

## Erosion Effects on Soil Organic Carbon Pool in Soils of Iowa

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### ABSTRACT

Soil erosion involves preferential removal and redistribution of the light soil fractions comprising soil organic matter and clay contents. Because soil organic matter content is concentrated in the surface soil, accelerated erosion leads to its progressive depletion. Yet, systematic assessment of the magnitude of loss of soil organic carbon content with the severity of soil erosion for major soils of the U.S. has not been undertaken. This report is based on soil carbon content of the top 25-cm layer of 250 soil profiles comprising 208 Mollisols, 27 Alfisols, and 15 Entisols from Iowa. Soil profiles were stratified into three erosional classes involving slightly eroded, moderately eroded and severely eroded. About 32% or 67 out of 208 Mollisols had a change in the soil order due to erosion-induced changes in soil quality. Soil erosion caused changes in soil structure, which was mostly granular in slightly eroded; sub-angular blocky in moderately eroded and cloddy in severely eroded phases. The range of soil organic carbon (SOC) lost by erosion in the top 25-cm of moderately and severely eroded soils was between 19 and 51% for Mollisols and 15 to 65% for Alfisols. Restoration of eroded soils has a potential to re-sequester C and reduce risks of the potential greenhouse effect.

### INTRODUCTION

Accelerated erosion adversely affects the quality of soil on site (Norton et al., 1998; Lowery et al., 1998; Lal, et al., 1998) and its agronomic productivity (Olson et al., 1998; Lal, 1998). Several erosion-induced processes adversely affect soil quality. However, the cause-effect relationship has not been adequately established. Soil organic matter (SOM) content is an important determinant of soil quality (Doran et al., 1998). Being concentrated in the soil surface horizon and having low bulk density, the SOM is preferentially removed by flowing runoff water and blowing wind. Consequently, the enrichment ratio of eroded sediments for SOM is  $>1$  and often as high as 3 to 5 (Lal, 1976; Zobeck and Fryrear, 1986).

Frye et al. (1982) observed less organic matter content in Ap horizon of two moderately eroded Kentucky soils, relative to uneroded phases. In Alabama, McDaniel and Hajek (1985) reported that SOM content declined with degree of erosion for all but Vertisols. Similar results of decline in SOM content with increasing severity of erosion have been reported for highly weathered Piedmont soils in Georgia (Langdale et al., 1979), loess soils in Illinois

(Nizeyimana and Olson, 1988) and Alfisols in central Ohio (Fahnestock et al., 1995).

For a Fragipan soil in Tennessee, Rhoton and Tyler (1990) observed drastic reductions in SOM as measured by soil organic carbon (SOC) content of a severely eroded Fragipan, relative to uneroded phases under cropland and forested land use. Gilley et al. (1997) observed that conversion of land under Conservation Reserve Program (CRP) to cropland resulted in drastic reductions in SOC pool by 20-Mg ha<sup>-1</sup> in the top 30-cm layer primarily due to on-set of severe soil erosion. Lowery et al. (1998) reported severe decline in SOC content of the Ap horizon of Marletta, Sharpsberg and Ves soil series due to increasing severity of erosion. The SOC pool in 1-m depth for the Ves soil series, the SOC pool to 1-m depth was 134.3 Mg C ha<sup>-1</sup> for slightly eroded phases. Therefore, relative to the slightly eroded phase, erosion-caused reduction in SOC pool was 17.7 Mg C ha<sup>-1</sup> for moderately eroded and 57.5 Mg C ha<sup>-1</sup> for severely eroded phase. Similar calculations for Dubuque soil series showed that SOC pool to 1-m depth was 108.4 Mg C ha<sup>-1</sup> for slightly eroded, 87.9 Mg C ha<sup>-1</sup> for moderately eroded and 118.3 Mg C ha<sup>-1</sup> for severely eroded phases. High SOC pool of the severely eroded phase may be due to methodological errors in estimating SOC content and soil bulk density, and in differences due to the landscape position. Conway-Nelson (1991) reported the impact of landscape position in SOC pool. Calculations based on the data show that SOC pool was 111.3 Mg C ha<sup>-1</sup> for the summit position, 178.4 Mg C ha<sup>-1</sup> for the backslope position and 170.6 Mg C ha<sup>-1</sup> for the bottom position.

