J Nat Env Sci 2010 1(2):19-27

Journal of
Natural & Environmental Sciences

www.academyjournals.net

ISSN 1309 7474

Original Article

The influence of land-use and seasons on SOM distribution in headwaters of a central Ohio watershed

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Received: 21.09.2010 ***Accepted: 20.10.2010*** ***Published: 26.10.2010***

Abstract
Soil organic matter (SOM), the accumulated, decaying debris of biota living on or in the soil, represents the largest of the active terrestrial C pools, holding about 1500 Pg C to a depth of 1 m. In aquatic ecosystems, SOM is a storehouse of inorganic nutrients which, after mineralization, are released to the stream and used by planktonic and benthic microorganisms. Here we present the results of a study designed to elucidate the controls on the spatial and temporal variations of the SOM distribution along the Clear Fork River, which drains a mixed urban-agricultural landscape in north-central Ohio. Fluvial bed sediments were sampled monthly (March to October) in eight stations along the river. Organic matter (OM) and carbonate content were determined by loss-on-ignition (LOI). Sediments from all stations were analyzed in triplicate to account for intrasample variation and to provide a measure of precision. Textural analysis was also performed in all samples. Results show OM content varying between 14 and 109 g kg-1, with highest values observed during spring, and lower values during summer. Sediments from stations where the stream flow is high generally presented lower OM concentration. In addition, stations located within urban landscapes presented the highest OM concentrations.

***Key words**: stream sediment, organic matter, carbon, Ohio streams, Mohican watershed*

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INTRODUCTION

Soil organic matter (SOM) comprises naturally occurring residues resulting from the decomposition of plant and animal remains (Duxbury et al., 1989; Swift, 1996), also defined as the nonliving component of organic matter in soil (Trumbore, 1997). These organic residues are complex mixtures that include humic substances, carbohydrates and other classes of organic compounds (Stevenson 1994). The composition of SOM varies from place to place and is affected by the local vegetation, climate and soil properties (Swift 2001). SOM plays a crucial role in the development and maintenance of soil fertility, mainly through the cycling, retention and supply of nutrients, and the creation and maintenance of soil structure (Stevenson 1994). SOM also represents the largest of the active terrestrial C pools (Trumbore 1997). Recent work on sustainable agriculture has emphasized the importance of SOM management in maintaining and improving soil fertility (Shibu et al. 2006). In addition, the potential of agro-ecosystems to absorb large quantities of atmospheric CO_2 through carbon sequestration in the form of SOM is widely being put forward as one of the mitigating options for climate change (Lal 2004; Post et al. 2001).

SOM is also a storehouse of inorganic nutrients in stream ecosystems (Tiessen et al. 1994). Each year, fluvial networks transport, transform or store nearly 2 Pg of terrestrial organic carbon (Battin et al. 2008). This is a large fraction of the world's annual net ecosystem production of organic C and recent estimates of C transport from streams and rivers have shown that the transfer of terrestrial C to inland aquatic ecosystems is considerably larger than delivery of that C to the sea (Cole et al. 2007). Contrary to the conventional wisdom that terrestrial organic C is recalcitrant and contributes little to freshwater metabolism, stream SOM supplies the ecosystem with nutrients that fuel the net heterotrophy of the stream, which may be responsible for much more CO_2 outgassing than previously thought (Battin et al. 2008).

Because SOM shows a strong positive linear relationship with soil organic carbon (SOC), it has commonly been used to predict SOC concentrations in soils (Konen et al. 2002). SOM distribution can also be used as an indicator of anthropogenic activities, since human perturbations to stream ecosystems tend to reduce SOM levels in stream beds (Shields et al. 2008).

The purpose of this study was to identify the spatial and seasonal controls on SOM distribution in a series of headwater streams draining mixed-use landscapes. Specifically, we evaluated the effects of multiple land uses, of seasonal shifts in hydrology and temperature, and of sediment texture on SOM concentrations. Describing the patterns and processes involved in SOM distribution across varying land uses is key to understanding the potential for carbon sequestration, as well as the development of models that can predict SOC distribution patterns on the landscape and its interactions with stream biological communities. Carbonate content is also discussed, since it constitutes one of the most important controls on the pH of soils (Madrid & Diaz-Barrientos 1992) which, in turn, affects the mineralization rates in the sediment (Curtin et al. 1998).

MATERIAL AND METHODS

Study Sites

The Clear Fork River watershed (Fig. 1) is located in the southern portion of Richland County, Ohio, USA. The Clear Fork River is 58.9 km long and has a drainage area of 567 km^2. Before sampling sites were selected, river catchment areas (RCAs) were created using the FLoWS tools developed by the STARMAP program at Colorado State University (Theobald et al. 2005). The RCAs are more sensitive to variations in land use than the 14-digit HUCs produced by the U.S. Geological Survey (USGS). Each RCA is associated with a stream reach (Fig. 1). Land cover data from the National Land Cover Database (Homer et al. 2004) was used to identify RCAs that were representative of the four land use types used in this study (cultivated row crop, hay/pasture fields, forested, and developed areas – Table 1).

