nitrogen-containing gas into the atmosphere (a process known as volatilization). Artificial nitrogenous fertilizers, which are widely produced from nonreactive nitrogen gas (N_2), have also increased volatilization of nitrogen as ammonia (*5*). Compared with nitrogen released through organic matter decomposition in soils, these gaseous origins of reactive nitrogen are typically more depleted in the stable isotope ^{15}N (*1*, *6*, *7*).

The marked ^{15}N depletion in plants in natural ecosystems over the past century likely reflects these much-increased anthropogenic nitrogen emissions and gases (*6*, *8*, *9*) rather than lower nitrogen availability as Mason *et al.* suggest. Therefore, we caution against Mason *et al.*'s recommendation to fertilize seminatural ecosystems with nitrogen to improve carbon sequestration. To prevent the negative effects of excess nitrogen (such as biodiversity loss), implementing this intervention should wait until more compelling evidence is available.

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Response

Olff *et al.* select only a subset of the evidence for declining nitrogen availability and assign unlikely mechanisms to reach the conclusion that nitrogen availability is not declining over large areas of Earth. We disagree that the evidence can be grouped into the categories that Olff *et al.* describe; the complete set of observations is wider in scope and cannot be explained by the mechanisms that the authors propose.

Olff *et al.* claim that declines in nitrogen emissions since 1990 can explain declining nitrogen availability. Our Review acknowledges reduced emissions, and the resulting reduction in atmospheric deposition of nitrogen onto ecosystems, as a likely contributing factor. However, we also present long-term records of declining nitrogen availability, including declining nitrogen concentrations in plant leaves since around 1930 (*1*, *2*) and in plant pollen since the early 1900s (*3*), as well as declines in a broad suite of soil nitrogen availability indicators and stream water NO_3^- at Hubbard Brook in New Hampshire, United States, that date back to the 1960s and 1970s (*4*, *5*). These observations predate reductions in nitrogen deposition. Moreover, as we explain in the Review, declines in nitrogen availability indicators have occurred in places that have never experienced substantially elevated nitrogen deposition (*1*) and alongside declines in concentrations of other elements in plants (*6*–*8*).

Olff *et al.* then propose that large-scale declines in natural abundance nitrogen isotope ratio ($\delta^{15}N$) values in sediment and plants can be explained by a change over time in the isotopic signature of anthropogenic nitrogen emissions toward isotopically lighter, reduced forms of nitrogen. However, the evidence they cite of possible effects of this shift on plant $\delta^{15}N$ refers only to a handful of case studies in atypical environments (*9*–*11*). The isotopic ratio of deposited nitrogen is elevated by processes in soil that discriminate against ^{15}N; the effects of such processes increase with increasing nitrogen supply (*2*, *12*). Models show that the isotopic signature of deposited nitrogen would have to be implausibly low to cause plant $\delta^{15}N$ to decline at the observed rate (*2*).

There is little doubt that massive and poorly managed anthropogenic nitrogen inputs have led to eutrophication and biodiversity loss in many locations. However, rising atmospheric CO_2, warming, and several other global changes are concurrently driving a reduction in nitrogen availability (i.e., nitrogen supply relative to nitrogen demand). The well-documented increases in anthropogenic nitrogen supply noted by Olff *et al.* have not affected global ecosystems uniformly and are unlikely to be the overriding driver of changes in nitrogen availability across all terrestrial ecosystems.

As we state in our Review, the fundamental response to declining nitrogen availability must be to reduce CO_2 emissions. We point out that, although fertilization may be one option for increasing nitrogen availability to plants, microbes, and herbivores, numerous factors must be taken into account when designing interventions that can achieve well-defined goals without unacceptable negative consequences. Further work is necessary to more fully demonstrate the extent of declines in nitrogen availability, to clarify the underlying mechanisms, and to delineate appropriate responses. But before this can happen, the scientific evidence for declining nitrogen availability must be acknowledged.

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