

COMMENTS AND LETTERS TO THE EDITOR

Comments on "Thirty Years of Change in Forest Soils of the Allegheny Plateau, Pennsylvania"

Bailey et al. (2005) found substantial declines in exchangeable base cations over a 30-yr period in soils of the Allegheny Plateau. They cannot attribute these changes to uptake and sequestration by vegetation and therefore ascribe the changes to "off-site leaching," and note that these changes are "consistent with studies that have suggested that acid deposition has induced significant losses of exchangeable base cation pools by hydrologic leaching" (p. 688). Close examination of Table 3 in their manuscript does not support this speculation, however. If the observed changes in exchangeable Ca^{2+} and Mg^{2+} are converted to $\text{kmol}_c \text{ ha}^{-1}$, the changes in $\text{Ca}^{2+} + \text{Mg}^{2+}$ (M^{2+}) that cannot be ascribed to vegetation uptake are 581.3, 184.0, 19.8, and $-9.0 \text{ kmol}_c \text{ ha}^{-1}$ for the Dewdrop (DD), Fools creek (FC), Heart's Content (HC), and North Branch (NB) sites, respectively. On an annual basis (dividing by 30 yr), this amounts to 19.4, 6.1, 0.7, and $-0.3 \text{ kmol}_c \text{ ha}^{-1} \text{ yr}^{-1}$, respectively. The values for DD and FC appear to be well beyond what could be attributed to total S and N deposition, equivalent to 310 and $98 \text{ kg ha}^{-1} \text{ yr}^{-1}$ of S or 271 and $86 \text{ kg ha}^{-1} \text{ yr}^{-1}$ of N. According to NADP maps, wet deposition of S for this region appears to be on the order of $12 \text{ kg ha}^{-1} \text{ yr}^{-1}$ as S ($35 \text{ kg S ha}^{-1} \text{ yr}^{-1}$ as SO_4^{2-}) and $(\text{NO}_3^- + \text{NH}_4^+)$ -N deposition is on the order of $8 \text{ kg ha}^{-1} \text{ yr}^{-1}$ as N ($21 \text{ kg ha}^{-1} \text{ yr}^{-1}$ as NO_3^- and $4.1 \text{ kg ha}^{-1} \text{ yr}^{-1}$ as NH_4^+) (NADP, 2003). Even if major N inputs occurred by dry deposition, it seems extremely unlikely that atmospheric deposition contributed substantially to the observed changes at DD and FC. Nor would natural leaching rates, typically on the order of 0.5 to $2 \text{ kmol}_c \text{ ha}^{-1} \text{ yr}^{-1}$ (Johnson and Lindberg, 1992), contribute this much to base cation leaching, unless limestone parent material is being weathered. The value for HC is within the range of what might be expected due to leaching processes, but the value for NB is in fact negative, implying that weathering exceeded base cation loss because soils did not lose as much base cations as were sequestered by vegetation.

Thus, the changes in soils documented by Bailey et al. (2005) are not consistent with what could be expected due to leaching or to acid deposition. Given their careful and extensive quality assurance program, the observed changes have to be accepted as real until proven otherwise, and further investigation is definitely warranted to uncover the causes of these changes.

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Response to "Comments on 'Thirty Years of Change in Forest Soils of the Allegheny Plateau, Pennsylvania'"

In our paper (Bailey et al., 2005) we document substantial reductions in exchangeable Ca and Mg at four forested sites over a 30-yr period. Expressed on a soil mass basis, these changes are remarkably consistent between and within sites. We also expressed these results on a landscape area basis (Table 3) and suggest that the changes in base cation pools are much too large to be accounted for by forest growth. We further suggest that long-term loss of exchangeable cations via leaching is consistent with mass balance, modeling, and experimental acidification studies. We did not attempt an exact accounting of soil losses by uptake versus leaching due to uncertainty in estimates of soil pools, biomass uptake, and leaching fluxes.

Conversion of the observed soil changes to a landscape area basis is necessary for an evaluation of nutrient cycling impacts but introduces uncertainty, primarily due to local variation in rock content. For example at Dewdrop, the site where leaching losses appear greatest, rock content is also most variable; in the five sampling pits rock content varied by a factor of ten, from 5 to 50% by volume. Use of quantitative pit sampling techniques would improve the accuracy of rock content measurements within individual sampling pits, but the number of pits needed to precisely address rock content variation would have been prohibitive here as it is in many forested sites.

Johnson (2005) argues that the estimated changes on a landscape area basis are much too large to be accounted for by leaching attributable to acid deposition. However, there is also uncertainty in the total acid deposition levels experienced over this region for the period between 1967 and 1997, as measurements at the nearby Kane Experimental Forest NADP site did not begin until the early 1980s and consider wet-only deposition. The estimate Johnson (2005) cites is unrealistically low because it is based on wet-only deposition for a single year, 2003. He fails to account for declining levels of S deposition, which are documented since 1980, the beginning of the record at Kane, and likely extend back to the early 1970s, following emission reductions implemented in response to the Clean Air Act. He also dismisses dry deposition, which is typically estimated at 25 to 50% of total deposition for SO_4 and about 50% of total deposition for NO_3 (Lovett, 1994).

Further, leaching of acid anions in this region is in excess of deposition, suggesting that soils are S (and perhaps N) saturated. For example, DeWalle et al. (1988) document that SO_4 leaching flux at the base of the B horizon was 56% greater than atmospheric deposition and NO_3 leaching flux was approximately equal to atmospheric deposition at a site in western Pennsylvania with the same bedrock and similar soils to those in our study. Leaching of SO_4 and NO_3 in the study by DeWalle et al. (1988) was $3.5 \text{ kmol}_c \text{ ha}^{-1} \text{ yr}^{-1}$, greater than the range of 0.5 to $2 \text{ kmol}_c \text{ ha}^{-1} \text{ yr}^{-1}$ reported for sites in the IFS study (Johnson and Lindberg, 1992).

Taken together, these factors suggest that the discrepancy be-

tween estimates of base cation pool reductions and acid deposition levels is much smaller than that suggested by Johnson (2005). Given the paucity of data on historic total deposition and uncertainty in soil pool estimates and leaching rates, it is possible that these quantities are equivalent, within the range of uncertainty. Coupled with the lack of a plausible alternative mechanism, we maintain that leaching likely is the dominant factor causing the changes in soil chemistry observed in our study.

In response to Johnson's (2005) comment that further study of these changes is warranted, we wholeheartedly agree. Although the access to well documented, archived historic samples limits the ability of the scientific community to document such temporal changes, we suggest that many more samples exist, collected in support of soil surveys conducted at least once in the past century in nearly every county of the country. This represents a largely untapped resource to extend the results of this study and evaluate the extent and magnitude of soil change in a great range of soil and forest types.

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