Table 1 Land use in the selected RCAs

	Developed	Cropland	Hay / Pasture	Forested
Station 1	6%	**45%**	16%	32%
Station 2	2%	10%	10%	**78%**
Station 3	**62%**	0%	13%	25%
Station 4	6%	0%	**55%**	32%
Station 5	**66%**	2%	8%	23%
Station 6	8%	**45%**	10%	36%
Station 7	0%	0%	5%	**95%**
Station 8	6%	12%	**48%**	34%

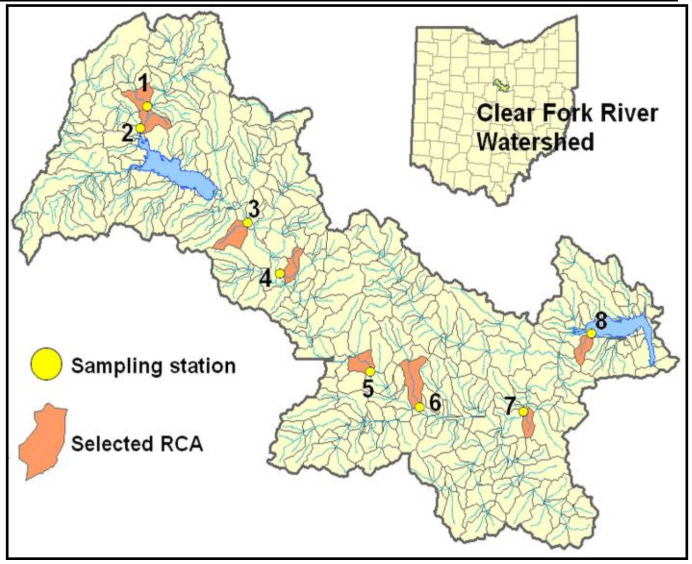

Figure 1 Map of the Clear Fork River Watershed showing selected RCA's and the sampling stations

Eight RCAs were selected for sampling (Fig. 1), including: 2 stream reaches whose catchments are predominantly forested (over 78% cover), 2 catchments dominated by cultivated row crops (over 45% cover), 2 others dominated by hay and/or pasture fields (over 48% cover) and 2 dominated by developed land (over 62% cover).

Most of the streams in the watershed run through the Killbuck-Glaciated Pittsburgh Plateau which contains ridges and flat uplands generally above 365 m, covered with thin drift and dissected by steep valleys (ODNR, 2004). The geology consists of thin to thick Wisconsinan-age clay to loam till over Mississippian- and Pennsylvanian-age shales, sandstones, conglomerates and coals (ODNR, 1998). The vegetation of forested areas is dominated by deciduous hardwood trees such as oak, maple, ash, hickory, and elm (Synder & Cowen 2001). The average annual precipitation for the study area is about 110 cm, with highest monthly averages from April to August (NWS 2009). The average air temperature is -2.3 °C in winter and 21.1 °C in summer (NWS 2009).

Historical streamflow data for the Clear Fork are available for three gauging stations at the villages of Butler (near RCA 7) and Newville (near RCA 8) and below the Pleasant Hill Dam. Monthly discharge data averaged between 1945 and 1975 (Fig. 2) indicates that peak discharges are observed in March (average 291.5 cfs) and the lowest discharge occurs in October (average 34.0 cfs).

Sampling Methods

Fluvial bed samples were collected monthly between March and October 2008 (n=56) and analyzed for SOM and carbonates using the Loss-on-ignition (LOI) method (Ball

1964; Dean 1974). Core samples were taken to a depth of 10 cm using a 2” diameter, stainless steel hand corer in the same location each month. About 150-200g of sediment (wet weight) was sampled on each site. Samples were placed in a Ziploc bag, labelled, preserved on ice until return to the lab and immediately frozen.

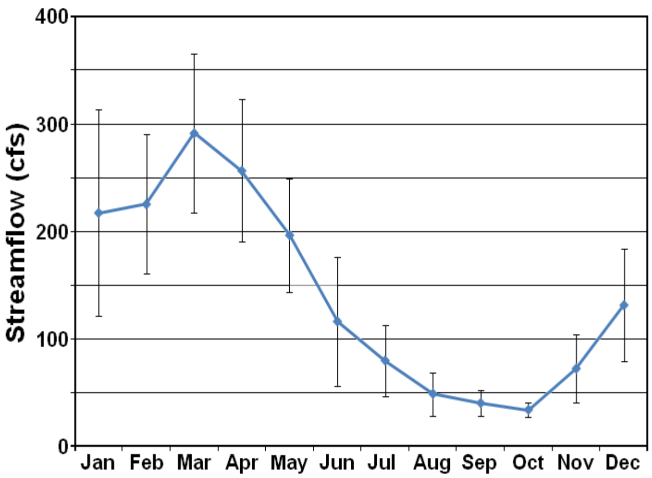

Figure 2 Historical stream flow for the Clear Fork River (1945 to 1975)

