Transactions of the Illinois State Academy of Science
(2021) Volume 114, pp. 39-43

received 4/15/21
accepted 7/17/21

# Distribution of Soil Organic Carbon Contents as a Result of Erosion in Soybean Fields of Illinois

*Elijah O. Openiyi, Julia D. Hill, and J. Scott McConnell
Department of Chemistry, Western Illinois University
1 University Circle, Macomb, IL 61455
*Correspondence: elijahopeniyi@gmail.com

## ABSTRACT

Soil organic matter is the fraction of the solid component of the soil composed of plant or animal remains that are in various stages of decomposition. Most soils used for agricultural purposes contain 3% to 6% of organic matter. Soil erosion in particular is a selective process that preferentially transports lightweight and fine sized particles from the topsoil. The effects of soil erosion can be seen in the physical, chemical, and biological changes in the soil organic carbon content of soils. Besides, soil erosion negatively affects the soil's organic carbon accumulation and reduces soil productivity. Soil samples were collected from three soybean (*Glycine max* L.) production fields in Illinois. Each production field represented a different state of erosion condition. Four randomly selected sites were sampled within each production field. Each site was sampled to a depth of 30 cm in 15 cm segments. The Walkley-Black wet chemistry method was used to find the organic carbon content. The Statistical Analysis System (SAS) was used to analyze the data. The objective of this research was to determine if organic carbon is retained or lost in soybean production fields when the erosion state of the soils is considered alongside the tillage practices on those fields. The results showed that non-eroded (conventional till) soils had more soil organic carbon whereas severely eroded (no-till) soils contain the least amount of soil organic carbon. The result of this research therefore affirms the effect of erosion on the redistribution of Soil Organic Carbon (SOC) content in eroded soils.

## INTRODUCTION

Carbon is present in soils in three basic forms, and they include, elemental carbon, organic carbon, and inorganic carbon (Schumacher, 2002). According (Pettit, 2008), organic matter is carbon containing compounds that have their origin from living organisms deposited on the earth. Soil organic matter (SOM) on the other hand, is a fraction of the solid component of the soil composed of plant or animal remains that are in various stages of decomposition (Awelewa & Ogban, 2015). Furthermore, soil organic matter can be grouped into three components: plant remains and the microbial population of the soil; active soil organic matter called detritus; and stable soil organic matter called humus. Soil organic carbon (SOC) is a subset of soil organic matter, it constitutes about fifty percent of the soil organic matter. Walia et al. (2017) stated that the SOC content may be used to estimate the SOM content. The terrestrial ecosystem is made up of the portion of the earth where living materials create a pool of carbon compounds of above and below ground organic matter. Soil organic matter is the largest source of terrestrial carbon pool (Cotrufo et al., 2015).

Soil erosion is the wearing away of the topsoil of a field caused by forces of wind and water (Balasubramanian, 2017). Soil erosion can be a slow process that happens over a long period, or it can be rapid, leading to grave loss in the topsoil. Soil erosion is a selective process that preferentially transports light-weighted and fine-sized particles from the topsoil (Wairiu & Lal, 2003).

There are three-stages work process involved in soil erosion: detachment; transport; and deposition of soil (Lal, 2001). The author further stated the four sources of energy available to trigger erosion and they include gravitational energy, physical energy such as water and wind, agitation from anthropogenic activities like tillage, and chemical reactions. The severity of the erosion process is dictated by how much of these energies are released and the rate of release into the soil.

The breakdown of soil aggregates is called detachment. Detachment is the first indication of soil erosion (Lal, 2001). The breakdown of organo-mineral complexes within the soil caused by the forces of wind and water or chemical reactions leads to the formation of primary particles and microaggregates. The microaggregates and detached particles formed are transported by the forces of water and wind which are then eventually deposited when the velocities of these forces decrease by changes in ground cover or slope (Lal, 2001).

