence future global climate. However, empirical evidence for the existence and strength of such a tropical CO_2 fertilization effect is scarce, and low soil phosphorus availability is likely to constrain the response of forest growth to CO_2 in the Amazon. The planned Amazon Free Air CO_2 Enrichment (FACE) is the first FACE experiment in an old-growth, highly diverse, tropical rainforest experiment to address these uncertainties.

Here, we present a priori model-based hypotheses of the major responses for the experiment derived from a set of 13 ecosystem models. The model comparison identified key uncertainties in our understanding of ecosystem processes and derived hypotheses of expected ecosystem responses to elevated CO_2 that can directly be tested during the experiment. Ambient model simulations compared satisfactorily with in-situ measurements of ecosystem carbon fluxes, as well as carbon, nitrogen, and phosphorus stocks, obtained during the pre-treatment phase. The degree to which biomass growth was stimulated by CO_2 in the models hinged on the adaptability of plants to grow under low soil P availability. Models in which no mechanisms were in place that allowed for more plant nutrient acquisition or more efficient use of phosphorus under elevated CO_2, predicted close to zero stimulatory effect of CO_2 on growth. Models that allow for additional phosphorus acquisition mechanisms, or consider flexibility in tissue nutrient stoichiometry and carbon allocation, predicted a CO_2 fertilization effect on biomass. These modelled plant adaptive mechanisms are poorly constrained by field data and our model simulations point to a need for greater understanding of phosphorus related plant internal and rhizosphere processes in order to forecast the Amazon rainforest's response to elevated atmospheric CO_2 in future scenarios with higher confidence. Our model-based hypotheses can directly be translated into monitoring priorities for the AmazonFACE experiment, but may similarly apply for field measurements and modelling efforts elsewhere.