Laboratory Methods

Sequential loss on ignition (LOI) is a common and widely used method to estimate the organic and carbonate content of sediments (e.g., Dean 1974; Schulte & Hopkins 1996; Sutherland 1998; Cambardella et al. 2001; Heiri et al. 2001). In a first reaction, organic matter is oxidised at 550 °C to carbon dioxide and ash. In a second reaction, carbon dioxide is evolved from carbonate at 950 °C, leaving oxide. The weight loss during the reactions is easily measured by weighing the samples before and after heating and is closely correlated to the organic matter and carbonate content of the sediment sample. Before analysis, sediment samples were thawed and then put to dry overnight at 105 °C in a convective oven. Once dry, samples were gently grinded using a porcelain mortar and pestle to break up the hard clumps of clay and silt and textural analysis was performed using standard brass sieves (samples were sieved sequentially through mesh sizes varying from 2-mm to 0.0625-mm). Sediment retained in the 2-mm sieve was discarded. Loss-on-ignition was performed on approximately 30g of the mixed sample in triplicate on porcelain crucibles. Triplicates were used to estimate measurement precision through the computation of %RSD (percent relative standard deviation) as described in De Vos et al. (2005). RSD for the fractions analyzed all remained below 5% throughout the study. In addition, it is important to use the same mass of sediment for each LOI test (30 g in our case) because the performance of LOI at 550 degrees Celsius is dependent on sample size (Heiri et al. 2001). After weighing, samples were ignited in a Thermo Scientific Benchtop muffle furnace at 550°C for 4 hours. After igniting for 4 hours, samples were left to cool for two minutes and the percentage of weight loss was determined with a precision of 10-4 g using a Mettler Toledo analytical balance. Samples were then returned to the muffle furnace and ignited at 950°C for 2 hours. Weight loss was again determined by weighing the sample after it was left to cool for two minutes.

Statistical Analysis

The data analysis package from Microsoft Excel and SPSS were used to analyze the data from both the LOI results and the textural analysis. SOM and carbonate content were calculated for each sample by taking the average of the triplicates accordingly. In order to elucidate the effects of land use as a control on SOM content, we normalized these concentrations using the proportion of OM g kg^{-1} to clay particles g kg^{-1} (grain size < 0.0625mm) in each sample. The results of this normalization provide the amount of OM in the sample relative to the amount of clay, and help to eliminate grain size as a confounding factor since texture also exhibits a control on SOM concentrations (Bergamaschi et al. 1997). This is an alternative to performing bivariate statistical analysis using grain size and land-use as variables. The results of the correlation can be seen in Figure 3.

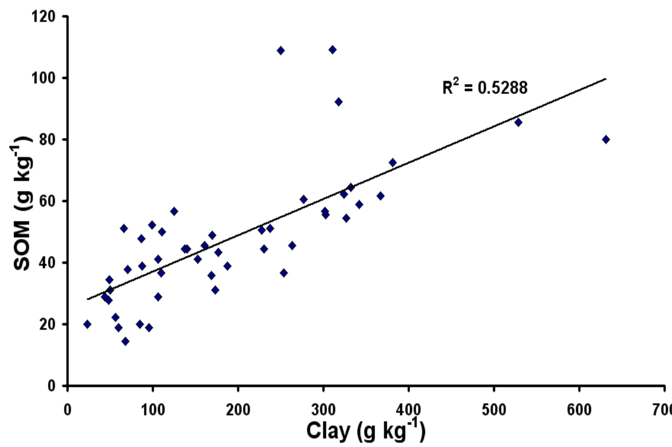

Figure 3 Results of regression analysis between SOM concentration and clay content (the 3 outliers with anomalously high SOM values all belong to the same sampling site which drained developed land).

RESULTS

There were several noticeable temporal and spatial (site-to-site – land-use effect) trends in fluvial bed SOM and carbonate content. SOM content tended to be highest in the spring and lower in the summer for all but forested land use areas (Fig. 4).

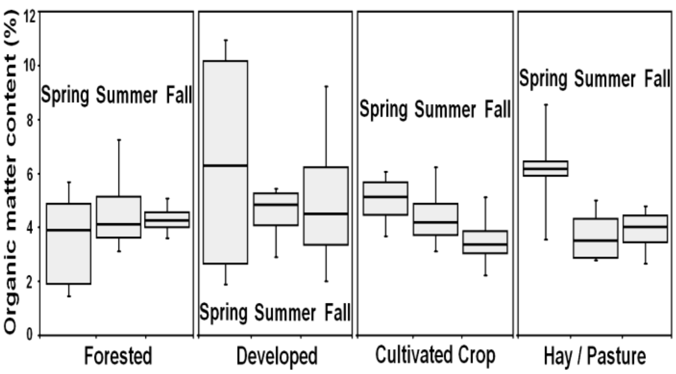

Figure 4 Box plot of SOM concentration by season for each of the four land use categories. Spring: March, April, May; Summer: June, July, Aug.; Fall: Sept., Oct. Error bars represent maximum and minimum values (spring: n=6; summer and fall: n=4).

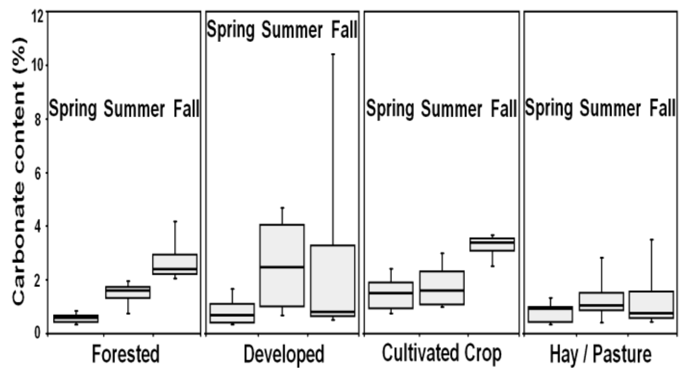

Figure 5 Box plot of carbonate content distribution by season for each of the four land use categories.

