Tracking Phosphorus and Sediment Sources and Transport from Fields and Channels in Great Lakes Restoration Initiative Priority Watersheds

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Introduction

Western Lake Erie is one of several freshwater ecosystems that have experienced record-high harmful algal blooms (HABs) in the last two decades, with notable issues occurring in 2008, 2011, 2014, and 2015 (Ho & Michalak, 2015; Michalak et al., 2013). These HABs have been linked to a combination of nutrient loads, specifically abundance, stoichiometry, and bioavailability of nitrogen (N) and phosphorus (P); algal and mussel populations; high spring runoff; and climate patterns that enable long residence times of algae in warm, calm conditions that extend from late spring into mid-fall (Ho & Michalak, 2017; Michalak et al., 2013; Zhang et al., 2016). For example, large precipitation events in late winter and spring of 2011 resulted in relatively high daily-mean streamflow from the Maumee River resulting in high loads of dissolved reactive phosphorus, also known as orthophosphate (PO^4; orthoP) (Michalak et al., 2013). Examination of historical abundance of HABs has shown that a high proportion of interannual variability can be linked to orthoP, especially high spring orthoP loads and decadal scale loading within Lake Erie (Ho & Michalak, 2017; Scavia et al., 2016). This is exacerbated by the sediment-bound pool of P (sed-P) in western Lake Erie and organic matter decay (Zhang et al., 2016), which may release P over multiple years as a result of resuspension, redoximorphic conditions, and biological processes in this shallow lake environment (Søndergaard et al., 2003). High total annual discharge directly correlates with high total P (TP) annual loads (Han et al., 2012). The implications are that minimizing spring P loading, while also limiting the overall contribution of P to the system, is key to minimizing blooms (Ho & Michalak, 2017; Scavia et al., 2016; Zhang et al., 2016).

Non-point sources, like cropland, animal operations, and septic systems, contribute a majority of TP delivered to western Lake Erie by the Maumee River (Han et al., 2012). On average, the western Lake Erie basin receives 60% of the TP load for the whole lake and 66% of the orthoP (Dolan & Richards, 2008); orthoP loads average 30% of the TP load to Lake Erie (Scavia et al., 2016). Agricultural watersheds export the most TP, combining sed-P with orthoP (Han et al., 2012). Fine-grained sediment is considered among the most significant of pollutants because in addition to transporting excess nutrients, especially P, and hydrophobic pesticides, fine-grained sediment physically degrades aquatic habitat by burying substrate and attenuating light

(Lowrance et al., 2006). However, in some cases, best management practices (BMPs) that successfully address sediment and sed-P, like conservation tillage, have been linked to increased dissolved nutrients, such as orthoP (Fanelli et al., 2019; Michalak et al., 2013). This further complicates the implementation of BMPs and underscores the need for quantifying how individual BMPs relate to both proportional and absolute contributions of sediment and TP to stream systems and larger water bodies like the Great Lakes.

Another complication in understanding the seasonal contribution of sediment and sed-P from agricultural landscapes to the stream system is identifying how material is eroded and transported from fields and how movement of sediment and sed-P differs as a function of field management. At the edge-of-field scale, distinguishing surficial erosion from erosion that extends deeper into the soil profile can help document and quantify the benefits of individual BMPs, including tile-drainage, conservation tillage, grassed waterways, and cover crops. Fallout radionuclides, such as cesium-137 (^{137}Cs), unsupported lead-210 ($^{210}Pb_{xs}$), and beryllium-7 (^{7}Be), have proved useful for this distinction. In particular, the 54-d half-life of ^{7}Be makes it appropriate for estimating surface erosion on short-term time scales (Ryken et al., 2018b), including removal and transport of surface soil from agricultural fields (Blake et al., 1999). Beryllium-7 is naturally occurring in precipitation as a consequence of cosmic ray spallation of N or oxygen (Blake et al., 1999) and provides an ability to examine short-term erosion because of its short half-life combined with a propensity for rapid, stable adsorption to soil particles at the surface that are the first to come in contact with precipitation (Ryken et al., 2018a). The concentration of ^{7}Be in precipitation can significantly vary geographically, among storms, and even during individual storms (Walling, 2013). Beryllium-7 is generally concentrated near the soil surface (organic litter layer and top 0.5-1 cm) in both cultivated and “undisturbed” soils (Walling, 2013). Comparison of the ^{7}Be signature of sediment leaving individual fields with different BMPs provides information on how the proportion of eroded material differs between near-surface and deeper soil sources as a function of current field conditions (Blake et al., 1999).

