

Comment on "Managing Soil Carbon" (II)

Lal *et al.* have recently argued (1, 2) that restoring soil carbon levels worldwide is important for a number of purposes, including reducing atmospheric CO₂ concentrations. We agree, but we question how much eroded soil C is ultimately delivered to the atmosphere. Previous estimates of the proportion of eroded soil carbon oxidized range from 0% to near 100% (3, 4). We believe that the true value is nearer the extreme low end of that range, because much of this soil carbon is deposited in depressions, water impoundments, and floodplains, where oxidation rates are lower than in the original soils (5, 6). Therefore, erosion-related emissions of C are probably much smaller than the ~1 gigaton (Gt) C/year estimated by Lal *et al.* We have argued previously (7) that erosion and subsequent deposition represent an apparent sink of ~1 Gt/year.

Our published estimates suggest that soil erosion globally mobilizes ~1.4 Gt carbon annually (7), based on a robust budgetary estimate for the United States of 0.05 Gt C mobilization per year from erosion. Further, we demonstrated that U.S. river discharge of total organic C is about 20% of soil C erosion. We identified storage compartments for bulk sediment on land—large (inventoried) impoundments, smaller (uninventoried) impoundments, and (by difference) alluvium—and estimated the organic carbon buried in each. The carbon not associated with any storage compartment was assigned to oxidation. Within the uncertainties in our bulk sediment budget, there was no evidence of net carbon oxidation, although we cited the basis on which our estimates could be raised from 0 to 20% oxidation. This estimate was based on budgetary calculations, not an assumption, as stated by Lal *et al.* (1, 3). Although the Lal *et al.* value of 20% is not inconsistent with that range, we believe that this high-end value is extreme for the United States and that higher percentages are well outside the constraints imposed by the budget. Indeed, the Lal *et al.* estimate of 1 Gt

yearly carbon loss to the atmosphere is itself based on two unsubstantiated assumptions: 20% C oxidation in the erosion/transport process and 3% C content of soils (8).

We have also demonstrated that deposition in artificial impoundments is the largest single sink for eroded soil in the United States (9, 10). The carbon content of this sediment is similar to that of the soil from which it was derived, which in turn indicates that there is little or no loss in transport (11).

In terms of effect on the CO₂ budget, the most important issue is how the oxidation rates for eroded and uneroded soil carbon compare. Rice (5) points out that soil C, at field moisture capacity, is more rapidly reactive than C in either water-saturated sediments or dry soil. If both our budgetary model and the assertions of Rice are valid, then erosion decreases the net rate of soil carbon oxidation by moving soil C from relatively reactive to relatively unreactive sites. However, the combination of tillage and erosion in fields does increase the C oxidation from soils in situ. The magnitudes of these counterbalancing processes are unknown or, at least, poorly quantifiable.

With respect to mass balance, a smaller source term (for example, less oxidation of eroded soil C) is equivalent to a net sink. The general equation is that net ecosystem production (NEP) equals net primary production (NPP) minus respiration (R). Soil C oxidizes, whether it is in place or not. Eroded soil carbon continues to oxidize, but we contend that the erosion and redistribution to buried, submerged, waterlogged, or even dry environments lowers the net oxidation rate. Thus, eroding soil C raises NEP by lowering R. We have estimated (4) that the difference between the Lal *et al.* estimate of soil C oxidation and our estimate corresponds to an apparent erosion-associated soil carbon "sink" of about 1 Gt/year. This virtual sink has gone unrecognized because it is passive (less oxidation than expected) rather than active (photosynthetic fixation).

Loss of soil C from an individual field represents a complex admixture of local translocation, local oxidation, and "downstream" oxidation and is difficult to describe at the field scale. Although our analysis differs in an important detail from that of Lal *et al.* (1), we fully support their call for the development and adoption of tools such as conservation tillage agriculture. This would not only increase the carbon content of soils, but also preserve storage capacity in impoundments where eroded soil and carbon are accumulating.

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