Stream reaches dominated by cultivated crop also showed its highest SOM in the spring but the lowest concentration was observed in the fall (not the summer). Forested sites had the lowest amount of variability, with the lowest SOM average observed in the spring and the highest in the summer. Sites dominated by pasture showed significantly lower SOM concentrations in summer and fall, compared to spring values. The highest average SOM content (54.68 g kg^{-1}) was observed in stream reaches draining developed land, while the forested stream reaches had the lowest total SOM average (40.35 g kg^{-1}). A developed land-use site contained the two highest values of SOM recorded: 108 and 109 g kg^{-1}, while a forested site contained the two lowest values recorded: 14 and 18 g kg^{-1}. In addition, samples from developed sites contained large amounts of clay size sediment (23-630 g kg^{-1}). The fluvial bed sediments from forested sites had considerably lower amounts of clay: 67-380 g kg^{-1}. Stream reaches dominated by developed landscapes showed the highest SOM concentrations and the largest temporal variation. Conversely, forested catchments contained the lowest values observed and the smallest temporal variations (Fig. 4). There is an abnormally high value of SOM in the spring for pasture/hay landscapes and an abnormally large amount of clay size particles (grain size < 0.0625 mm).

Carbonate contents were generally lower in the spring and increased in the fall (Fig. 5), and negatively correlate with stream flow. The correlation coefficient between monthly average stream flow (from USGS historical data) and carbonate content was R= -0.732 (Fig. 6). A simple linear regression model between SOM concentration (g kg^{-1}) and the amount of clay in all samples produced a correlation coefficient of R= 0.727 (Fig. 3).

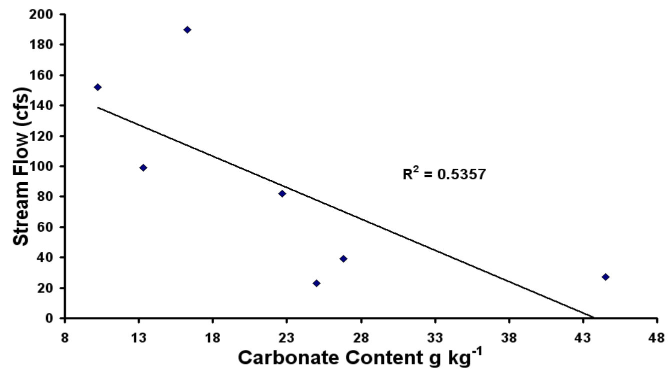

Figure 6 Results of regression analysis between stream flow data (historical monthly averages from USGS) and monthly carbonate content.

Figure 7 shows similar seasonal patterns between the amounts of OM relative to the amount of clay in the sediment. Figure 7 also shows that developed catchments had the most OM relative to clay while forested sites had the least OM relative to clay; in addition, the mass fraction SOM:clay was lower in the spring and higher in summer for all but the forested sites. Figure 8 shows the relationship between average air temperature for each of the sampling months and average OM concentration.

Although seasonality constitutes a significant control on both SOM and clay distribution (Fig. 7), the effect of temperature alone is not very apparent (Fig. 8). This could be just an artifact from average values being used in the construction of the graph. More likely, temperature is just one of multiple factors acting synergistically to control SOM and clay distribution.

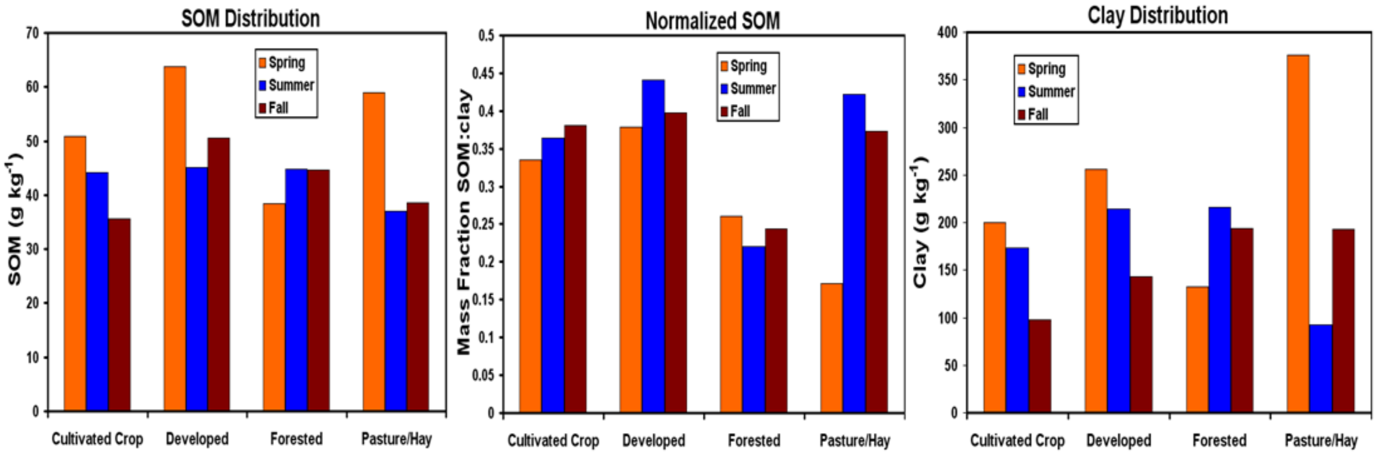

Figure 7 Comparison between SOM distribution, normalized values (mass fraction of SOM relative to the amount of clay in the sediment) and clay content. Averages were used; n=6 for spring, n=4 for summer and fall.