Sediment source tracking provides a direct method to quantify suspended sediment, and consequently sed-P, sources by identifying a minimal set of properties (or fingerprint) that uniquely defines individual sources of sediment in the basin (Gellis & Walling, 2013). Sediment source tracking can be applied on a range of temporal scales, focusing on individual storms (Cashman et al., 2018), seasonal patterns (Crain et al., 2017), and annual synopses (Williamson et al., 2014). Sediment source tracking has been successfully used to discriminate both provenance (Collins et al., 1998) and land use, including differentiating active cropland from both pasture land and retired cropland (Crain et al., 2017; Williamson et al., 2014). Sediment source tracking can also help distinguish sediment from roadside ditches, gullies, and streambanks (see Fitzpatrick et al., this volume). Knowing more about when and from where suspended sediment is being transported provides an opportunity to understand how seasonal variability in nutrient and sediment loads might relate to land use -- key information for resource managers. Moreover, quantifying the effects of independent BMP implementation on sediment and nutrient movement provides a mechanism of isolating and valuing the potential of these BMPs to help reach nutrient and sediment reduction targets.

The study-design described here is for the Black Creek, IN basin (12-digit hydrologic unit code [HUC-12] 041000050104; USGS Site ID 04183038), a tributary to the Maumee River that has been identified as a significant contributor to nutrient and sediment loads (Robertson & Saad, 2011). In October 2015, long-term, continuous streamflow and water-quality monitoring began along Black Creek (32 km^2 at the gage; Figure 1). This watershed-scale monitoring is supplemented by edge-of-field monitoring of a pair of agricultural fields in the basin where discharge and water quality of both surface runoff and tile-drain flow are being monitored.

