

Soil Carbon Management Publications

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Owens, L.B., Shipitalo, M.J. 2011. Sediment-bound and dissolved carbon concentration and transport from a small pastured watershed. Agriculture, Ecosystems and Environment. 141(1-2):162-166. **(NAEW #473)**

Abstract:

With the current emphasis on the role of carbon in the environment, agricultural systems and their impacts on the carbon cycle are important parts of the overall issue. Pasture systems and organic carbon that is transported attached to sediment has been addressed at the North Appalachian Experimental Watershed near Coshocton, Ohio. In a pasture system where a beef cow-calf herd was rotated weekly among 4 paddocks during the grazing season, one paddock was used for winter feeding. Surface runoff was measured and sampled throughout the year from 4 watersheds, one watershed per paddock. The watershed in the winter paddock was the only watershed to yield measureable levels of sediment loss, and those samples were collected during the dormant season (November – April). With continuous winter occupancy, the percent vegetative cover was often < 50% in the late winter/early spring, which increased the potential for soil loss. During the 10-year period of sample collection, there were 376 runoff events and 115 events with sediment loss >10 kg ha⁻¹ from the watershed in the winter feeding area. The largest 6 events carried nearly 50% of the total sediment and sediment-attached organic C lost during this period. Annual losses of sediment and sediment-OC varied considerably but averaged 2,642 and 140 kg ha⁻¹, respectively. There was no significant correlation between the amount of sediment transported during individual events and the C concentration on the associated sediment. The pasture sediments have a OC enrichment ratio of 1.2-1.5 compared with the 0-2.5 cm soil layer. Pasture sediment-OC concentrations were > 2x the OC concentrations on sediments from nearby row crop watersheds. Pasture sediment OC losses can be reduced by using management practices that reduce sediment losses.

Lorenz, K., Lal, R., Shipitalo, M.J. 2011. Stabilized soil organic carbon pools in subsoils under forest are potential sinks for atmospheric CO₂. *Forest Science*. 57(1):19-25. **(NAEW #471)**

Abstract:

The soil organic carbon (SOC) pool stored in sub-soil horizons in forests plays an important role in the global C cycle. Strategies are needed to increase the sub-soil SOC pool in forests because the turnover time of SOC increases with increase in soil depth as sub-soil SOC is chemically and physically stabilized. We compared the total SOC and total nitrogen (TN) pools, chemically and physically separated SOC fractions, and C and N pools in fine roots in a soil pedon in an oak-hickory forest type consisting of white oak (*Quercus alba* L.) and red oak (*Quercus rubra* L.), with yellow-poplar (*Liriodendron tulipifera* L.) at the North Appalachian Experimental Watershed near Coshocton, Ohio, USA. The SOC pool (Mg/ha) was the highest in the A horizon (47.4), and smaller in the Bt1 (6.9) and Bt2 (6.7) horizons. The SOC and TN concentrations sharply decreased with depth. Fine root C and N pools (Mg/ha) were much larger in the A horizon (0.71 and 0.025) than in underlying horizons. Although only 22% of the SOC pool was stored below the A horizon, 58% of the chemically stabilized and 31% of the physically stabilized SOC fractions pool occurred in the sub-soil horizons. Thus, studies are needed to test if forest management can strengthen the stabilized SOC pool in sub-soil horizons to mitigate the human-induced climate change.

Lopez-Bellido, J., Lal, R., Owens, L.B., Lopez-Bellido, L. 2010. Does North Appalachian Agriculture Contribute to Soil Carbon Sequestration. *Agriculture, Ecosystems and Environment*. 137(3-4):373-376. **(NAEW #464)**

Abstract:

Agricultural systems are important for world ecosystems. They can be managed to moderate CO₂ emissions. World soils can be both a sink and source of atmospheric CO₂, but it is a slow process. Data from long-term soil management experiments are needed to assess soil carbon (C) sink capacity through a complete life cycle analysis of direct and hidden C changes. Eight commonly used agricultural systems in northern Appalachia (Ohio, USA) were tested after 38 yr to assess the magnitude of the soil C pool. Only a forest ecosystem and a no-tillage corn (*Zea mays* L.) crop plus manure increased soil organic carbon (SOC) by 37.3 and 33.3 Mg C ha⁻¹, respectively; meanwhile monoculture corn and/or no-tillage practices maintained the SOC level over the period. Thus, most of North Appalachian agriculture, with current practices, does not contribute to C sequestration. Improved agricultural practices for no-tillage continuous corn should include cultivars with higher residue production (above- and belowground) and slower decomposition rates in order to increase SOC sequestration.

Jacinthe, P.A., Lal, R., Owens, L.B. 2008. Application of stable isotope analysis to quantify the retention of eroded carbon in grass filters at the North Appalachian experimental watersheds. *Geoderma*. 148(3-4):405-412. **(NAEW #460)**

Abstract:

The entrapment of eroded soil organic carbon (SOC) in grass filters could affect watershed C export, but the magnitude of the process is poorly quantified. In order to assess the retention of eroded C in these settings, SOC stock was measured in grass buffers receiving runoff from cropped watersheds under long-term (>20 y): chisel-till (CT) corn (*Zea mays*, L.)-soybean (*Glycine max*, L.) rotation, moldboard plowing (MP) continuous corn (CC), and no-till (NT) CC. Adjacent reference grasslands not affected by erosion were also sampled. In the CC watersheds, the $\delta^{13}\text{C}$ of bulk soil and soil separates was determined to gain insight into the source of SOC in the grass filters. When compared to NT, SOC stock in the MP watershed showed a corn-C deficit of 12.1 Mg C ha⁻¹. Corn-C accounted for 2 to 16 % (mean: 4.8 Mg C ha⁻¹) of the total SOC pool in the grass filter, and assuming water erosion as the main driver of C distribution, this corn-C gain translates into the retention of 40% of eroded C in the grass strip. Relative to the reference grassland, SOC stock in the grass filter was up to 30 Mg C ha⁻¹ higher, an amount deemed too large to be attributed solely to retention of eroded C (export rate: 0.05-0.08 Mg C ha⁻¹ y⁻¹). Periodic delivery of nutrients may have enhanced biomass production and indirectly contributed to the observed SOC accrual in grass filters. Higher extractable P and higher C/N ratios at these locations support that interpretation. These results demonstrate the applicability of ¹³C isotope to trace SOC sources in buffers receiving runoff from areas supporting C₄ vegetation. They also underscore the need to incorporate in-situ biomass production and burial processes in assessing the temporal evolution of SOC stocks in terrestrial deposits and the contribution of these landscape segments to watershed C budget.

Lorenz, K., Lal, R., Shipitalo, M.J. 2008. Chemical stabilization of organic carbon pools in particle size fractions in no-till and meadow soils. *Biology and Fertility of Soils*. 44:1043-1051. **(NAEW #453)**

Abstract:

Land use and soil management affects soil organic carbon (SOC) pools associated with particle size fractions and their chemical stabilization. No-till (NT) production of corn (*Zea mays* L.) is a recommended management practice that reduces erosion and increases SOC concentration, but the knowledge about the relevance of physical and chemical fractionation methods to SOC stabilization mechanisms is fragmentary. Therefore, our objective was to compare the stabilization of the SOC pool in coarse (0.25-2.00 mm dia.) and fine (0.05-0.25 mm dia.) sand, silt (0.002-0.050 mm dia.) and clay (<0.002 mm dia.) particle size fractions by oxidative degradation with disodium peroxodisulfate and destruction of the mineral phase by hydrofluoric acid (HF). The uppermost two horizons of three pedons from the same soil series under three different long-term management practices were studied: (i) meadow converted from NT corn in 1988 (Meadow), (ii) continuous NT corn since 1970 (NT); and (iii) continuous NT corn with beef cattle manure since 1964 (NTm) at the North Appalachian Experimental Watershed near Coshocton, Ohio. Land use and soil management had no significant effects on particle size distribution among horizons. Coarse sand and clay size particles, however, were quantitatively more effective in enriching SOC than the other size fractions. The SOC pool (Mg/ha) in silt size particles from 0-30 cm was greatest in NTm (27.1) and progressively smaller in NT (15.5), and Meadow (14.9), representing

44, 39, and 39% of the total SOC pool, respectively. The pools of oxidizable C in 0-30 cm depth were comparable among particle size fractions and pedons, as indicated by treatment with disodium peroxodisulfate. The amounts of C preferentially associated with soil minerals were also comparable among pedons, as indicated by treatment with HF to release mineral-bound SOC. However, the NTm pedon stored the largest pool (12.6 Mg/ha) of mineral associated C in 0-30 cm depth. The silt associated and mineral-bound SOC pool in NT with manure was greater compared to NT corn without manure due to increased organic matter (OM) input and most likely by promoting earthworm activity. Thus, the silt particle size fraction at NAEW has the potential for SOC sequestration by increasing OM inputs. Mineralogical and molecular level analyses on a larger set of fractions obtained from entire rooted soil profiles are required, however, to compare the SOC sequestration capacity of the land uses.

Starr, G.C., Lal, R., Owens, L., and Kimble, J. 2008. Empirical relationships for soil organic carbon transport from agricultural watersheds in Ohio. *Land Degradation and Development* 19:57-64. **(NAEW #448)**

Abstract:

Improved quantification is needed for long-term soil organic carbon (SOC) transport in runoff at watershed scales. Coshocton wheel samplers were used to collect runoff samples from no-till and chisel-till watersheds in corn (*Zea mays*) and soybean (*Glycine max*) rotations over 13 years. Samples were analyzed for SOC, N, P, K, and soil losses. The SOC losses, ranging from 0 to 357 kg ha⁻¹ event⁻¹, were correlated ($r^2=0.80-0.94$) in power law relationships with N, P, K, soil loss, and runoff. Two events occurring in corn when soybean and cover crop residue were present in no-till had combined SOC transport of 460 kg ha⁻¹, nearly double the no-till losses of a previous 11-year period and 20 times higher than chisel-till in the same events. Infrequent, extreme transport events that are not well characterized empirically, particularly in no-till, can strongly influence hydrologic C transport from agriculture watershed.