DISCUSSION

Our results have shown that land use exerts a strong influence in the distribution of SOM. Stream reaches draining landscapes with similar physical characteristics (such as hay fields, pasture and cultivated crop) presented similar SOM concentration and similar seasonal behavior. As well, the removal of nutrients from soils through the growing season is reflected in the seasonal distribution of SOM from streams (especially those draining cultivated row crops).

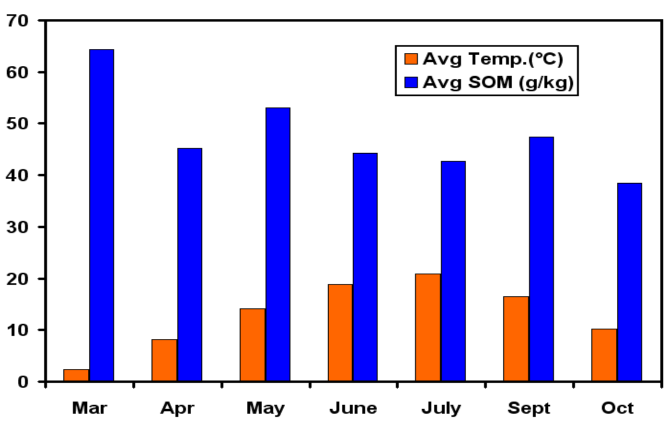

Figure 8 Comparison between temperature and SOM concentration.

Our results also show that clay content is an good predictor of SOM distribution. High normalized SOM content in early spring on forested sites is probably linked to the major litterfall period (October-December), since litter decomposition rates are very slow during winter (Seastedt et al. 1983). In the Clear Fork River, allochtonous leaf fall dominates the annual organic matter budget in forested catchments. Mean annual leaf litter inputs in comparable streams have been found to vary between 218 and 736 g AFMD m^{-2} y^{-1} (Webster and Meyer 1997). There is also a relatively dry period in late summer/early fall which contributes to the lack of SOM in all stream reaches, the only exception being those draining predominantly forested catchments.

This seasonal shift in the hydrologic conditions is also a major control in the distribution of carbonate content. The rise in carbonate content between the spring and the fall has a strong negative correlation with stream flow and is the result of reduced dilution. In all but the forested sites, a large spike in SOM was observed in the spring, which has a major impact on stream water quality, since such pulses are associated with high concentrations of inorganic N in these stream reaches (Costa, in review). The transport of SOM downstream has been found to be a power function of stream flow which causes pulses of OM to be transported downstream with large storms or high flows (Wallace et al. 1995). The large spikes of SOM in the spring for these sites may be from proximal bank erosion and lack of riparian vegetation (Castelle et al. 1994). If SOM values are normalized to clay content, an inverse trend is observed, with the lowest values occurring in the spring (summer for forested sites). This suggests that clay content is a strong predictor of SOM concentration across all land uses.

The spring flushes of SOM may not be of high value to the stream's net heterotrophy due to their low residence times and low water temperature in the spring, which do not allow microbial bacteria sufficient time to feed (Fischer et al 2002). However if the geomorphology of the stream reach provides enough obstructions to cause longer residence times for suspended materials, the microbes can form "biofilms" and attach to the suspended OM (Battin et al. 2008). Forested headwater streams usually have large amounts of large wood and other physical obstructions which trap debris causing a build-up of OM which may be released during high flows. This supports the idea that forested headwaters are important contributors of OM and nutrients, crucial to downstream riverine ecosystems (Wipfli et al. 2007). Headwaters, however, typically have little protection under current land management policies – compared to larger rivers – even though they have a large influence on downstream water quality (Wipfli et al. 2007).

Although our findings provide additional insights into the seasonal and land-use controls of SOM and soil carbonate content that account for a large component of the stream reach supply of carbon, it is still insufficient to explain how much of this carbon is oxidized, since we have not measured CO_2 fluxes from the studied streams. Because direct contact between the microbial community and their substrate is needed for the metabolism of SOC, the residence time of DOC, SOM and dissolved carbonate is a crucial factor in predicting the flux of CO_2 from streams to the atmosphere and to the downstream network (Battin et al., 2008). Natural factors such as water temperature, light, and nutrient concentrations would also need to be measured as they elicit controls on the amount of decomposition/metabolism that occurs in a stream (Young et al. 2008). However since most downstream SOM transport occurs in pulses associated with high water flows, we should expect an increase in the concentration of remineralized nutrients just after these pulses, which could result in large algae blooms. Since our results show the developed stream reaches having the largest SOM contents, these reaches are probably the largest contributors of CO2 outgasing among the land uses evaluated in this study.