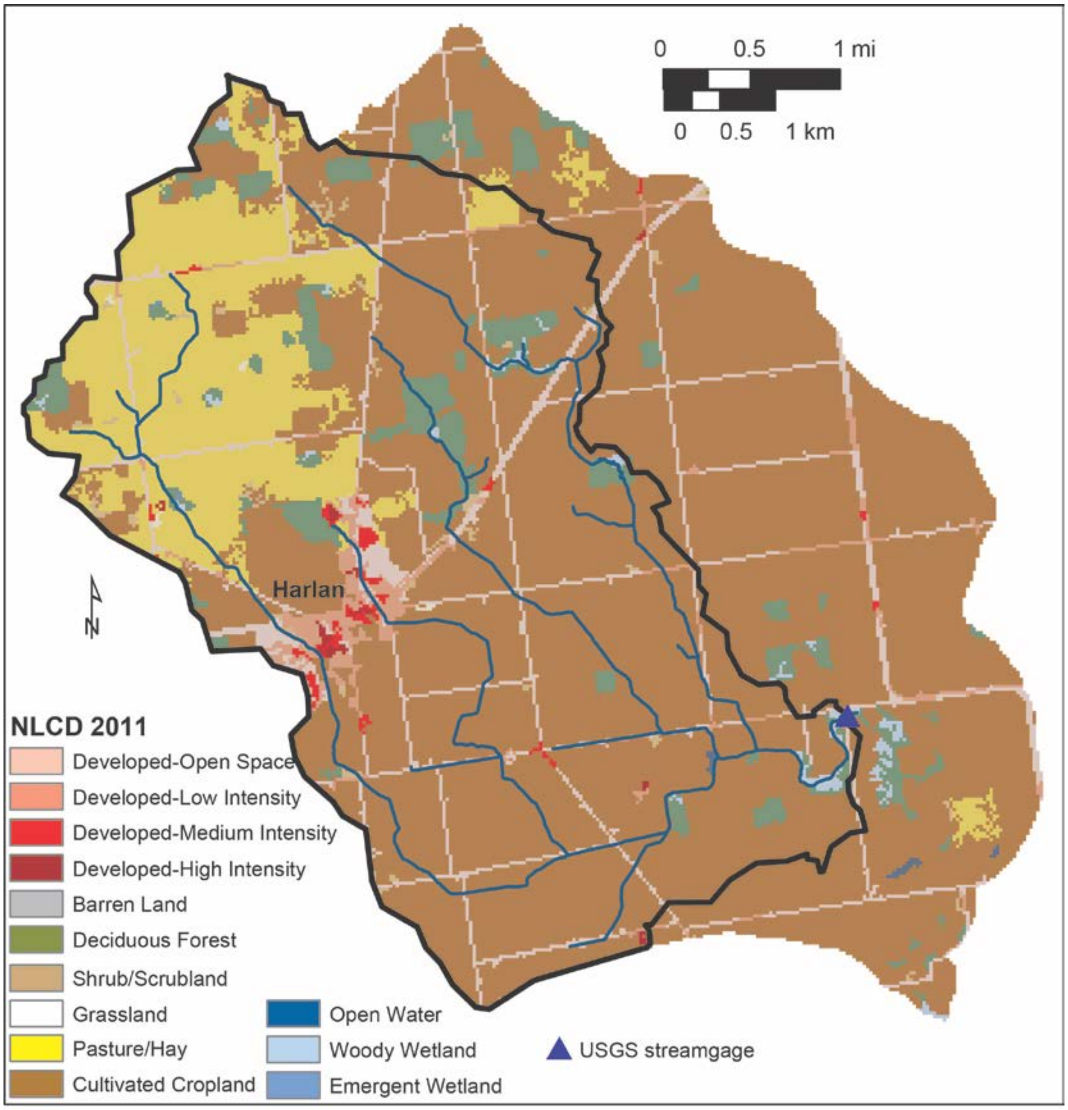

Figure 1. Black Creek basin, Indiana. The population center is Harlan, Indiana. Land cover is shown for the entire basin, a tributary to the Maumee River. The black outline and stream network shows the basin that is sampled by the USGS streamgage (Site ID 04183038).

Edge-of-field monitoring included three years when these fields were managed the same way (pre-BMP), and is continuing through a period after adoption of a new BMP (cover crop) on one of the fields in November 2018. In addition, sediment source tracking is being combined with ^{7}Be sampling to apportion sources of sediment from these agricultural fields both before and after implementation of the cover-crop BMP; these fields are bounded by forest and a road that are additional potential sources of sediment. Sediment source tracking and ^{7}Be analysis at the edge-of-field site was combined with sediment source tracking for the Black Creek basin during the 2018 water year to differentiate the seasonal contribution of cropland sediment from that derived from developed areas, forested patches, and pastures. Microbial source tracking began in January 2019 at the Black Creek gage to complement the sediment source tracking. Our objective is to provide local resource managers, including the Allen County Soil and Water Conservation District, local residents, US Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS), and the US Environmental Protection Agency (USEPA) information on:

- the variability of sources of sediment and sed-P during the year, especially during the March to July period of concern;
- the relation between agricultural-management practices and subsurface versus surface flow paths of nutrients and sediment;
- the contribution of non-cropland sources to nutrient and sediment loads in the basin.

Parallel work is also underway in Plum Creek, WI (HUC-12 040302040204, USGS Site ID 04084911), a tributary of the Lower Fox River, with a focus on similar land uses and the construction of a grassed waterway as the BMP being evaluated.