The effects of soil erosion can be seen in the physical, chemical, and biological changes in the SOC content of soils (Lal, 2003; Olson et al., 2016). Soil erosion negatively affect the SOC accumulation and sequestration, reduces soil productivity and may increase greenhouse gas emissions. A high proportion of the humus and clay in soils are sorted by water or wind erosion thereby leaving stones, sand and gravel which are less productive. Fertility of soil is associated with the humus and clay amount and by extension the SOC content of the soil (Troeh et al., 2004).

An unbalanced carbon sink in the terrestrial pool is created by an erosion caused change in the SOC content in soils (Olson et al., 2016). Thus, when coupled with erosion, modern agricultural practices like tillage may lead to a significant imbalance in the terrestrial carbon sink.

Several studies have shown that factors such as soil erosion, type of tillage system, nutrient management practices, and crop residue are key in soil organic carbon dynamics (Lal, 2004a, 2004b; Lal, 2019a, 2019b; Lal et al., 2007, 2018; Olson, 2010; Olson et al., 2012). Researchers have observed that depositional agricultural fields had more SOC content in the topsoil when compared to uncultivated soils, slightly eroded cultivated soils, and severely eroded side slope cultivated soil. Additionally, more SOC content was observed on the depositional field due to erosion and transport of SOC stocks from eroded soils (Lal, 2001; Olson, 2010; Olson et al., 2012).

The experiments of this study were carried out at soybean production fields in McDonough County, Illinois. Each production field represented a different tillage practice (conventional, vertical and no-till) in different erosion conditions (none, moderate, and severe). When erosion is not considered as a factor, it may be expected that the no-till field should have more SOC content because no-till fields are less disturbed and may accumulate SOC in its topsoil. However, when erosion is considered as a factor, the dynamics of the SOC content may change in the study sites. Therefore, depending on the level of erosion and slopes of these fields, their SOC content distribution may change.

The objective for this research was to determine if organic carbon is retained or lost in soybean production fields when the erosion state of the soils is considered alongside the tillage practices on those production fields (Busari et al., 2015; Olson, 2010; Shulan et al., 2010; Walia et al., 2017; Zoltan et al., 2016). We hypothesized that soils from the field with the steepest slope and most severe erosion should retain less soil SOC even though the soils may be no-till (Busari et al., 2015; Olson, 2010; Shulan et al., 2010; Walia et al., 2017; Zoltan et al., 2016).

## MATERIALS & METHODS

**Sampling Procedure and Sample Preparation.** Soil samples were collected from three soybean (*Glycine max* L.) production fields in McDonough County, Illinois. Each production field represented a different type of tillage practice and different erosion conditions (none, moderate, and severe). Four randomly selected sites were sampled within each production field. The production fields were sampled from October 27, 2018, to November 10, 2018. The exact location of the soybean production fields was determined using a global positioning system (GPS) technology (Table 1).

The soil sampling was done using nickel-plated probes. The probes have an internal diameter of 2.54 cm. Four randomly selected sites were sampled within each production field. Each site was sampled to a depth of 30 cm in 15 cm segments. A total of eight samples were taken from each field for a total of twenty-four soil samples collected. The soil samples were divided into two sections of 0-15 cm (topsoil) and 15-30 cm (subsoil). Soil samples of the same depth, site and location were kept in resealable plastic bags that were properly labelled. The soil samples from the production fields were air dried and ground with a ceramic mortar and pestle and the large particles were separated with a 2 mm sieve (Nelson & Sommers, 1996). Each sample was stored in airtight containers until analyzed for soil carbon.

**Table 1.** GPS coordinates for all three soybean production fields sampled. Each site had two individual samples taken at depth of (15 and 30 cm) for that site.

| | No Erosion (Conventional Till) | | Moderate Erosion (Vertical Till) | | Severe Erosion (No-Till) | |
|---|---|---|---|---|---|---|
| Site | Latitude | Longitude | Latitude | Longitude | Latitude | Longitude |
| 1 | 40.41300 °N | 90.61700 °W | 40.44058 °N | 90.61919 °W | 40.45316 °N | 90.60918 °W |
| 2 | 40.40936 °N | 90.61658 °W | 40.44083 °N | 90.62012 °W | 40.45377 °N | 90.60909 °W |
| 3 | 40.407690 °N | 90.61757 °W | 40.44177 °N | 90.61958 °W | 40.45439 °N | 90.60904 °W |
| 4 | 40.408500 °N | 90.61807 °W | 40.44163 °N | 90.61896 °W | 40.45365 °N | 90.60967 °W |