Izaurrealde, R.C., J.R. Williams, W.M. Post, A.M. Thomson, W.B. McGill, L.B. Owens, and R. Lal. 2007. Long-term modeling of soil C erosion and sequestration at the small watershed scale. *Climatic Change* 80:73-90. **(NAEW #442)**

Abstract:

The soil C balance is determined by the difference between inputs (e.g. litter, crop residues, decaying roots, organic amendments, depositional C) and outputs (e.g. soil respiration, dissolved organic C leaching and eroded C). Two competing hypotheses suggest erosion may either increase or decrease output. One hypothesis states that C from eroded fields becomes "sequestered" in depressional areas and thus is rendered unavailable for decomposition. An alternative hypothesis argues that due to aggregate breakdown during erosion events, physically-protected C becomes accessible, thereby increasing oxidation of C and emission of CO₂. This study applied the EPIC (Erosion Productivity Impact Calculator) model to evaluate the role of erosion-deposition processes on the C balance at the small watershed scale. The experimental records of three small watersheds (~1 ha) from the USDA North Appalachian Experimental

Watershed facility north of Coshocton, OH, were used in the study. Predominant silt loam soils in the area have developed from loess-like deposits over residual bedrock. Soil and crop management in the three watersheds has changed over time. Currently, watershed 118 (W118) is under a corn (*Zea mays* L.) - soybean (*Glycine max* (L.) Merr.) no till rotation, W128 is under conventional till continuous corn, and W188 is under no till continuous corn. Predictions of sediment C yields were made through simulation of an entire range of ecosystem processes including plant growth, runoff, and water erosion. A simulated sediment C yield of 39 kg C ha⁻¹ y⁻¹ compared well against an observed value of 31 kg C ha⁻¹ y⁻¹ in W118. EPIC overpredicted the soil C stock in the top 30-cm soil depth in W188 by 21% of the measured value (36.8 Mg C ha⁻¹). Predictions of soil C stocks in the other two watersheds (42.3 Mg C ha⁻¹ in W128 and 50.4 Mg C ha⁻¹ in W188) were off by <1 Mg C ha⁻¹. Although these results do not directly answer any of the two prevailing hypotheses, they do provide insight as to the importance of erosion-deposition processes in the C cycle at the small watershed scale. In future work, the APEX model, the landscape version of EPIC, will be used to study the role of erosion and deposition as sources or sinks of atmospheric C.

Tan, Z., R. Lal, L. Owens, and R.C. Izaurralde. 2006. Distribution of light and heavy fractions of soil organic carbon as related to land use and tillage practice. *Soil & Tillage Research* 88(1): **(NAEW #437)**

Abstract:

Mass distributions of different soil organic carbon (SOC) fractions are influenced by land use and management. Concentrations of C and N in light- and heavy fractions of bulk soils and aggregates in 0 – 20 cm were determined to evaluate the role of aggregation in SOC sequestration under conventional tillage (CT), no-till (NT), and forest treatments. Light- and heavy fractions of SOC were separated using 1.85 g mL⁻¹ sodium polytungstate solution. Results showed that soils under forest and NT preserved, respectively, 167% and 94% more light fraction than those under CT. The mass of light fraction decreased with increase in soil depth, but significantly increased with increase in aggregate size. C concentrations in light fraction in all aggregate classes were significantly higher under NT and forest than under CT. C concentrations in heavy fraction averaged 20, 10, and 8 g kg⁻¹ under forest, NT, and CT, respectively. Of the total SOC pool, heavy fraction C accounted for 76% in CT soils and 63% in forest and NT soils. These data suggest that there is a greater protection of SOC by aggregates in the light fraction of minimally-disturbed soils than that of disturbed soil, and the SOC loss following conversion from forest to agriculture is attributed to reduction in C concentrations in both heavy and light fractions. In contrast, the SOC gain upon conversion from CT to NT is primarily contributed by increase in C concentration in the light fraction.

Blanco-Canqui, Humberto, R. Lal, W.M. Post, R.C. Izaurralde, and L.B. Owens. 2006. Corn stover impacts on near-surface soil properties of no-till corn in Ohio. *Soil Science Society America Journal* 70:266-278. **(NAEW #425)**

Abstract:

Corn (*Zea mays* L.) stover is a primary biofuel feedstock and its expanded use could help reduce reliance on fossil fuels and net CO₂ emissions. Excessive stover removal may, however, negatively impact near-surface soil properties within a short period after removal. We assessed changes in soil crust strength, bulk density (p_b), and water content over a 1-yr period following a systematic removal or addition of stover from three no-till soils under corn in Ohio. Soils from ongoing experiments at the North Appalachian Experimental Watershed (NAEW), Western Agricultural Experiment Station (WAES), and Northwestern Agricultural Experiment Station (NWAES) of Ohio Agricultural Research and Development Center (OARDC) were studied. Six stover treatments of 0 (T0), 25 (T25), 50 (T50), 75 (T75), 100 (T100), and 200 (T200) % were imposed on 3 by 3 m plots corresponding to 0, 1.25, 2.50, 3.75, 5.00, and 10.00 Mg ha¹ of stover, respectively. Cone index (CI), shear strength (SHEAR), p_b , and volumetric water content (Θ), were measured monthly from June through December 2004 and in May 2005. Effects of stover removal on increasing CI and SHEAR were soil-specific. Stover removal consistently increased p_b and decreased Θ , across soils ($P < 0.01$). Compared with the normal stover treatment (T100), doubling the amount of stover (T200) did not significantly affect soil properties except Θ , where, after 1 yr. T200 increased Θ , by 1.3 to 1.6 times compared with T100 across all sites ($P < 0.05$). After 1 yr, complete stover removal (T0) increased CI by 1.4 times and SHEAR by 1.3 times at NAEW compared with T100 and T75, but CI increases at other sites were nonsignificant. At NWAES, T0 increased SHEAR by 26% compared with T100 ($P < 0.05$). The T0 decreased Θ , by two to four times except in winter months and increased p_b by about 10% compared with T100 ($P < 0.05$). In a short-term test, stover removal resulted in increased soil crust strength and reduced soil water content.