Study Design

As part of the Great Lakes Restoration Initiative (GLRI), sediment and microbial source tracking is being combined with P and sediment monitoring in stream water within two study watersheds identified as major contributors of P to the Great Lakes (Robertson & Saad, 2011): the 50 km^2 Black Creek, Indiana in the Maumee River basin (Lake Erie) and the 90 km^2 Plum Creek in the Lower Fox River basin (Lake Michigan). Details below focus on aspects of the Indiana site. The Lower Fox site is discussed elsewhere in these proceedings (see Fitzpatrick et al.).

Multiple tracking methods are being used and adapted for best results in these watersheds, including a suite of trace elements for overall source apportionment in addition to the short-term fallout radionuclide ^{7}Be for high-flow event-based transport on fields and in stream channels. Tile-drain connectivity to the surface is of critical interest in the Black Creek watershed, as both nutrients and sediment are transported through tile systems (e.g. Cuadra & Vidon, 2011; Vidon & Cuadra, 2011; Williamson et al., 2019); this is less of a concern in the Plum Creek basin, where the steep topography precludes the need for sub-surface drainage. Microbial source tracking has been integrated in the Black Creek basin because of the abundance of active horse pastures alongside confined animal operations that include poultry, swine, and cattle.

Sediment Source Tracking: Upland sources were sampled during July and August 2017 throughout the Black Creek basin upstream of the gage (Table 1), including sites close to 1st thru 5th order streams (Horton, 1945). Fifteen samples were obtained for each source type, with multiple source types sampled at the same general location when possible to limit the potential for localized differences in parent material to obscure the land-use signature. For each of the four land-use type sources (cropland, pasture, forest, and roads), the top 1-2 cm of soil material was composited along a total transect of 250 m, with one sample collected every 10 m, usually along five parallel lengths; roads were sampled along a 150-m transect, collecting from both sides and the center. Fields sampled included corn, soybean, wheat, and alfalfa under traditional tillage and conservation tillage and a combination of fertilizer and manure management. Roads included both those within and outside the population center of Harlan, IN. Because previous researchers have shown that streambanks generally contribute a majority of the material carried as suspended sediment in both agricultural and rural/suburban environments (Cashman et al., 2018; Gellis & Noe, 2013; Lamba et al., 2015), low and middle streambanks were also sampled from both sides of a stream for a 100-m length. Streambanks were sampled at sites that included streams bounded by a combination of the land-use source types and riparian environments. Sampling and laboratory materials used for both upland source samples and sediment samples were plastic to avoid any potential for metal contamination.

Table 1. Upland area and land use[1] distribution for each sampling site.

Site	Area	Cropland	Pasture	Forest	Developed	Stream Length[2]
	km^2		%			km
Black Creek	34.5[3]	66	20	6	8	260
Western Tributary	5.85	19	65	5	11	52
Eastern Tributary	5.56	66	17	11	6	60
BMP field	0.25	66	0	34	0[4]	NA
Control field	0.15	100	0	0	0[4]	NA

[1]Land use from NLCD 2011 (Homer et al., 2012) – roads are grouped with developed areas; [2]stream length calculated from National Hydrography Database (U.S. Geological Survey et al., 2009); [3]area upstream of USGS gage; [4]a road divides these two fields, so each has the potential to receive surface runoff from the road.

Each source sample was sub-sampled at the USGS Kentucky Sediment Laboratory, where material was wet sieved to remove particles larger than 63 micrometers in diameter, freeze dried, and sent for trace metal (Table 2) and carbon-form analysis (USGS Central Region Mineral Laboratory schedules 3a, 3b, and 17; https://minerals.usgs.gov/science/analytical-chemistry/) in addition to stable isotope analysis of total carbon (TC) and TN (USGS Reston Stable Isotope Laboratory schedule 1832) of the fine-grained sediment. An additional sub-sample was sent to the USGS Cascades Volcano Observatory Sediment Laboratory, where particle-size distribution was analyzed using an x-ray absorption particle-size analyzer (SediGraph III) to obtain a mean particle diameter by mass (d_{50}).