**Determination of erosion level.** The sampled soils in each agricultural field were identified after using the National Resources Conservation Service (NRCS) system (Table 2). Soil survey maps and website were used to obtain the surface texture, slopes, and level of erosion for each of the sampled field and presented in Table 2. The soil survey website showed that the soils on the conventional till field were not eroded with a maximum slope of 5%. The soils on the vertical till field were moderately eroded with a maximum slope of 5% while the soils on the no-till field were severely eroded with a maximum slope of 10% (Soil Survey Website).

**Chemicals and solvents.** Research grade chemicals were purchased and used from Fisher Scientific (American Chemical Society certified). Deionized water from the chemistry laboratory at Western Illinois University was used. There were no purification tests performed on the chemicals and water. Following the Walkley-Black wet chemistry method (Nelson & Sommers, 1996) of SOC analysis, the following chemicals were prepared in the laboratory; potassium dichromate (0.167 M); ferrous sulfate heptahydrate (0.5 M); and o-phenanthroline-ferrous complex (0.025 M). Concentrated sulfuric acid was used as received. The crystalline potassium dichromate was oven-dried at 100 °C for 12 hours and cooled under desiccation before the potassium dichromate solution was prepared.

**Procedure to determine soil carbon.** Soil from each sample was weighed (approximately 0.75 g) into a 500 mL Erlenmeyer flask (Nelson & Sommers, 1996). A 10.0 mL aliquot of 0.167 M potassium dichromate, $K_2Cr_2O_7$, was added to the soil in the flask and the soil was gently swirled. A 20 mL aliquot of sulfuric acid, $H_2SO_4$, was then added to the flask, and the contents were gently swirled to mix thoroughly. The slurry was left to cool for thirty minutes, after which 200 mL of deionized water was added to the mixture in the flask to halt the reaction (Nelson & Sommers, 1996). A Buchner funnel connected to a vacuum system was used to filter the soil particles from the slurry into a Buchner flask. Six drops of 0.025 M o-phenanthroline indicator was added to the filtrate solution. The solution was titrated with 0.5 M ferrous sulfate heptahydrate, $FeSO_4{\cdot}7H_2O$. As the titration proceeds, the initial orange colored solution changes to bluish-green. At the endpoint, the solution changes to a dark red/wine color. All the soil samples at every depth and site were titrated in triplicate. Every day a titration was performed, the $K_2Cr_2O_7$ and $FeSO_4{\cdot}7H_2O$ were standardized by performing a blank determination using the titration process with everything but the soil. The molarity of the ferrous sulfate was calculated using the blank determinations.

**Statistical analysis of the data.** The Statistical Analysis System (SAS) was used for the analysis of the data collected and calculated (SAS Institute Inc, 2003). The SAS was used to compare soil carbon percentages between the different eroded soils. F-tests were conducted as the test of significance at the $\alpha = 0.05$ level. Least significant differences (LSD) were calculated at the $\alpha = 0.05$ level for significant effects.

## RESULTS & DISCUSSION

The SOC content of all the sites analyzed for each of the three production fields are shown below (Table 3).

The mean soil carbon content of all three fields across depths (0-15 cm and 15-30 cm) was analyzed and shown to be significantly different across depths (Table 4). The mean soil carbon content of each soil type was statistically analyzed at ($\alpha = 0.05$) for each depth and at each site and showed to be significantly different across the different eroded soils while not being significant across different sites for the same field (Table 3-4).