Blanco-Canqui, Humberto, R. Lal, L.B. Owens, W.M. Post, and R.C. Izaurralde. 2005. Mechanical properties and organic carbon of soil aggregates in the Northern Appalachians. *Soil Science Society of America Journal* 69:1472-1481. **(NAEW#420)**

Abstract:

Aggregate properties determine the macro-scale structural condition of the soil. However, soil properties are ordinarily measured on bulk soil rather than on discrete aggregates, and thus data on aggregate properties are limited. This study assessed the mechanical properties of soil aggregates and their relationships with soil organic carbon (SOC) content for long-term (>15 yr) conventional tillage (CT), chisel plow (CP), disk with manure (DM), no-till with manure (NTM), no-till without manure (NT), pasture, and forest management practices in the North Appalachian region. Tensile strength (TS), aggregate bulk density, soil moisture retention (SMR), and SOC content were determined on soil aggregates (1-8 mm) for 0-10, 10-20, and 20-30 cm depths. Aggregates from forest had the lowest TS (63 kPa) and aggregate bulk density (0.99 Mg m⁻³) and the highest SOC content (70 g kg⁻¹), whereas the CT and CP treatments had the highest TS (~358 kPa) and the lowest SOC content (14 g kg⁻¹) for 0-10 cm ($P < 0.01$). The TS and SMR (0 to -333 kPa) in NTM were about 1.8 times higher than the average of CT and CP. The SOC content for NTM was 3.4 times higher than the average of CT and CP and 2.2 times higher than that for NT. The aggregate bulk

density was 1.35 Mg m⁻³ in NTM and ~1.61 Mg m⁻³ in CT and CP. Manuring had a positive and excessive tillage negative impact on properties of soil aggregates. Mean aggregate bulk density was significantly higher than the density of bulk soil. Increase in SOC content reduced aggregate bulk density and TS and increased SMR (0 to -10 kPa). The log-transformed TS (LogTS) increased with increasing aggregate bulk density and decreased with increasing aggregate size. Size, SOC content, and aggregate bulk density explained about 84% of the variability of LogTS of aggregates using pedotransfer functions (PTFs). Long-term land use and management practices caused significant changes in the properties of soil properties.

Puget, P., R. Lal, C. Izaurrealde, M. Post, and L. Owens. 2005. Stock and distribution of total and corn-derived soil organic carbon in aggregate and primary particle fractions for different land use and soil management practices. *Soil Science* 170(4):256-279. **(NAEW #419)**

Abstract:

Land use, soil management, and cropping systems affect stock, distribution, and residence time of soil organic carbon (SOC). Therefore, SOC stock and its depth distribution and association with primary and secondary particles were assessed in long-term experiments at the North Appalachian Experimental Watersheds near Coshocton, Ohio, through $\delta^{13}C$ techniques. These measurements were made for five land use and soil management treatments: (1) secondary forest, (2) meadow converted from no-till (NT) corn since 1988, (3) continuous NT corn since 1970, (4) continuous NT corn-soybean in rotation with rye grass since 1984, and (5) conventional plow till (PT) corn since 1984. Soil samples to 70-cm depth were obtained in 2002 in all treatments. Significant differences in soil properties were observed among land use treatments for 0 to 5-cm depth. The SOC concentration (g C kg⁻¹ of soil) in the 0 to 5-cm layer was 44.0 in forest, 24.0 in meadow, 26.1 in NT corn, 19.5 in NT corn-soybean, and 11.1 in PT corn. The fraction of total C in corn residue converted to SOC was 11.9% for NT corn, 10.6% for NT corn-soybean, and 8.3% for PT corn. The proportion of SOC derived from corn residue was 96% for NT corn in the 0 to 5-cm layer, and it decreased gradually with depth and was 50% in PT corn. The mean SOC sequestration rate on conversion from PT to NT was 280 kg C ha⁻¹ y⁻¹. The SOC concentration decreased with reduction in aggregate size, and macro-aggregates contained 15 to 35% more SOC concentration than microaggregates. In comparison with forest, the magnitude of SOC depletion in the 0 to 30-cm layer was 15.5 Mg C/ha (24.0%) in meadow, 12.7 Mg C/ha (19.8%) in NT corn, 17.3 Mg C/ha (26.8%) in NT corn-soybean, and 23.3 Mg C/ha (35.1%) in PT corn. The SOC had a long turnover time when located deeper in the subsoil. Additional research is needed to understand association of SOC with particle and aggregate size fractions and temporal changes and depth-distribution with regard to land use and soil management.

Blanco-Canqui, H.R., R. Lal, L.B. Owens, W.M. Post, and R.C. Izaurrealde. 2005. Strength properties and organic carbon of soils in the North Appalachian region. *Soil Science Society of America Journal* 69:663-673. **(NAEW #417)**

Abstract:

Soil strength, influenced by management and soil properties, controls plant growth, root development, and soil-moisture relations. The impact of textural and structural parameters on soil strength is moderated by soil organic carbon (SOC) content. Therefore, the objectives of this study were to assess changes in soil strength and SOC content in watersheds under long-term (>10 yr) management practices in the north Appalachian region on a predominantly Typic Hapludults on undulating slopes (>6% slope). Seven watersheds under conventional tillage (CT), no-till with manure (NTm), no-till with no manure (NTnm), chisel plow, disk with manure (DiskM), forest, and pasture were studied. Cone index (CI), shear strength, bulk density, volumetric water content, and SOC content were determined at the summit, backslope, and footslope landscape positions at 0-100, 100-200, and 200-300 mm depths. The SOC content was slightly higher at footslope than at summit position in the cultivated watersheds. The bulk density was lower at footslope than at summit in NTm (1.22 vs. 1.42 Mg/m³) and chisel (1.34 vs. 1.47 Mg/m³) treatments. Forest had the lowest CI (0.19 MPa), shear strength (6.11 kPa), and bulk density (0.93 Mg/m³) and the highest SOC content (62.7 g/kg), whereas CT had the highest CI (0.67 MPa), shear strength (25.5 kPa), bulk density (1.44 Mg/m³), and the lowest SOC content (13.6 g/kg) in the 0-100 mm depth ($P < 0.01$). The Ntm had higher SOC content (49.9 g/kg) than NTnm (30.0 g/kg), and both no-till treatments had lower bulk density (<1.21 Mg/m³) than CT (1.44 Mg/m³) at 0-100 mm depth ($P < 0.01$). Manuring decreased both CI and shear strength, but increased SOC content. Shear strength and volumetric water content were the best predictors of CI; whereas SOC content, CI, volumetric water content were shear strength ($r^2 > 0.76$; $P < 0.01$). Results show that landscape positions had small effect, but management, particularly manuring, had large and significant effects on soil strength and SOC content.

Owens, L.B. and M.J. Shipitalo, 2005. Management practices and carbon losses via sediment and subsurface flow. *In*: Climate Change and Global Food Security. Lal, R., N. Uphoff, B.A. Stewart, D.O. Hansen, editors. CRC Press, Boca Raton, FL. pp. 451-465. **(NAEW #416)**

Abstract:

Annual concentrations of TOC in lysimeter percolate from a corn/soybean-rye rotation and in springflow from pastured watersheds ranged between 0.5 and 3.2 mg/L. These concentrations are low in the range of published TOC concentrations in stream flow. No major trends in TOC concentrations were observed during the 10-yr for either management treatment. Annual average losses of TOC were similar for both management practices, ranging from 1.2 to 14.9 kg/ha. TOC leaching losses are small compared with other pathways. Carbon concentrations on sediment lost from watersheds with different tillage practices (e.g. no-till, chisel-plow, paraplow, and disk) varied little with time. Tillage practices and weather had major impacts on soil loss from field scale watersheds; however, they had much less impact on sediment C concentration. Management systems that control sediment loss have greater impact on reducing C loss via erosion than those that might change sediment C concentration.

Owens, L.B. and M.J. Shipitalo. 2004. Rate of soil carbon loss resulting from tillage. Proceedings of ISCO 2004, 13th International Soil Conservation Organization Conference, Brisbane, Australia. July 2004. Paper 772. CDROM. **(NAEW #403)**

Abstract:

Land management practices can have major impacts on soil carbon levels. Tillage practices cause reductions in soil carbon levels. How rapidly these reductions occur is a topic of major concern. The purpose of this study was to ascertain the rate of reduction of soil carbon with tillage over time. At the North Appalachian Experimental Watershed near Coshocton, Ohio (USA), portions of fields under multi-year no-tillage with corn (*zea mays* L.) or corn-soybean (*zea mays* L./*glycine max* L.) rotations have received conventional tillage. Conventional tillage includes moldboard plowing followed by disking. After the first year of conventional tillage, total carbon in the top 2.5 cm of the soil profile (3.5 Mg C/ha) was only 41 and 46% of the carbon in the top 2.5 cm of the soil profile of multi-year no-till corn (8.6 Mg C/ha) and meadow (7.7 Mg C/ha) areas, respectively. However, in the top 22.5 cm, there was no significant difference in the carbon among the three practices (35.9, 35.4, and 34.7 Mg C/ha for first year tillage, no-till, and meadow, respectively). After 13 years of consecutive conventional tillage, total carbon in the top 22.5 cm of the soil profile (30.2 Mg C/ha) was 15 and 13% less carbon than the corresponding soil depth for the no-till (35.4 Mg C/ha) and meadow (34.7 Mg C/ha), respectively. Although tillage can cause significant carbon losses over several years, the first year of tillage may not result in significant carbon loss. Other time periods of consecutive tillage are being evaluated for carbon loss with soil depth on silt loam soils to see if there is a relatively linear relationship for carbon loss with tillage over time. These additional results will be presented.

Ritchie, J.C., G.W. McCarty, E.R. Venteris, T.C. Kaspar, L.B. Owens, B.K. Slater, M. Nearing, and M.H. Nichols. 2004. Assessing soil organic carbon redistribution with fallout ¹³⁷Cesium. Proceedings of ISCO 2004, 13th International Soil Conservation Organization Conference, Brisbane, Australia. July 2004. Paper 613, CDROM. **(NAEW 402)**

Abstract:

Patterns of soil organic carbon (SOC), the largest component of the terrestrial carbon cycle, vary with climate, topography, biological activity, soil movement, and land management leading to large uncertainties/changes in the SOC budget especially in agricultural areas. This study was designed to determine SOC distribution related to soil movement. Soil redistribution (erosion/deposition) patterns were estimated using radioactive fallout cesium-137. Agricultural landscapes were sampled in Maryland, Ohio, and Iowa. A semiarid rangeland area was sampled in Arizona. In the Iowa field, SOC had an order of magnitude difference in concentration (0.5 to 5%) and was significantly correlated to soil cesium-137 concentration and soil erosion/deposition rates. Sites of soil erosion have lower concentrations of SOC (2.4 %) than sites of soil deposition (3.4 %). SOC was highly correlated with cesium-137 concentration in the soil. Similar patterns were noted for the Ohio and Maryland fields. These studies show the importance of being able to measure soil redistribution patterns within a field to

understand SOC patterns and the potential of developing or implementing better management systems to increase SOC in agricultural areas based patterns of soil movement. With climate, soil movement, and SOC being interdependent components of the earth's hydrologic and carbon budgets, combining information on soil movement and SOC from different locations will allow a better understanding of SOC budgets.

