TECHNICAL COMMENT

Response to Comment on "A Reservoir of Nitrate Beneath Desert Soils"

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We appreciate the comment by Jackson *et al.* (*1*), which underscores two points made in our recent paper (*2*): (i) that desert subsoil nitrate (NO_3^-) inventories are spatially highly variable, and thereby warrant substantial measurement efforts to reduce uncertainty in global extrapolations, and (ii) that Chihuahuan Desert subsoil NO_3^- inventories tend to be much smaller than inventories in other western U.S. deserts.

The limited yet geographically diverse data that we compiled display a "high intra- and interregional variability," yielding "subsoil NO_3^- N inventories that vary from 30 to 13,600 kg of N ha^{-1}" (*2*). Thus, we explicitly acknowledged large uncertainty in estimated global inventories. The intention was not to quantify precisely the global subsoil N pool, but rather to demonstrate the subsoil NO_3^- N inventory as a potentially large component of vadose-zone N that has generally been neglected. We agree with Jackson *et al.* (*1*) that large-scale spatial extrapolations must be treated with caution. Accordingly, we emphasized in (*2*) that considerably more coverage is needed to improve global estimates. This current exchange will hopefully motivate additional data collection to reduce the uncertainty.

In their comment, Jackson *et al.* (*1*) cite only the upper limits of extrapolated subsoil N provided in (*2*) for global (16%) and desert (71%) vadose zones. In fact, we presented ranges with quite wide bounds [3 to 16% for global and 14 to 71% for desert (*2*)], which reflected the high degree of variability in the limited available data. The data presented in (*1*) appear to be consistent with our approach for estimating a full range of possible nitrate inventories. As we noted in (*2*), assuming that inventories of 1 to 5×10^3 kg ha^{-1} (*3*) exist elsewhere, subsoil N inventories in deserts and arid shrublands contain approximately 3 to 15 Pg of bioavailable N. The lower limit estimate was conservatively obtained by assuming a 1×10^3 kg ha^{-1} global desert average that is consistent with the median of our compilation as well as with the relatively small inventories measured at the Chihuahuan Desert sites in West Texas, and that is more than one order of magnitude smaller than the largest inventories measured at the other desert sites (*2*).

The data presented by Jackson *et al.* (*1*) from the Jornada and Sevilleta (New Mexico) areas of the Chihuahuan Desert confirm our conjecture that nitrate retention in various desert ecosystems operates quite differently depending on precipitation patterns, vegetation type, vegetation history, and other factors. In particular, the Chihuahuan Desert sites in (*2*) had the smallest subsoil NO_3^- inventories of all of the desert sites. The relatively large proportion of summer precipitation in the Chihuahuan Desert (70%) (*5*) may be an important factor contributing to the relatively low subsoil NO_3^- accumulation and poor correlation to Cl^- observed in (*1*); historic changes in vegetation may be another. The Jornada and Sevilleta areas have undergone desertification of formerly productive grasslands within the past 100 to 150 years (*5, 6*). In contrast, the Mojave and Sonoran desert sites in (*2*) have long-standing desert vegetation communities established as early as 10 to 15 thousand years ago (*7*). The long-term nature of subsoil NO_3^- reservoir development, as well as the association with paleoclimate and paleovegetation transitions, was emphasized by us in (*2*) and in the article's supporting online material. The small NO_3^- inventories at the sites investigated by Jackson *et al.* (*1*) appear consistent with the pattern of NO_3^- control by climate and vegetation history postulated in (*2*).

References and Notes

1. R. B. Jackson *et al.*, *Science* **304**, 51; www.sciencemag.org/cgi/content/full/304/5667/51b.
2. M. A. Walvoord *et al.*, *Science* **302**, 1021 (2003).
3. Owing to a typographical error, this figure was incorrectly reported in this context in (*2*) as 1 to 5 kg ha^{-1}. Values in Fig. 4 in (*2*) are correct.
4. R. H. Schmidt, *J. Arid Environ.* **2**, 243 (1979).
5. W. H. Schlesinger *et al.*, *Science* **247**, 1043 (1990).
6. W. A. Dick-Peddie, *New Mexico Vegetation: Past, Present and Future* (Univ. of New Mexico Press, Albuquerque, NM, 1993).
7. J. L. Betancourt, T. R. Van Devender, P. S. Martin, *Packrat Middens: The Last 40,000 Years of Biotic Change* (Univ. of Arizona Press, Tucson, AZ, 1990).

23 December 2003; accepted 18 February 2004