**Table 2.** Classification of all three soybean production fields.

| | No Erosion (Conventional Till) | Moderate Erosion (Vertical Till) | Severe Erosion (No-Till) |
|---|---|---|---|
| Taxonomy | Fine-smectitic, mesic Aquic Argiudolls | Fine-smectitic, mesic Aquic Argiudolls | Fine-silty, mixed, superactive, mesic Typic Argiudolls |
| Soil Series | Ipava | Ipava | Osco |
| Soil Order | Mollisol | Mollisol | Mollisol |
| Map Unit Symbol | 43A, 43B | 43A, 43B, 43B2 | 86B, 470C2, 43B |
| Surface Texture | **43A**<br>Ipava silt loam<br>0 - 2 % slopes<br>**43B**<br>Ipava silt loam<br>2 - 5 percent slopes | **43A**<br>Ipava silt loam<br>0 - 2 % slopes<br>**43B**<br>Ipava silt loam<br>2 - 5 % slopes<br>**43B2**<br>Ipava silt loam<br>2 - 5 % slopes, eroded | **86B**<br>Osco silt loam<br>2 - 5 % slopes<br>**470C2**<br>Keller silt loam<br>5 - 10 % slopes, eroded<br>**43B**<br>Ipava silt loam<br>2 - 5 % slopes |
| Soil Profile | **Ap**<br>0 - 10 in: silt loam<br>**A**<br>10 - 18 in silty clay loam<br>**Btg1**<br>18 - 31 in: silty clay loam<br>**Btg2**<br>31 - 50 in: silty clay loam,<br>**Cg**<br>5 - 60 in: silt loam | **Ap**<br>0 - 10 ins: silt loam<br>**A**<br>10 - 18 in: silty clay loam<br>**Btg1**<br>18 - 31 in: silty clay loam<br>**Btg2**<br>31 - 50 in: silty clay loam<br>**Cg**<br>50 - 60 in: silt loam | **Ap**<br>0 - 14 ins: silt loam<br>**Bt**<br>14 - 55 in: silty clay loam<br>**C**<br>55 - 60 in: silt loam |

**Table 3.** Percent SOC content of all three soybean production fields.

| Site | Sample Depth (cm) | No Erosion (Conventional Till) | Moderate Erosion (Vertical Till) | Severe Erosion (No-Till) |
|---|---|---|---|---|
| 1 | 0 - 15 | 2.30 | 2.11 | 1.57 |
| | 15 - 30 | 1.77 | 1.70 | 0.76 |
| 2 | 0 - 15 | 2.09 | 1.82 | 1.73 |
| | 15 - 30 | 1.66 | 1.29 | 1.57 |
| 3 | 0 - 15 | 2.48 | 1.97 | 2.06 |
| | 15 - 30 | 1.78 | 1.14 | 1.40 |
| 4 | 0 - 15 | 2.15 | 2.10 | 1.29 |
| | 15 - 30 | 1.92 | 1.65 | 0.66 |

**Table 4.** Mean SOC variation with depth.

| Depth (cm) | No Erosion (Conventional Till) | Moderate Erosion (Vertical Till) | Severe Erosion (No-Till) | Mean |
|---|---|---|---|---|
| 0 - 15 | 2.22 | 2.00 | 1.66 | 1.96 |
| 15 - 30 | 1.80 | 1.44 | 1.07 | 1.44 |
| LSD (0.05)* | 0.06 | 0.03 | 0.04 | 0.12 |
| Mean | 2.01 | 1.72 | 1.37 | 1.70 |
| LSD (0.05)** = 0.12 | | | | |

*Least Significant Difference for each eroded soil type across depths

**Least Significant Difference for all fields across depths

All sites are significantly different across all depth

The non-eroded (conventionally tilled) soils showed the smallest difference in SOC between the topsoil and subsoil. This difference in SOC content between the topsoil and subsoil is expected since the soils are not eroded and may also be due to the mixing of topsoil and subsoil from tillage activities on the field. The statistical analysis showed a significant difference between the SOC content between depths for non-eroded (conventionally tilled) soils. Moderately eroded (vertically tilled) soils showed a moderate difference in SOC between the topsoil and sub soil. The moderate difference in SOC content between the topsoil and subsoil is expected since the soil is moderately eroded. The statistical analysis showed a significant difference between the SOC content between depths for moderately eroded (vertically tilled) soils. Severely eroded (no-till) soils showed the highest difference in soil organic carbon between the topsoil and subsoil. This difference in SOC content between the topsoil and subsoil is expected since the soils are severely eroded. Water or wind erosion may have washed away the SOC from the topsoil. Since the severely eroded soil was not tilled, it is also possible that the non-mixing of the soil by tillage activities may have been responsible for the high difference in the SOC between the topsoil and subsoil. The statistical analysis showed a significant difference between the SOC between depths for the severely eroded (no-tilled) soils.