Jacinthe, P.A., R. Lal, L.B. Owens, and D.L. Hothem. 2004. Transport of labile carbon in runoff as affected by land use and rainfall characteristics. *Soil & Tillage Research* 77:111-123. (Available online at www.sciencedirect.com) (NAEW #400)

Abstract:

The immobilization of organic carbon (C) by water erosion occurs over large areas of the terrestrial biosphere and thus could impact the global C cycle. The magnitude and direction of that impact remain uncertain given a lack of data regarding the fates of eroded C. A study was conducted to monitor total organic C and mineralizable C (MinC) in eroded materials from watersheds under no till (NT), chisel till (CT), disk till low input (DT-LI), pasture and forest. The DT-LI treatment relies on manure application and legume cover crops to partly supply the N needed when corn is grown, and on cultivation to reduce the use of herbicides. Each watershed was instrumented with a flume and a Coshocton wheel sampler for runoff measurement. Carbon dioxide (CO₂) evolved during incubation (115 days) of runoff samples was fitted to a first-order decomposition model to derive MinC. Annual soil (7.8 Mg/ha) and organic C (113.8 kg C/ha) losses were twice as much in the DT-LI than in the other watersheds (<3.6 Mg soil/ha, <60 kg C/ha). More than management practices, rainfall class (based on intensity and energy) was a better controller of sediment C concentration and biodegradability. Sediment collected during the low intensity (fall/winter) storms contained more organic C (37 g C/kg) and MinC (30-40% of sediment C) than materials displaced during the high intensity summer storms (22.1 g C/kg and 13%). These results suggest a more selective detachment and sorting of labile C fractions during low intensity storms. However, despite the control of low intensity storm on sediment C concentration and quality, increased soil loss with high energy rainfall suggests that a few infrequent but high energy storms could determine the overall impact of erosional events on terrestrial C cycling.

Hao, Y., R. Lal, L.B. Owens, R.C. Izaurralde, W.M. Post, and D.L. Hothem. 2002. Effect of cropland management and slope position on soil organic carbon pool at the North Appalachian Experimental Watersheds. *Soil & Tillage Research* 68:133-142. (NAEW #379a)

Abstract:

Soil organic matter is strongly related to soil type, landscape morphology, and soil and crop management practices. Therefore, long-term (15-36 years) effects of six cropland management systems on soil organic carbon (SOC) pool in 0-30 cm depth were studied for the period of 1939-1999 at the North Appalachian Experimental Watersheds (<3 ha, Dystric Cambisol, Haplic Luvisol, and Haplic Alisol) near Coshocton, OH, USA. Six management treatments were: (1) no tillage continuous corn with NPK (NC); (2) no

tillage continuous corn with NPK and manure (NTC-M); (3) no tillage corn-soybean rotation (NTR); (4) chisel tillage corn-soybean rotation (CTR); (5) moldboard tillage with cornwheat-meadow-meadow rotation with improved practices (MTR-I); (6) moldboard tillage with corn-wheat-meadow-meadow rotation with prevalent practices (MTR-P). The SOC pool ranged from 24.5 Mg ha⁻¹ in the 32-years moldboard tillage corn (*Zea mays* L.)-wheat (*Triticum aestivum* L.)-meadow-meadow rotation with straight row farming and annual application of fertilizer (N:P:K = 5:9:17) of 56-112 kg ha⁻¹ and cattle (*Bos Taurus*) manure of 9 Mg ha⁻¹ as the prevalent system (MTR-P) to 65.5 Mg ha⁻¹ in the 36-years no tillage continuous corn with contour row farming and annual application of 170-225 kg N ha⁻¹ and appropriate amounts of P and K, and 6-11 Mg ha⁻¹ of cattle manure as the improved system (NTC-M). The difference in SOC pool among management systems ranged from 2.4 to 41 Mg ha⁻¹ and was greater than 25 Mg ha⁻¹ between NTC-M and the other five management systems. The difference in the SOC pool of NTC-M and that of no tillage continuous corn (NTC) were 16-21 Mg ha⁻¹ higher at the lower slope position than at the middle and upper slope positions. The effect of slope positions on SOC pools of the other management systems was significantly less (<5 Mg ha⁻¹). The effects of manure application, tillage, crop rotation, fertilizer rate, and soil and water conservation farming on SOC pool were accumulative. The NTC-M treatment with application of NPK fertilizer, lime, and cattle manure is an effective cropland management system for SOC sequestration.

Owens, L.B., G.C. Starr, and D.L. Lightell. 2002. Total organic carbon losses in subsurface flow under two management practices. *Journal of Soil and Water Conservation* 57(2):74-81. **(NAEW #376)**

Abstract:

Greenhouse gases and global warming have become major topics. Much of the greenhouse gas discussion has dealt with carbon dioxide (CO₂) and methods to sequester or store atmospheric carbon in soils and forests. The entire carbon cycle needs to be studied to better understand the overall process. The major carbon transformations are loss of CO₂ to the atmosphere or the storage of carbon in sinks such as soil. Although it is a minor pathway, carbon leached through the soil and into groundwater needs to be quantified. Numerous carbon studies have been performed, but concentrations and losses of total organic carbon (TOC) moving through a soil profile have received little attention. Therefore, this study was to assess TOC levels in subsurface flow under two management practices. TOC was determined monthly in the percolate from large soil blocks, called lysimeters, (2.4 m [8 ft] deep) with undisturbed soils under row crops. Most of the TOC concentrations in the percolate ranged from 0.5 to 6.0 mg/L with the corn/soybean-rye rotation. Developed springs in two rotational grazing systems were sampled for 10 years. TOC concentrations in the groundwater from the springflow developments had less variability than in the lysimeter percolate. Most TOC values from these pasture systems were in a concentration range of 1 to 3 mg/L. Annual averages of TOC transport were similar for the lysimeter percolate and groundwater springs, ranging from 3.7 to 6.0 kg/ha (3.3 to 5.4 lb/ac).

