# Land unlikely to become large carbon source

**To the Editor** — Increasing $CO_2$ concentration and rising temperatures are both expected to have important impacts on plant productivity. Models used to simulate how terrestrial carbon stocks change in response to climate change, such as those used in the Coupled Model Intercomparison Project Phase 5 (CMIP5), do not account for how changes in the availability of nutrients such as nitrogen or phosphorus may limit net primary production. Wieder *et al.* point out that the CMIP5 models overestimate future land carbon storage[1]. Although this finding is in line with earlier work[2,3], we disagree with their conclusion that nutrient limitation of net primary production could cause terrestrial ecosystems to transition from being a net carbon sink to a large carbon source.

Several feedback processes not considered by Wieder *et al.* make it unlikely that land will become a carbon source[2,3]. First, Wieder *et al.* assume that warming stimulates decomposition of soil organic carbon but does not affect the mineralization of nutrients from soil organic matter. This assumption maximizes the effect of nutrient limitation on land carbon storage under warming. It contradicts soil-warming experiments showing enhanced mineralization in a range of ecosystems, which potentially compensates soil carbon losses by stimulating plant productivity due to increased nutrient availability[4].

Changes in mineralization, as well as additional processes governing the recycling of nutrients, pose a large source of uncertainty in the amount of nutrients available for the build-up of new biomass. In the case of phosphorus (P), changes in dust deposition and other external inputs (the only source of P considered by Wieder *et al.*) are of minor importance for the terrestrial carbon balance on decadal to centennial timescales, since more than 95% of annual net primary productivity is supported by recycled P rather than P from external sources[2,5]. The amount of P available for the build-up of new biomass accounted for by Wieder *et al.* is of the same order of magnitude as estimates of present-day labile inorganic P concentration in soils, a conservative estimate of P availability on a timescale of years to decades[6]. In addition, under the conditions of strong warming evaluated by Wieder *et al.*, the amount of new P from weathering can be expected to double by the end of the twenty-first century. These two examples illustrate how uncertain the availability of P is. Although Wieder *et al.* discuss these processes, they either neglect them in their calculations or provide no uncertainty range.

Currently, land ecosystems absorb a quarter of anthropogenic $CO_2$ emissions. Potential turning of this sink into a source conveys a strong warning message to policymakers. Such a message should not be based only on uncertain assumptions regarding nutrient dynamics in ecosystems and upper-end warming scenarios. ❐


References

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## Reply to 'Land unlikely to become large carbon source'

**Wieder *et al.* reply** — Brovkin and Goll argue that the effects of potential changes in nitrogen (N) and phosphorus (P) mineralization are important to consider[1]. We agree that warming can stimulate N mineralization, and our results — which are generally consistent with other analyses[2] — reflect the effects of such an increase. Yet, the magnitude and duration of this effect across different ecosystems is unclear.

The effects of climate warming on P dynamics, which govern the bulk of carbon (C) losses in our study, are even more unclear. Even if future N limitation is largely mitigated by increased N mineralization, a similar scenario for P seems implausible. Increasing biological P demand is likely to outpace exogenous P inputs, suggesting that accelerated cycling of extant P pools will be critical[3]. Mounting evidence indicates that total soil P is probably important in determining the amount of P that is ultimately available to plants, suggesting that a better understanding of the factors that regulate exchanges between 'available' and 'unavailable' soil P pools is critically needed. Although these processes are poorly understood, our results are consistent with the conclusion that P availability may ultimately constrain the terrestrial C sink[4].

Many other fundamental questions about the response of terrestrial ecosystems to environmental change contribute to nutrient–C cycle uncertainty. For example, under increased $CO_2$ concentration, changes in soil moisture and plant C allocation may accelerate soil nutrient cycling in the short term; however, whether high rates of nutrient mineralization can be sustained over decadal to century timescales remains unclear. Similarly, global change may decouple N and P stoichiometry, adding additional uncertainties to the representation of C–nutrient biogeochemistry, but we agree that the models we analysed did not include these important interactions.

Addressing uncertainties in terrestrial nutrient–C cycle interactions and responses to global change was well beyond the scope of the work[3]. Yet, these uncertainties arise as geophysical models attempt to simulate increasingly sophisticated and often poorly understood ecological processes. Global

C-cycle projections typically do not consider uncertainties driven by potential biological response to environmental change, thus we deem future consideration and resolution of these uncertainties critical.

We maintain that future land C storage projected in the Coupled Model Intercomparison Project Phase 5 (CMIP5) models is probably overstated as a result of potential nutrient constraints. ❐

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