SOM Behaviour in Developed Catchments

A previous study has found population density to be the largest factor controlling total carbon (TC) and total organic carbon (TOC) concentrations in fluvial bed sediments in streams throughout the conterminous U.S. (Horowitz & Stephens 2008). They concluded that population density is a good measure of anthropogenic activity likely to increase sediment-associated chemical concentrations (including TC and TOC). Similar trends were found in our study. Developed sites had the highest SOM and carbonate content concentrations and also contained the most spatial and temporal variation. Some of the increased SOM in these areas is probably the result of septic tank leakage. Additionally, urban areas are usually associated with large surface water runoff due to large impervious surfaces (e.g. roofs, parking lots, asphalt). As a result, more nutrients and sediment will be removed from the surrounding lands and carried to the stream during storm events. These large pulses of surface water runoff often degrade stream banks making them less stable and more susceptible to erosion, eventually creating an incised channel. A feedback loop is then established, since incised channels typically promote larger peak flows during storm events, especially in urban catchments (Simon & Rinaldi 2006). Developed areas also frequently lack riparian buffers to prevent stream-bank erosion due to pre-existing bank degradation or from anthropogenic removal (Castelle et al. 1994). Our results indicate higher SOM content in the spring, which corresponds to snowmelt and spring rains, resulting in high stream flows. If the stream banks are exposed (i.e. lack vegetation or natural cover) the sediment will likely contain less OM due to the large amount of erosion and transport of fine grain sediments, not to mention the sunlight degradation of OM components (Larson et al. 2007; Wetzel et al. 1995). In much of the urban stream reaches, vegetation is essentially trimmed grass with no buffer zone. We found the developed land-use catchments to have less SOM relative to fine grain sediment in the spring then it does in the summer using the normalized values, even though the total SOM was highest in the spring. This increase in the decomposition rates of fine OM particles has been observed elsewhere (Jackson and Vallaire 2007). It is important to note that there are significant differences in SOM values and temporal trends between the two developed sites. One possible reason for this could be that one site drained a much larger catchment area thus resulting in higher flow values. Also, the site with the highest amounts of SOM content (site 3) had much higher proportions of clay in its sediment than the other developed site (site 5). Anthropogenic activities/urbanization can cause channel incision, removal of natural flood plains, oversized stream cross sectional areas, higher overland flows, etc. which can all influence deposition and accumulation of clay and fine particles in these stream reaches. These activities are evident and most common in the urban and cultivated crop catchments, channelling and straightening of the natural stream path is prevalent upstream near station 3.

SOM behavior in forested catchments

Forested sites, with well developed riparian vegetation (mainly deciduous trees) showed the lowest degree of variation in SOM content between seasons. The forested watershed's banks are more stable due to plants roots. Forested areas also produce less surface runoff after storm events. Therefore they exhibit smaller pulses of increased sediment loads than developed catchments. Since the forested sites are tree-covered, they may also have cooler water temperatures. The small increase in SOM between seasons in forested areas may be due to the presence of a constant supply of litter with a longer residence time than other land uses. The spike of SOM concentrations in the spring in all but the forested land sites can be explained by the spring melting and increased runoff of sediments and organic debris to the streams. The forested sites show low values of clay sediment in the spring, which is probably due to increased sediment export during periods of high flow. Since all but the forested catchments may have been subject to anthropogenic modification (e.g. ditches, bank modification), these geomorphologic changes may significantly alter stream hydrology and thus downstream transport rates of SOM. Assuming the forested catchments have not been altered, this may contribute to their stability between seasons.

SOM behavior in cultivated crop catchments

Cultivated lands are exposed during the winter and early spring while in the summer and fall they are covered with row crops. The crops and tilled soil may slow surface runoff during the growing season, which is not true for the rest of the year. Organic fertilizer, such as manure, is commonly applied to these areas and contributes to increased SOM concentration during spring (Gong et al. 2009). The low values of SOM in the fall for most sampling sites but particularly the cultivated crop areas may be due to the lack of supply from the catchment as a result of another hydrological shift (low flows carry a decreased loads of mineral and organic material), this time resulting from the dry conditions found at the end of the summer and beginning of fall (the headwaters in some of the first order streams were completely dry in the September field sampling). The high values of carbonate content in the fall are related to carbonate mineral abundances, decreased dilution effect and in this case could be possibly from lime fertilizers that were deposited in the fields in earlier months (as suggested by Hamilton et al. 2007).

SOM behavior in pasture/hay catchments

Pasture/ hay dominated landscapes consist of large open fields and surfaces which contribute to somewhat large volume of surface runoff during months of high precipitation. This accounts for the spike in SOM during the spring months when soil moisture is high when compared to summer and fall. Lower infiltration rates and thus higher over-land flows contribute to higher sediment deposition and thus SOM concentrations in the spring months. Summer and fall months are considerably drier and have lower stream flows associated with them, which decreases the deposition rates of new sediment and SOM into the stream. The abnormally low values of normalized SOM in the spring indicates that there is less fine grain particles in the fluvial sediment than usual, which could be the result of increased sediment export due to high stream flows. Spring is also the beginning of the calving season in Ohio, when livestock and their offsprings are often seen grazing by or drinking straight from the stream.

Sediment Texture

SOM concentrations increase with decreasing grain size because organic matter adsorbs onto mineral surfaces. Given that fine grain sediment has more surface area available for absorption than courser grained sediments, it is able to hold more OM (Bergamaschi et al. 1997). A simple linear regression model found the correlation coefficient between the amount of clay size grains and the amount of OM in all samples to be R= 0.727 (R2 = 0.529), which indicates that about half of the variation in SOM is caused by the amount of clay size particles available. The correlation would be higher if not for three outliers which were samples taken from a developed site that had anomalously high concentrations of SOM. Two of these samples were taken during the spring, which probably contained larger pieces of organic debris that washed into the stream during high flows. The sediment displayed spatial and temporal variations in grain size distribution that could be attributed to a hydrodynamic control that, in return, influences the amount of OM present. As a result, what has been described above as controls on the distribution of SOM may actually be a control on the distribution of fine grain particles in the stream bed. To accurately describe land use and seasonal shifts as factors controlling SOM future tests will involve taking separate LOI measurements of SOM and carbonate for each grain size within each sediment sample, thus eliminating this confounding factor.

