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Optimal plant nitrogen use improves model representation of vegetation response to elevated CO_2

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Existing global vegetation models often cannot accurately represent observed ecosystem behaviour under transient conditions such as elevated atmospheric CO_2, a problem that can be attributed to an inflexibility in model representation of plant responses. Plant optimality concepts have been proposed as a solution to this problem as they offer a way to represent plastic plant responses in complex models. Here we present a novel, next generation vegetation model which includes optimal nitrogen allocation to and within the canopy as well as optimal biomass allocation between above- and belowground components in response to nutrient and water availability. The underlying hypothesis is that plants adjust their use of nitrogen in response to environmental conditions and nutrient availability in order to maximise biomass growth. We show that for two FACE (Free Air CO_2 enrichment) experiments, the Duke forest and Oak Ridge forest sites, the model can better predict vegetation responses over the duration of the experiment when optimal processes are included. Specifically, under elevated CO_2 conditions, the model predicts a lower optimal leaf N concentration as well as increased biomass allocation to fine roots, which, combined with a redistribution of leaf N between the Rubisco and chlorophyll components, leads to a continued NPP response under high CO_2, where models with a fixed canopy stoichiometry predict a quick onset of N limitation.Existing global vegetation models often cannot accurately represent observed ecosystem behaviour under transient conditions such as elevated atmospheric CO_2, a problem that can be attributed to an inflexibility in model representation of plant responses. Plant optimality concepts have been proposed as a solution to this problem as they offer a way to represent plastic plant responses in complex models. Here we present a novel, next generation vegetation model which includes optimal nitrogen allocation to and within the canopy as well as optimal biomass allocation between above- and belowground components in response to nutrient and water availability. The underlying hypothesis is that plants adjust their use of nitrogen in response to environmental conditions and nutrient availability in order to maximise biomass growth. We show that for two FACE (Free Air CO_2 enrichment) experiments, the Duke forest and Oak Ridge forest sites, the model can better predict vegetation responses over the duration of the experiment when optimal processes are included. Specifically, under elevated CO_2 conditions, the model predicts a lower optimal leaf N concentration as well as increased biomass allocation to fine roots, which, combined with a redistribution of leaf N between the Rubisco and chlorophyll components, leads to a continued NPP response under high CO_2, where models with a fixed canopy stoichiometry predict a quick onset of N limitation.