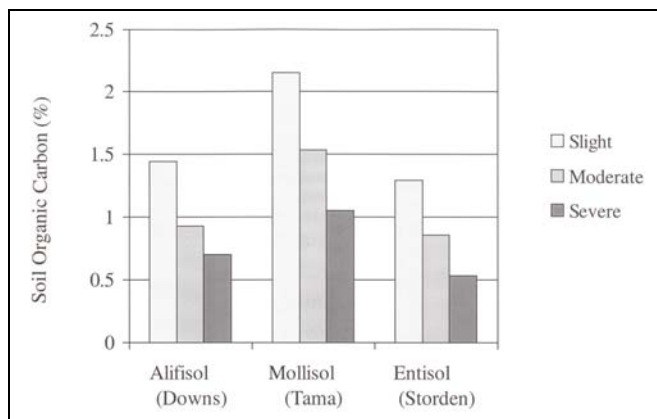
There is a lack of data based on systematic assessment of erosional impact on SOC pool of principal soils of the U.S. Thus, the objective of this study was to quantify SOC pool in relation to erosional phases. Precautions were taken to select sites and soils located on identical landscape position, and analyses of SOC done with standard methods and total SOC values were corrected for the presence of carbonates.

### MATERIAL AND METHODS

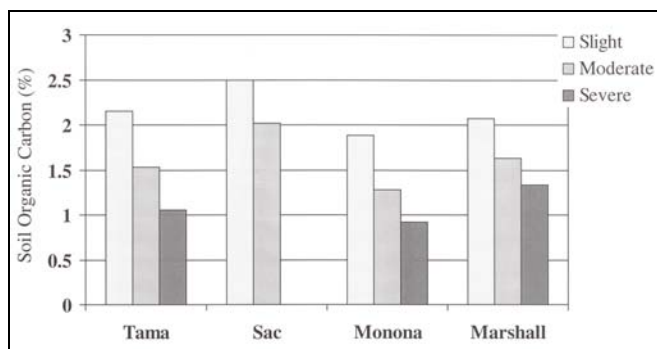
During the period 1984 to 1986 many soils were sampled in Iowa, using the procedures outline in Soil Survey Laboratory Methods Manual (1996), to look at the percent carbon based on the degree of erosion to help in classification of the soils. A total of 250 soil profiles were selected randomly from the sites sampled these sites representing 208 Mollisols, 27 Alfisols, and 15 Entisols. The samples represented varying numbers from different soil series and for a given series, the values were averaged. Where the data is presented in figures

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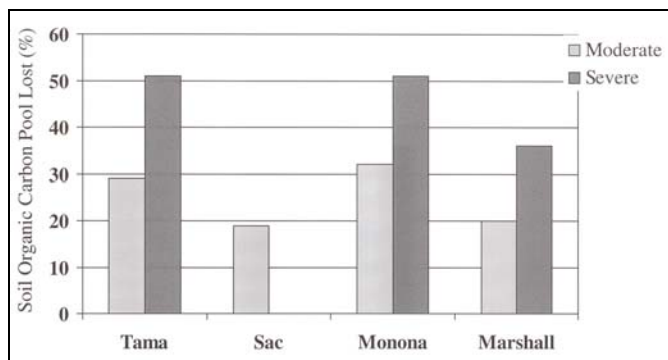
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**Figure 1. Average carbon content in the top 25 cm as function of the degree of erosion by soil order for three selected series.**



**Figure 2. Comparison of four Mollisols for SOC content in the top 25 cm of the profile by degree of erosion.**



**Figure 3. Comparison of four Mollisols for the SOC pool lost in the top 25 cm of the profile with moderate and severe erosion.**

by soil order for other comparisons within orders single representative profiles for each series were used. The soil profiles were stratified for this paper by degree of soil erosion, into 3 epipedon for Mollisols and the judgment of the field soil scientists based on observations of many soils within the area. For the Alfisols and Entisols the assignment was also based on the thickness of the epipedon but it was more subjective than in the Mollisols making the distinction into erosional phases more difficult. Out of 208 profiles of Mollisols, 141 were slightly eroded, 37 moderately eroded and 30 severely eroded. There was a change in the soil order of the 67 profiles representing moderate and severe erosion

classes. There was also order change in severely eroded Alfisols. However, none of the 15 Entisols sampled had an order classification change due to soil erosion.