Table 2. Indicators used for fingerprint analysis of sediment denoted by Name (Symbol).

Silver (Ag)	Cobalt (Co)	Lanthanum (La)	Phosphorus (TP-s)	Tantalum (Ta)	Yttrium (Y)
Aluminum (Al)	Chromium (Cr)	Lithium (Li)	Lead (Pb)	Terbium (Tb)	Ytterbium (Yb)
Arsenic (As)	Cesium (Cs)	Lutetium (Lu)	Rubidium (Rb)	Tellurium (Te)	Zinc (Zn)
Barium (Ba)	Copper (Cu)	Magnesium (Mg)	Sulfur (S)	Thorium (Th)	Zirconium (Zr)
Beryllium (Be)	Iron (Fe)	Manganese (Mn)	Antimony (Sb)	Titanium (Ti)	
Bismuth (Bi)	Gallium (Ga)	Molybdenum (Mo)	Scandium (Sc)	Thallium (Tl)	Nitrogen (TN-s), $\delta^{15}N$
Calcium (Ca)	Hafnium (Hf)	Sodium (Na)	Selenium (Se)	Uranium (U)	Carbon (TC-s), $\delta^{13}C$
Cadmium (Cd)	Indium (In)	Niobium (Nb)	Tin (Sn)	Vanadium (V)	Organic C (OrgC)
Cerium (Ce)	Potassium (K)	Nickel (Ni)	Strontium (Sr)	Tungsten (W)	Carbonate C (CO3)

-s: sediment; δ: delta

Suspended sediment was collected monthly (Table 3) from two passive samplers (also known as Walling Tubes; Phillips et al., 2000) that were installed upstream of the USGS gage on Black Creek. Suspended sediment was also collected at two smaller, parallel tributary sites (Western and Eastern Tributaries) with drainage areas of approximately 6 km^2 and different land-use distributions (Table 1). Each of these in-situ, passive samplers was placed along the thalweg, at the water surface during low flow with the opening submerged, to provide a flow-integrated sample that included both low-flow and stormflow conditions. Black Creek is a 5th order stream and each of the sampled tributaries are 4th order streams. Passive samplers at the Black Creek gage were removed after the November 2017 sampling and replaced at the end of February 2018 because the stream was covered with ice; the tributaries continued to flow. Soft sediment from the stream bottom was collected along a 50-m transect centered on the passive samplers before they were installed in August 2017. This provided a second type of time-integrated sediment sample focused on sediment accumulation on the bottom of the channel. Suspended sediment was also collected from the edge-of-field site by placing a passive sampler immediately downstream of the flume that concentrates overland flow for the surface-runoff and water-quality monitoring. Sediment from the passive samplers and soft-bottom sediment, both of which are considered "target" samples, was processed similarly to the source material. Passive samplers usually contained stream water in addition to suspended sediment; these samples were rinsed into buckets using additional native water and then allowed to settle to isolate the sediment. In the case of the edge-of-field site, samplers were generally rinsed with deionized water. In two cases, these samplers were rinsed with pumped groundwater, and in one case, stream water from one of the tributary sites was used, so this sample was only analyzed for particle size analysis (PSA) and not metal or nutrient abundance. For several months, there was not enough material from the edge-of-field site for all of the laboratories and, therefore, particle size will be estimated using data from other months.