Owens, L.B., R.W. Malone, D.L. Hothem, G.C. Starr, and R. Lal. 2002. Sediment

carbon concentration and transport from small watersheds under various conservation tillage practices. *Soil and Tillage Research* 67:65-73. (NAEW #374)

Abstract:

Carbon sequestration by soils is viewed as a process that can reduce CO₂ emissions and their potential impacts on global climate change. Therefore, impacts of various agricultural management practices on carbon (C) release/sequestration need to be assessed. The objectives of this study were to measure the carbon concentrations and transport in sediments lost with various tillage practices on small watersheds and to relate these losses to the management practices. Corn-soybean rotations with No-till, Chisel-plow and Paraplow were studied on small watersheds (0.55 - 0.79 ha). Disk tillage preceding the corn and soybean crops of a corn-soybean-wheat/clover rotation was also studied. A rye winter cover crop was used following soybean. Each small watershed is instrumented with a 60-cm H-flume mounted on a concrete approach and a Coshocton wheel for collecting a proportional sample of water and sediment. Samples of sediment in runoff were collected over a 15 year period and analyzed for total carbon (Tot C). Weighted averages of Tot C in the sediment that passed through the flumes during the treatment periods did not differ significantly among tillage treatments, although No-till was the highest (2.8%) and Paraplow was the lowest (2.1%). Average annual sediment loss was 532, 828 and 956 kg ha⁻¹ for No-till, Chisel-plow and Disk, respectively. Annual average transport of Tot C (the product of total sediment transported and the Tot C concentration) in the sediment was 13.7, 15.0, 12.7 and 22.2 kg ha⁻¹ for No-till, Chisel-plow, Paraplow and Disk, respectively. Although tillage practices may reduce C transport in sediment by lowering concentrations, a greater factor for reducing C movement is reducing sediment movement.

Hao, Y., R. Lal, R.C. Izaurralde, J.C. Ritchie, L.B. Owens, and D.L. Hothem. 2001. Historic assessment of agricultural impacts on soil and soil organic carbon erosion in an Ohio watershed. *Soil Science* 166:116-126. (NAEW #366)

Abstract:

Agricultural management affects soil and soil organic carbon (SOC) erosion. The effect was assessed for a watershed (0.79 ha, 10% slope steepness, 132 m slope length) at the North Appalachian Experimental Watershed research station near Coshocton, Ohio, from 1951 to 1998. The agricultural management included: (i) plow-till corn (*Zea mays* L.)-wheat (*Triticum aestivum* L.)-meadow-meadow rotation (CWMM) from 1951 to 1970, (ii) plow-till continuous corn (CC) from 1971 to 1975, (iii) meadow (M) from 1976 to 1983, and (iv) no till corn-soybean (*Glycine max* (L.) Merr) rotation (CS) from 1984 to 1998. Soil erosion was assessed by sediment collection, the Revised Universal Soil Loss Equation (RUSLE), and the ¹³⁷Cesium (¹³⁷Cs) method. The SOC erosion was computed as a product of the soil erosion multiplied by the SOC content of 1.51% in the surface soil and by the SOC enrichment ratio of 1.71 except for the proportional equation of the ¹³⁷Cs method. Sediment collection measurements indicated that the annual soil and SOC erosion rates (Mg ha⁻¹ yr⁻¹) for the corn cycles were, respectively, 1.55 and 0.040 for CWMM, 5.88 and 0.15 for CC, 0.63 and 0.016 for CS, and 2.34 and 0.060 for the entire period. The rates were, respectively, 0.35 and 0.009 for wheat

cycles, 0.63 and 0.016 for soybean cycles, and essentially zero for meadow. Furthermore, the rates for the crop rotation periods were, respectively, 0.50 and 0.013 for CWMM, 5.88 and 0.15 for CC, 0.63 and 0.016 for CS, and 1.02 and 0.026 for the entire study period. The estimates by the RUSLE and proportional equation were 3 to 14 and 10 to 55 times the sediment values, respectively. However, the estimates by the revised exponential equation were 1 to 3 times the sediment values. (Soil Science 2001;166:116-126).

Hao, Y., R. Lal, L.B. Owens, and R.C. Izaurralde. 2001. Soil organic carbon erosion assessment by Cesium-137. Chapter 31, pp. 451-465. *In: Assessment Methods for Soil Carbon*. R. Lal, J.M. Kimble, R.F. Follett, B.A. Stewart (eds), Lewis Publications, Boca Raton, FL. **(NAEW #365)**

Abstract:

Soil organic carbon (SOC) dynamics is an important issue in increasing soil fertility and improving water and air quality. SOC erosion is one of the processes depleting the SOC pool. The methods of assessment of SOC erosion can elucidate the effects of management on SOC dynamics by erosion, oxidation and leaching. Soil ¹³⁷Cs method is a unique tool for assessing SOC erosion in that it can assess total erosion by water, wind, gravity and tillage. It is a simple, rapid and relatively low cost method for historic, comparative and long-term erosion studies for point, plot and watershed scales. The analyses of our and other data indicate that the revised exponential equation and proportional equation can provide a satisfactory assessment for historic and long-term soil and SOC erosion. The accuracy of the ¹³⁷Cs method can be further improved by obtaining information about the potential loss of ¹³⁷Cs with runoff, particulate organic matter and fine mineral particles.

