INTEGRATION OF EXISTING DATA TO ESTIMATE THE INFLUENCE OF SOIL AND WATER MANAGEMENT ON CARBON EROSION AND BURIAL IN THE CONTERMINOUS UNITED STATES

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ABSTRACT

Human activities have altered rates of carbon erosion from soils and carbon deposition in sediments. We are developing methods to quantify the present-day and historical effects of these changes on the carbon mass balance of the conterminous U.S. land surface. Because our analysis uses a combination of diverse existing datasets, we devote particular attention to methods for the estimation of uncertainties that are consistent with the statistical character of the source data.

BACKGROUND

The acceleration of soil erosion is one of the most pervasive effects of human land-cover modification. As human activities have spread across the landscape, erosion has depleted the fertility of agricultural soils, contributed to declining water quality, and caused sedimentation problems in waterways, lakes, and reservoirs. There are two contrasting perspectives regarding the effects of accelerated soil erosion on atmospheric CO_2. On the one hand, the loss of carbon from agricultural soils has long been identified as a significant contribution to the historical increase in concentrations of carbon dioxide in the atmosphere. Enhancement of erosion has been identified as one of the mechanisms causing carbon loss to the atmosphere through the breakdown of aggregates, acceleration of organic decomposition, and decline of soil fertility [*Lal*, 1995]. On the other hand, burial of carbon in terrestrial sediments has been accelerated by human management of water resources, particularly by construction of dams and reservoirs. The burial of eroded soil carbon, coupled to its ongoing replacement at sites of erosion, has been hypothesized as a significant global and U.S. carbon sink [*Stallard*, 1998; *Smith et al.*, 2001]. Are these contrasting perspectives incompatible? What are their areas of inconsistency and/or agreement? Why do they lead to such disparate conclusions? We are examining these questions in the context of carbon mass-balance estimates for the conterminous U.S.

APPROACH

The documented history of U.S. soil and water management provides a unique opportunity to examine soil and sediment carbon storage under conditions of changing management practices. Our approach is based on the application of existing datasets to landscape mass balance calculations that encompass both erosional and depositional sites. These calculations are performed in a spatially explicit manner using geographic information systems (GIS) analysis of relationships among cropping, soil management, soil properties, water management, topography, and other relevant features.

For erosion estimates, we rely especially on the U.S. National Resources Inventory, (NRI) (USDA 1997), which includes statistical estimates that are calculated using the Universal Soil Loss Equation (USLE) [*Wischmeier and Smith*, 1965]. The NRI estimates of erosion apply to recent decades for U.S. croplands, pastures, and lands in the Conservation Reserve Program. For trends prior to 1982, we apply the USLE to historical trends in cropping and soil management in a manner that is consistent with the NRI estimates. Historical estimates of cropland areas are drawn from U.S. Census county-level records extending back to the mid-nineteenth century [*Waisanen and Bliss*, 2002].

Our estimates of sediment transport and deposition are constrained to meet requirements of mass balance through time. We estimate historical rates of sediment burial in reservoirs using sedimentation rates compiled in the U.S. Reservoir Sedimentation Survey Information System (RESIS) (Steffen, 1996). These estimates are extrapolated to historical sedimentation estimates for the more extensive U.S. National Inventory of Dams (NID) (FEMA and ACE, 1993). We estimate deposition in upland areas from sediment mass balance calculations coupled to analysis of soil and slope datasets.

Our estimates of the carbon content of soils at erosional and depositional sites are derived by linking soil information in the NRI to soil carbon estimates derived from the STATSGO database (USDA, 1994). Rates of carbon erosion, degradation, transport, and burial are constrained by carbon mass-balance calculations coupled to representations of landscape soil-carbon dynamics.

UNCERTAINTY ANALYSIS

Because none of the existing source datasets were originally designed for carbon mass-balance calculations, a major focus of our study is the estimation of uncertainties in a manner consistent with the statistical design and character of the source data. Even when different datasets report the same attributes, linkages between datasets using these shared attributes must be applied with caution. Significant differences may arise from structural and definitional differences in database design and purpose. Additional statistical challenges occur in transferring the geospatial and other characteristics of the various source data to the functional elements (e.g., drainage basins) that are necessary in our mechanistic mass balance approach. In all phases of our analysis, data are compiled at the most detailed spatial and temporal resolution feasible, followed by analysis and aggregation to scales consistent with the statistical design of the source datasets and the constraints inherent in their differences.

RELATIONSHIP TO EXISTING MODELS AND MASS-BALANCE CALCULATIONS

To assure that the calculated effects of erosion and deposition can be related to other U.S. land surface carbon budget calculations, effects of erosion and deposition are determined in the context of spreadsheet calculations of historical land-use effects [e.g., *Houghton et al.*, 1999] and, where possible, compared to mechanistic models of soil and vegetation response to changes in land use. Our preliminary calculations suggest that the historical influence of enhanced erosion and deposition must be included in the cumulative carbon mass balance of the U.S. land surface, and that storage of carbon in alluvium and colluvium is a significant source of uncertainty in these estimates.

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