Table 3. Monthly collection and aggregation of suspended sediment at each site

	2017				2018												2019								
Site	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
Black Creek	↔	↔	x				x	x	x	x	x	x	x												
Western T.	↔	↔	x	↔	↔	x	x	x	x	x	x	x	x												
Eastern T.			x	↔	↔	x	x	x	x	x	x	x	x												
BMP Field			x		x*	x[1]	x[1]	x[1]	x[1]	x		x[1]		x		x		x		B		B		B	

T. – tributary; ↔ multiple months were composited to have enough sample for lab analyses; *used only for particle size analysis (PSA); [1]not enough material for PSA; B bi-monthly sampling planned for the second year at the edge-of-field site only

The Sediment Source Assessment Tool (SedSAT; Gorman Sanisaca et al., 2017) was used for source apportionment. SedSAT includes preliminary steps for data normality checks, data transformations, and handling non-detect data. Indicator values can be adjusted as a function of median particle size and organic carbon abundance (OrgC); this addresses differences in surface area which may affect the abundance of different indicators. A bracket test eliminates any indicators for which the target sample exceeds the range of the upland source samples. Sources are apportioned through individual runs for each target sample. A linear discriminant function analysis (DFA) evaluates each indicator in order to identify those that best separate the source categories; additional indicators are incorporated if they improve this separation at a significance level of 0.01. Once each indicator has been evaluated and ranked for the contribution to discrimination of sources, a mixing model uses the relation among these indicators to apportion the original source samples, providing a confidence level for target sample apportionment; this mixing model is run as a Monte Carlo analysis with 1000 iterations. The fluvial target sample is then evaluated using the same mixing model, again using a Monte Carlo analysis with 1000 iterations.

For this *preliminary work*, data were only adjusted by the OrgC, but final results will also incorporate adjustment using median particle size. Source data and target data for the tributaries and edge-of-field monitoring will be published as a USGS Data Series when all analyses have been completed. Data for the Black Creek gage site will be published on the National Water Information System (NWIS) as per USGS fundamental science practices.

Characterization of Soil Erosion at Edge-of-Field Site Using ^{7}Be: To evaluate the effect of a cover crop on field erosion, ^{7}Be is being used to characterize surface erosion at paired fields (BMP and control) at the edge-of-field site. ^{7}Be activity is being measured in:

- the soil profile sampled before a precipitation event,
- rainfall for a discrete period, and
- sediment from field runoff corresponding to the same precipitation period.

To maximize the likelihood of enough overland flow to provide an adequate volume of sediment, precipitation events that extend over a series of days have been targeted.

Beryllium-7 is a naturally-derived radionuclide tracer mainly delivered to the soil surface in precipitation (Kaste et al., 2002). In soils, the ^{7}Be activity density (becquerel per kilogram; Bq/kg) is generally highest at the surface and decreases exponentially with depth. Overall, ^{7}Be binds strongly to surface soils and sediments, with some variation due to organic content and soil or sediment grain size and surface area (Ryken et al., 2018a). Beryllium-7 has been shown to rapidly and stably bind to arable (drained) soils like the Aqualfs (U.S. Department of Agriculture - Natural Resource Conservation Service [USDA-NRCS], 2016) at the Indiana edge-of-field site (Ryken et al., 2018a), with potentially higher sorption to the finer-grained Aquolls that define the preferential flowpaths in these fields (Ryken et al., 2018b). Due to its strong binding affinity and short half-life, ^{7}Be provides a means of differentiating surface soil from that below the surface (Walling, 2013). The ^{7}Be activity of suspended sediment in runoff from the field can be compared to the established field inventory (pre-precipitation activity resulting from previous event(s) and decay since previous event(s)) and that in the precipitation event, indicating whether sediment is majorly derived from the surface or from deeper soil erosion. Conceptually, if the ^{7}Be activity in the suspended sediment is relatively high, then surface erosion is the dominant source of the suspended sediment because this material came in contact with precipitation because of its location at the top of the soil profile and/or its contact with event precipitation while traveling in suspension. Conversely, if the ^{7}Be activity in the suspended sediment is lower than that in the baseline soil, then rilling and gully erosion deeper into the soil profile (of material that has no ^{7}Be activity) is contributing to sediment at the edge-of-field collection point. At the edge-of-field site, this ^{7}Be signature can be combined with the suspended-sediment concentration to understand if the abundance of eroded material is a function of how erosion is occurring and enables quantification of surface versus deeper erosion processes. Additionally, a mass balance can be performed on an event timescale to determine the net surface erosion during storm events.