CONCLUSION

This study provides additional evidence that catchments draining urbanized land show the highest export of nutrients and OM to streams compared to other land uses. It also supports the contention that SOM concentrations depend highly on the proportion of fine grain particles available for adsorption. Our results also suggest that OM transport is highly dependent on catchment hydrology, mainly surface runoff that transports fine particles to streams during high precipitation events.

Future research directions include: (1) expanding the study to include more sampling sites that account for additional factors such as stream flow, microbial community, and underlying geology, among others; (2) comparing our results of a temperate deciduous forested region to those found in other biomes; (3) Develop an equation to correlate OM to OC in order to predict precise total soil carbon concentrations in the Clear Fork River by measuring both SOM (using LOI) and SOC separately; (4) apply the scenarios for precipitation changes from current climate models to predict future SOM and carbonate content in the streambed, including suspended DOC.

Acknowledgements

We gratefully acknowledge the financial support of the Professional Development Committee at the Mansfield Campus of the Ohio State University.

REFERENCES

Ball DF, 1964. Loss-on-ignition as an estimate of organic matter and organic carbon in non-calcareous soils. Journal of Soil Science 15: 84–92.

Battin TJ, Kaplan LA, Findlay S, Hopkinson CS, Marti E, Packman AI, Newbold JD, Sabater F, 2008. Biophysical controls of organic carbon fluxes in fluvial networks. Nature Geoscience 1: 95–100.

Bergamaschi BA, Tsamakis E, Ceil RG, Eglinton TI, Montlucon DB, Hedges JI, 1997. The effect of grain size and surface area on organic matter, lignin and carbohydrate concentration, and molecular compositions in Peru Margin sediments. Geochimica et Cosmochimica Acta 61: 1247–1260.

Cambardella CA, Gajda AM, Doran JW, Wienhold BJ, Kettler TA, 2001. Estimation of particulate and total organic matter by weight loss-on-ignition. In: Lal R, Kimble JM, Follett RF, Stewart BA (Eds.), Assessment Methods for Soil Carbon. Advances in Soil Science. CRC Press, Boca Raton, FL, pp. 349–359.

Castelle AJ, Johnson AW, Conolly C, 1994. Wetland and stream buffer size requirements: a review. Journal of Environmental Quality 23:878–882.

Cole JJ, Prairie YT, Caraco NF, McDowell WH, Tranvik LJ, Striegel RG, Duarte CM, Kortelainen P, Downing JA, Middelburg JJ, Melack J, 2007. Plumbing the global carbon cycle: integrating inland waters into the terrestrial carbon budget. Ecosystems 10: 171–184.

Curtin D, Campbell CA, Jalil A, 1998. Effects of acidity on mineralization: pH-dependence of organic matter mineralization in weakly acidic soils, Soil Biology and Biochemistry 30: 57–64.

Dean WE Jr, 1974. Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition: Comparison with other methods. Journal of Sedimentary Petrology 44: 242–248.

De Vos B, Vandecasteele B, Deckers J, Muys B, 2005. Capability of loss-on-ignition as a predictor of total organic carbon in non-calcareous forest soils Communications in Soil Science and Plant Analysis 36: 2899-2921.

Duxbury JM, Smith MS, Doran JW, Jordan C, Szott L, Vance E, 1989. Soil Organic Matter as a Source and a Sink of Plant Nutrients. In: Coleman DC, Oades JM, Uehara G (Eds.), Dynamics of Soil Organic Matter in Tropical Ecosystems. University of Hawaii Press, Honolulu, 33–67.

Fischer H, Wanner SC, Pusch M, 2002. Bacterial abundance and production in river sediments as related to the biochemical composition of particulate organic matter (POM). Biogeochemistry 61: 37–55.

Gong W, Yan X, Wang J, Hu T, Gong Y, 2009. Long-term manure and fertilizer effects on soil organic matter fractions and microbes under a wheat–maize cropping system in northern China. Geoderma 149: 318–324.

Hamilton SK, Kurzman AL, Arango C, Jin L, Robertson GP, 2007. Evidence for carbon sequestration by agricultural liming. Global Biogeochemical Cycles 21, GB2021, doi:10.1029/2006GB002738.

Heiri O, Lotter AF, Lemcke G, 2001. Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. Journal of Paleolimnology 25: 101–110.

Homer C, Huang C, Yang L, Wylie B, Coan M, 2004. Development of a 2001 National Landcover Database for the United States. Photogrammetric Engineering and Remote Sensing 70: 829–840.

Horowitz AJ, Stephens VC, 2008. The effects of land use on fluvial sediment chemistry for the conterminous U.S. – Results from the first cycle of the NAWQA Program: Trace and major elements, phosphorus, carbon and sulfur. Science of the Total Environment 400: 290–314.

Jackson CR, Vallaire SC, 2007. Microbial activity and decomposition of fine particulate organic matter in a Louisiana cypress swamp. Journal of the North American Benthological Society 26: 743–753.