The results showed that the non-eroded (conventionally tilled) soils had more SOC (2.01%) while the severely eroded (no-till soils) had the least SOC (1.37%). The moderately eroded (vertical tilled) soils had intermediate SOC content of 1.72% (Table 4). It was hypothesized that soils from the severely eroded soils (no-till) field may have less SOC due to erosion of the topsoil that occurred on the field. Should the soils not be eroded; then, the no-till field may have had more SOC because there is little disturbance to the topsoil and subsoil which may favor the accumulation of SOC. Clearly, erosion on the no-till field was responsible for this change in SOC dynamics. The results from this research suggest that the severely eroded soils from the no-till field may be in their initial stage of restoration. The results from Luo et al. (2010) and Olson et al. (2012) agree with the results for all three fields in this research. All three fields showed a decrease in SOC with increasing depth.

Zoltan et al. (2016) and Shulan et al. (2010) reported that selective SOC erosion and deposition occurred in their field of study irrespective of the effect of tillage practices on the field. The topsoil on the steepest parts of their study sites showed a decrease in SOC content. Their result showed the preferential transport of fine soil particles rich in soil organic matter in eroded soil thereby leading to a decrease in SOC content. This research also reported a decrease in SOC concentration with increasing depths on eroded soils.

## SUMMARY

Our objective of this research was to determine if organic carbon is retained or lost in soybean production fields when the erosion state of the soils is considered. The tillage practices must also be considered. The statistical analysis of all three soybean production fields in this study has shown significant differences in SOC content. Our findings also affirm the effect of erosion on the distribution of SOC content in eroded soils.

## ACKNOWLEDGEMENTS

The authors thank the landowner of the sites sampled, Mr. Larry Butcher. We also wish to thank ISA Endowed Soybean Internal Support Fund for the research grant.

## LITERATURE CITED

Awelewa, E. and Ogban, P.I. (2015). Effect of intensive vegetable cultivation on soil organic carbon storage in Akwa Ibom State, Southeastern Nigeria. British Journal of Environment and Climate Change, 5, 310-323. doi.org/10.9734/Bjecc/2015/22942

Balasubramanian, A. (2017). Soil erosion- causes and effects. 10.13140/RG.2.2.26247.39841.

Busari, M. A., Kukal, S. S., Kaur, A., Bhatt, R., & Dulazi, A. A. (2015). Conservation tillage impacts on soil, crop and the environment. International Soil and Water Conservation Research, 3(2), 119-129. doi.org/10.1016j.Iswcr.2015.05.002

Cotrufo, M. F., Soong, J. L., Horton, A. J., Campbell, E. E., Haddix, Michelle L., & Wall, D. H. (2015). Formation of soil organic matter via biochemical and physical pathways of litter mass loss. Nature Geoscience, 8, 776. doi.org/10.1038/Ngeo2520

Lal, R. (2001). Soil degradation by erosion. Land Degrad. Dev., 12: 519-539. doi.org/10.1002/ldr.472

Lal, R. (2003). Soil erosion and the global carbon budget, Environment International, 29(4), 437-450. doi.org/10.1016/S0160-4120(02)00192-7

Lal, R. (2004a). Carbon sequestration in soils of Central Asia. Land Degradation & Development, 15(6), 563-572. doi.org/10.1002/Ldr.624

Lal, R. (2004b). Soil carbon sequestration impacts on global climate change and food security. Science, 304(5677):, 1623. doi.org/10.1126/Science.1097396

Lal, R. (2019a). Conceptual basis of managing soil carbon: inspired by nature and driven by science. Journal of Soil and Water Conservation, 74(2):, 29A-34A. doi.org/10.2489/Jswc.74.2.29A