Soil samples for measurement of SOC content were air dried, ground, and passed through 2 mm-mm sieves. The SOC content was measured by the wet combustion method (Soil Survey Laboratory Methods Manual, 1996). The data were expressed as SOC content (% by weight) for different erosional phases.

## RESULTS

### Relative SOC Content In Three Soil Orders

The average SOC content of three orders differed among erosional phases (Fig. 1) as show by representative profiles for each of the orders. The mean SOC content in the top 25-cm of slightly eroded phase was 2.1% for Mollisols, 1.4% for Alfisols, and 1.25% for Entisols. The SOC content decreased with increasing severity of erosion. The mean SOC content for the moderately eroded phase was 1.5% for Mollisols, 0.9% for Alfisols, and 0.85% for Entisols. Similarly, the mean SOC content for the severely eroded phase was 1.0% for Mollisols, 0.7% for Alfisols and 0.5% for Entisols. The loss in SOC was proportional to the antecedent level. The higher the antecedent SOC content the higher the loss due to erosion.

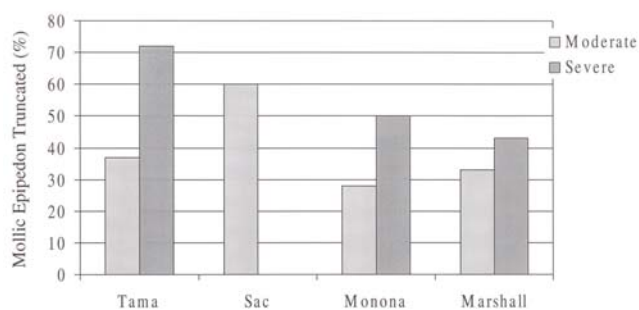
### Soil Erosion and SOC Content of Mollisols

The SOC content of the slightly eroded phase was in the order Sac > Tama > Marshall > Monona (Fig. 2). SOC content ranged from 1.8 to 2.5% for the slightly eroded phase, 1.2 to 1.6% for the moderately eroded phase, and 0.9 to 1.3% for severely eroded phase. Similar trends with regard to erosional phases occurred in most profiles of Mollisols analyzed.

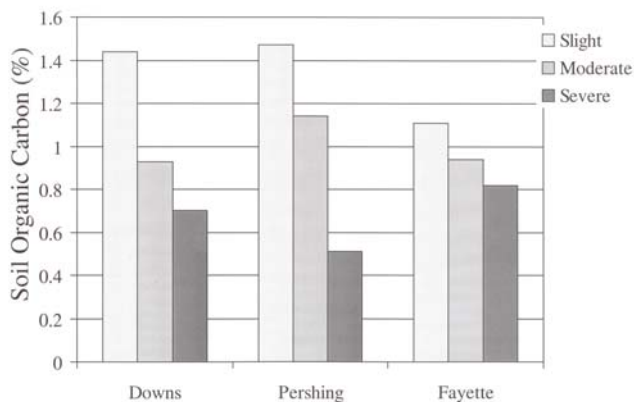
Relative to slightly eroded phase, the magnitude of SOC lost differed among soils (Fig. 3). The data for the four Mollisols showed the magnitude of SOC lost was 18 to 31% for moderately eroded phase and 34 to 50% for the severely eroded phase. The relative loss of SOC in the moderately eroded phase was in the order Monona > Tama > Marshall > Sac. Because of the loss of Mollic epipedon and reduction in SOC content, several severely eroded Mollisols were reclassified into other orders. Reduction in the thickness of Mollic epipedon ranged from 27 to 60% for moderately eroded soils, and from 41 to 71% for severely eroded phases (Fig. 4). The loss of Mollic epipedon in severely eroded phase was in the order Tama > Monona > Marshall. There was a drastic adverse effect on quality of severely eroded Mollisols, as was also reported for other soils by Doran et al. (1998). The loss of the Mollic epipedon resulted in a change in the soil structure, a lost of fertility and a reduction in the over all water holding capacity of the soil.