Starr, G.C., R. Lal, J.M. Kimble, and L. Owens. 2001. Assessing the impact of erosion on soil organic carbon pools and fluxes. Chapter 29, pp. 417-426. *In: Assessment Methods for Soil Carbon*. R. Lal, J.M. Kimble, R.F. Follett, B.A. Stewart (eds), Lewis Publications, Boca Raton, FL. **(NAEW #364)**

Abstract:

There are an array of interrelated pools, fluxes, and processes that have some bearing on the problem of assessing the impact of erosion on SOC dynamics. The fluxes of direct erosional transport, GHG emission, and sedimentation are inter-linked with pools of C in eroded and depositional landscapes, buried aquatic sediments, and dissolved and particulate suspended sediment C in rivers, lakes, and oceans. Assessment methods focus on specific pools and fluxes. As a result, data are disjointed and a comprehensive understanding of interconnected pools and fluxes remains elusive. Quantitative inferences drawn from the limited and sketchy data sets that exist are, by necessity, hypothetical when larger (i.e. continental and global) scales are considered or the net impact of erosion on GHG dynamics are estimated. Based on the literature discussed in this manuscript, erosion leads to losses of SOC from the soil pool and reductions in above and below ground biomass in eroded landscapes while transferring some C to sediments and depositional landscapes that accumulate C.

Starr, G.C., R. Lal, R. Malone, D. Hothem, L. Owens, and J. Kimble. 2000. Modeling soil carbon transported by water erosion processes. *Land Degradation & Development*

11:83-91. (NAEW #355)

Abstract:

Long-term monitoring is needed for direct assessment of soil organic carbon (SOC), soil, and nutrient loss by water erosion on a watershed scale. However labor and capital requirements preclude implementation of such monitoring at many locations representing principal soils and ecoregions. These considerations warrant the development of diagnostic models to assess erosional SOC loss from more readily obtained data. The same factors affect transport of SOC and mineral soil fraction, suggesting that given the gain or loss of conservative soil minerals, it may be possible to estimate the SOC flux from the data on erosion and deposition. One possible approach to parameterization is the use of the Revised Universal Soil Loss Equation (RUSLE) to predict soil loss and this multiplied by the percent of SOC in the near surface soil and an enrichment factor to obtain SOC loss. The data obtained from two watersheds in Ohio indicate that a power law relationship between soil loss and SOC loss may be more appropriate. When measured SOC loss in individual events over a 12 yr period was plotted against measured soil loss the data are logarithmically linear ($R^2=0.75$) with a slope (or exponent in the power law) slightly less than would be expected for a RUSLE type model. The stable aggregate size distribution in runoff on a plot scale may be used to guess the fate of size pools of SOC by comparing size distributions in the runoff plot scale and river watershed scales. Based upon this comparison, a minimum of 73% of material from runoff plots is deposited on the landscape and the most stable carbon pool is lost from watershed soils to aquatic ecosystems and atmospheric carbon dioxide. Implicit in these models is the supposition that water stable soil aggregates and primary particles can be viewed as a tracer for SOC.

Owens, L.B. and D.L. Hothem. 1999. Carbon stored in soils under eastern grasslands. Proceedings of the 2nd Eastern Native Grass Symposium, Baltimore, MD, November 1999. pp. 231-234. (NAEW #352)

Abstract:

To evaluate the potential for agricultural practices to mitigate CO₂ emissions through C storage, many cropping practices need to be studied, including grasslands. At the NAEW near Coshocton, OH different grazing/grassland management practices have been studied for over 20 years. With archived soil samples from these areas, total carbon (TC) concentrations and amounts are being assessed. Management systems evaluated include: A.) continuous (non-rotational) grazing on unimproved pasture (28 ha); B.) four orchardgrass (*Dactylis glomerata* L.)/Kentucky bluegrass (*Poa pratensis* L.) paddocks (17 ha) for summer rotational grazing with 56 kg N/ha annually supplied for 5 years followed with 11 years of annual applications of 162 kg N/ha; C.) four orchardgrass paddocks (14 ha) for rotational summer grazing and 224 kg N/ha was annually applied for 5 years, followed by 10 years where the N source was from alfalfa (*Medicago sativa* L.) that had been interseeded into the orchardgrass; and D.) four tall fescue (*Festuca arundinacea* Schreb.) paddocks (10 ha) for winter grazing and feeding of the hay made during the summer; this area had the same N management as system C. TC contents were greatest for the summer grazed, fertilized pastures, ranging from

1.56 and 2.02% in 1975 to 2.22 and 2.37% in 1998 in the 0-15 cm layers for systems B and C, respectively. Systems A and D had similar TC concentrations, ranging from 1.30 and 1.37% to 1.88 and 1.81%, respectively. Amounts of TC in the 0-15 cm layer showed a similar pattern, with 1998 values of 34.8 and 36.0 Mg/ha for systems B and C, respectively and 30.2 Mg/ha for both systems A and D. For comparison, a 12-year no-till corn/soybean rotation had 24.8 Mg/ha of TC. Soils under grasslands may store more C than soils with no-till crops.