Konen ME, Jacobs PM, Burras CL, Talaga BJ, Mason JA, 2002. Equations for predicting soil organic carbon using loss-on-ignition for north central U.S. soils. Soil Science Society of America Journal 66: 1878–1881.

Lal R, 2004. Soil carbon sequestration to mitigate climate change. Geoderma 123: 1–22.

Larson JH, Frost PC, Lodge DM, Lamberti GA, 2007. Photodegradation of dissolved organic matter in forested streams of the northern Great Lakes region. Journal of the North American Benthological Society 26: 416–425.

NWS (National Weather Service) 2009. Mansfield Climate Graphs. http://www.erh.noaa.gov/cle/climate/graphs/MFD_graph.html. Accessed 14 March 2010.

ODNR (Ohio Department of Natural Resources), 2004. Soil Survey of Richland County, OH. http://www.dnr.state.oh.us/Portals/12/soils/pdf/survey_pdfs/richland_supplement.pdf. Accessed 27 September 2009.

ODNR, 1998. Physiographic regions of Ohio. Division of Geological Survey, Ohio Department of Natural Resources, page-size map with text, 2 p., scale 1:2,100,000

Post WM, Izaurralde RC, Mann LK, Bliss N, 2001. Monitoring and verifying changes of organic carbon in soil. Climatic Change 51: 73–99.

Schulte EE, Hopkins BG, 1996. Estimation of Soil Organic Matter by Weight Loss-On-Ignition. In: Magdoff FR, Tabatasbai MA, Hanlon, EA Jr. (Eds.), Soil Organic Matter: Analysis and Interpretation. SSSA, Inc., Madison, Wis. Special Pub. No. 46; Proceedings of a symposium sponsored by Divisions S-4 and S-8 of the Soil Science Society of America in Seattle, Wash., pp. 21-31.

Seastedt TR, Crossley DA Jr, Meentemeyer V, Waide JB, 1983. A Two-Year Study of Leaf Litter Decomposition as Related to Macroclimatic Factors and Microarthropod Abundance in the Southern Appalachians. Holarctic Ecology 6: 11–16.

Shibu ME, Leffelaar PA, Van Keulen H, Aggarwal PK, 2006. Quantitative description of soil organic matter dynamics—a review of approaches with reference to rice-based cropping systems. Geoderma 137: 1–18.

Shields FD Jr, Knight SS, Stofleth JM, 2008. Stream bed organic carbon and biotic integrity. Aquatic Conservation 18: 761–779.

Simon A, Rinaldi M, 2006. Disturbance, stream incision, and channel evolution: The roles of excess transport capacity and boundary materials in controlling channel response. Geomorphology 79: 361–383.

Stevenson FJ, 1994. Humus chemistry: Genesis, composition, reactions. John Wiley & Sons, New York, 512 p.

Sutherland RA, 1998. Loss-On-Ignition estimates of organic matter and relationships to organic carbon in fluvial bed sediments. Hydrobiologia 389: 153–167.

Swift RS, 1996. Organic matter characterization. In: Sparks DL (Ed.), Methods of soil analysis. Part 3—Chemical methods. SSSA Book Ser. No. 5. SSSA and ASA, Madison, WI, pp. 1011–1069.

Synder TD, Cowen WF, 2001. Ohio Trees Bulletin. Department of Natural Resources, The Ohio State University. http://ohioline.osu.edu/b700/index.html. Accessed 30 December 2009.

Theobald DM, Norman J, Peterson E, Ferraz S, 2005. Functional Linkage of Watersheds and Streams (FLoWS): Network-based ArcGIS tools to analyze freshwater ecosystems, ESRI International Users Conference. Redlands, CA, ESRI headquarters.

Tiessen H, Cuevas B, Chacon P, 1994. The role of soil organic matter in sustaining soil fertility. Nature 371: 783–785.

Trumbore SE, 1997. Potential Responses of Soil carbon to Global Change. Proceedings of the National Academy of Sciences 94: 8284–8291.

USGS (United States Geological Survey) 2009. Surface Water data for Ohio: USGS Surface-Water Monthly Statistics, http://waterdata.usgs.gov/oh/nwis/monthly/?referred_module=sw&site_no=04196000&por_04196000_2=707574,00060,2,1925-09,2008-09&format=html_table&date_format=YYYY-MM-DD&rdb_compression=file&submitted_form=parameter_selection_list. Accessed 27 September 2009.

Wallace JB, Whiles MR, Eggert S, Cuffney TF, Lugthart GJ, Chung K, 1995. Long-term dynamics of coarse particulate organic matter in three Appalachian Mountain streams. Journal of the North American Benthological Society 14: 217–232.

Webster JR, Meyer JL, 1997. Stream organic matter budgets - introduction. Journal of the North American Benthological Society 16: 5–13.

Wetzel RG, Hatcher PG, Bianchi TS, 1995. Natural photolysis by ultraviolet irradiance of recalcitrant dissolved organic matter to simple substrates for rapid bacterial metabolism. Limnology and Oceanography 40: 1369–1380.

Wipfli MS, Richardson JS, Naiman RJ, 2007. Ecological linkages between headwaters and downstream ecosystems: transport of organic matter, invertebrates, and wood down headwater channels. Journal of the American Water Resources Association 43: 72–85.

Young RG, Matthaei CD, Townsend CR, 2008. Organic matter breakdown and ecosystem metabolism: functional indicators for assessing river ecosystem health. Journal of the North American Benthological Society 27: 605–625.