Lal, R. (2019b). Eco-intensification through soil carbon sequestration: harnessing ecosystem services and advancing sustainable development goals. Journal of Soil and Water Conservation, 74(3):, 55A-61A. doi.org/10.2489/Jswc.74.3.55A

Lal, R., Follett, R., Stewart, B. A., & M. Kimble, J. (2007). Soil carbon sequestration to mitigate climate change and advance food security. Soil Science, 172:, 943-956. doi.org/10.1097/Ss.0b013e31815cc498

Luo, Z., E. Wang, & O. J. Sun. (2010). Can no-tillage stimulate carbon seques¬tration in agricultural soils? A meta-analysis of paired experiments. Agric. Ecosyst. Environ. 139:224–231. doi.org/10.1016/j.agee.2010.08.006

National Resources Conservation Service (NRCS) and United States Department of Agriculture (USDA) in Cooperation with Illinois Agricultural Experiment Station. Soil Survey of Mcdonough County, Illinois. (2002).

Nelson D. W., & Sommers L. E. (1996). Methods of soil analysis part 3 chemical methods. Soil Science Society of America, Inc. American Society of Agronomy, Inc. Madison, Wisconsin, USA: Soil Science Society of America, Inc. American Society of Agronomy, Inc. Madison, Wisconsin, USA.

Olson, K. R. (2010). Impacts of tillage, slope and erosion on soil organic carbon retention. Soil Science, 175:562-567.

Olson, K. R., Gennadiyev, A. N., Zhidkin, A. P., & Markelov, M. V. (2012). Impacts of land-use change, slope, and erosion on soil organic carbon retention and storage, Soil Science, 177(4): 269-278 doi.org/10.1097/SS.0b013e318244d8d2

Olson K. R, Al-Kaisi M, Lal R., & Cihacek, L. (2016). Impact of soil erosion on soil organic carbon stocks. Journal of Soil and

Water Conservation May 2016, 71 (3): 61A-67A. doi.org/10.2489/jswc.71.3.61A

Pettit, R. (2008). Organic matter, humus, humate, humic acid and fulvic acid. https://www.semanticscholar.org/paper/organic-matter-%2c-humus-%2c-humate-%2c-humic-acid-%2c-acid-pettit/bd2e61da484c14d9325d16024360a118c4809ba1 (accessed October 23, 2019)

Schumacher, B. A. (2002, April). Methods for the determination of total ogranic carbon (TOC) in soils and sediments. Ecological Risk Assessment Support Center. U.S. Environmental Protection Agency.

Shulan C., Huajun F., Tianhong Z., Jiaojiao Z., Xueming Y., Xiaoping Z., & Guirui Y. (2010). Effects of soil erosion and deposition on soil organic carbon dynamics at a sloping field in Black Soil region, Northeast China, Soil Science & Plant Nutrition, 56:4, 521-529. doi.org/10.1111/j.1747-0765.2010.00492.x

Soil Survey Website. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx (accessed June 28, 2019)

Troeh, F.R., Hobbs J.A., & Donohue R.L. (2004). Soil and water conservation: Productivity and environmental protection. 4th ed. Upper Saddle River, NY: Prentice-Hall, Inc.

Walia, M. K., Baer, S. G., Krausz, R., & Cook, R. L. (2017). Deep soil carbon after 44 years of tillage and fertilizer management in southern illinois compared to forest and restored prairie soils. Journal of Soil and Water Conservation:, 72(4): 405-415. doi.org/10.2489/Jswc.72.4.405

Wairiu, M., & Lal, R. (2003). Soil organic carbon in relation to cultivation and topsoil removal on sloping lands of Kolombangara, Solomon Islands. Soil & Tillage Research - SOIL TILL RES. 70. 19-27. doi.org/10.1016/S0167-1987(02)00116-2

Zoltán S., Judit S., József K., Erzsébet M., Gáspár A., Csaba C., Boglárka S., Balázs M., Dóra Z., & Gergely J. (2016). Redistribution of soil organic carbon triggered by erosion at field scale under subhumid climate, Hungary. Pedosphere, 26(5): 652-665. doi.org/10.1016/S1002-0160(15)60074-1