### Soil Erosion and SOC Content of Alfisols

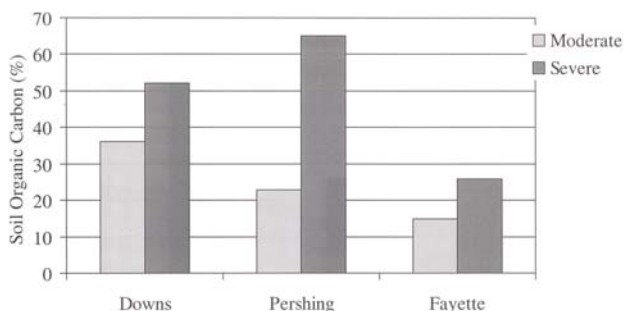
Similar to the effects on Mollisols, accelerated soil erosion also reduced the SOC content of Alfisols. The SOC content in slightly eroded phases was in the order Pershing > Downs > Fayette. Erosional impacts on SOC content of top 25-cm layer of three Alfisols are shown in Fig. 5. The mean SOC content range from 1.1 to 1.45% for



**Figure 4. Comparison of four Mollisols and the percent of the mollic epipedon lost by moderate and severe erosion.**



**Figure 5. Comparison of three Alfisols and the percentage of soil organic carbon in the top 25 cm of the profile.**



**Figure 6. Comparison of three Alfisols for the % SOC content lost in the top 25 cm of the profile by moderate and severe erosion.**

slightly eroded phases, 0.9 to 1.15% for moderately eroded phases, and 0.45 to 0.8% for severely eroded phases. The relative magnitude of SOC loss due to erosion also differed among soils and erosional phases. Relative to the slightly eroded phase, the magnitude of SOC loss ranged from 14 to 34% for moderately eroded phase, and 24 to 63% for severely eroded phase. The SOC loss was the least in Fayette soil series and the maximum in the Pershing soil series (Fig. 6). The estimation of the degree of erosion in the Alfisols is much more difficult because of the lack of a define surface epipedon yet trained field soil scientists were still able to determine which soils had eroded the most.

## DISCUSSION

Erosion-induced depletion in SOC content results in decline in soil quality due to a reduction in available water capacity, decreased nutrient holding capacity, reduction in water infiltration capacity, loss of soil structure and aggregation, and further increase in runoff and erosion. In addition to the adverse impacts on water quality, a reduction in soil quality leads to decline in agronomic productivity (Doran et al., 1998; Lal, 1998).

Erosion-caused displacement and redistribution of SOC may accentuate mineralization and release of C to the atmosphere (Lal, 1995). Erosion breaks down aggregates, exposes SOC locked in them, and increases mineralization through increased microbial decomposition. Some of the SOC transported by erosion may be buried in depositional sites and aquatic ecosystems.

Field observations showed that erosion caused visible changes in soil structure. The soil structure of Ap horizon was granular in most soils with slight erosion, sub-angular blocky with moderate erosion, and cloddy with severe erosion this was a result of the physical changes to the soil as SOC was lose as a binding agent. This decline in soil structure was related to the reduction in SOC content in severely eroded phases.

The magnitude of reduction in SOC content due to soil erosion differed among soils. The mean loss was 19 to 51 percent of the SOC in the top 25-cm of Mollisols due to moderate and severe erosion. The magnitude of SOC loss in Alfisols in the top 25-cm ranged from 15 to 65%. It is because of these historic losses in SOC due to the past erosion that restoring eroded soils have a high potential for sequestering C. Restoration of eroded soils has a potential to sequester 9-20 Tg (terra gram =  $10^{12}$  g = 1 MMTc) C yr<sup>-1</sup>, and erosion control on cropland can reduce emission by 15 Tg C yr<sup>-1</sup> (Lal et al., 1998). Therefore, erosion control and restoration of eroded soils is an important strategy to enhance soil quality and reduce the dangers of greenhouse effect.

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