Spring, summer, and fall events were monitored for surface erosion in 2018; winter (snow) events were not sampled because precipitation coming into contact with the soil surface must be from discrete events and these sites experience snowpack accumulation and melt that integrates multiple storms. Suspended sediment was collected in the same type of passive sampler used for sediment source tracking; three passive samplers were placed at the edge-of-field outlet. Both the BMP and the control field were sampled for each event; this is being repeated in 2019 now that the cover-crop BMP is in place. The first year of data, with both fields managed the same way, will illustrate if the fields undergo similar surface erosion for each of the sampled events. The second year of sampling will provide an ability to assess the effect of the BMP on surface erosion and how that relates to suspended-sediment concentration and proportional contribution from cropland relative to adjacent forest and roads.

Previous work at the Indiana edge-of-field site has shown a difference in tile-drain connectivity between the paired fields as exhibited by consistent differences in duration, magnitude, and water quality of tile-drain discharge, especially sediment, orthoP, and TP concentrations (Williamson et al., 2019). Consequently, ^{7}Be is also being analyzed for composited field runoff collected as part of the general edge-of-field monitoring. This is only being attempted for storms that produce a large volume of runoff from both overland and tile-drain samples; no precipitation or baseline soil samples are being collected. The hypothesis is that the ^{7}Be analysis will distinguish material derived from surface erosion, that may be delivered to the tile system by unintentional exposure to the surface, from deeper soil material entering through weak or broken connections in this aged, clay, tile-drain system.

Beryllium-7 activity is being measured at the University of Minnesota short-term radionuclide lab via gamma-ray spectrometry on high-purity germanium gamma-ray spectrometers

(Canberra Broad Energy and Canberra Coaxial type detectors). Solids and sediments are oven dried (55^{o}C) for 48 hours before being analyzed. Liquid samples, including rainfall, tile-drain effluent, and overland flow, are first precipitated onto ion-exchange resins before analysis by the methods of Karwan et al. (2016). The ^{7}Be activity density (Bq/kg) associated with suspended sediments and soils and the activity concentration (Bq/L) in precipitation, was computed based upon the multi-channel peak area centered at 477.7 keV; background was computed for each sample using the 5-channels bracketing each peak and an empty counting vessel. Efficiency of the ^{7}Be peak was determined through interpolation between known peaks (Lead-210 at 46.5 keV, Americium-241 at 59.5 keV, Cadmium-109 at 88.0 keV, Cobalt-57 at 122.1 keV, and Cesium-137 at 661.7 keV) in a mixed isotope standard (Eckert & Ziegler Analytics, Atlanta, GA). The detectors used in this project have been previously calibrated with ^{7}Be standard reference material (Eckert & Ziegler Analytics, Atlanta, GA) added to both the ion exchange resins and characteristic suspended sediment. Correction for interference from the ^{228}Ac peak centered at 478.3 keV was based on the methods of Landis et al. (2012).

Preliminary Results and Integration of Tracer Methods

Preliminary results from the Black Creek basin show that critical indicators of sediment source include: Zr, W, TN-s, Mo, OrgC, TC-s, TP-s, Mg. Together, these indicators discriminate the five sources to a confidence of 91% (Figure 2). Similar to Williamson et al. (2014), both TP-s and carbon forms were identified as critical indicators, reflecting expected differences in nutrient abundance among these five environments (Figure 3), with the highest TP-s on active cropland and the highest OrgC on forested land and roads. This source discrimination is being used in a mixing model (Gorman Sanisaca et al., 2017) to apportion sediment among the different land uses on a seasonal time step. For example, the first aggregated sample for the Black Creek gage site, including September and October 2017, is derived mainly from streambank (39%) and pasture (33%) sources, combined with 18% cropland and 11% roads – there was no apparent contribution from forested land (Figure 4).

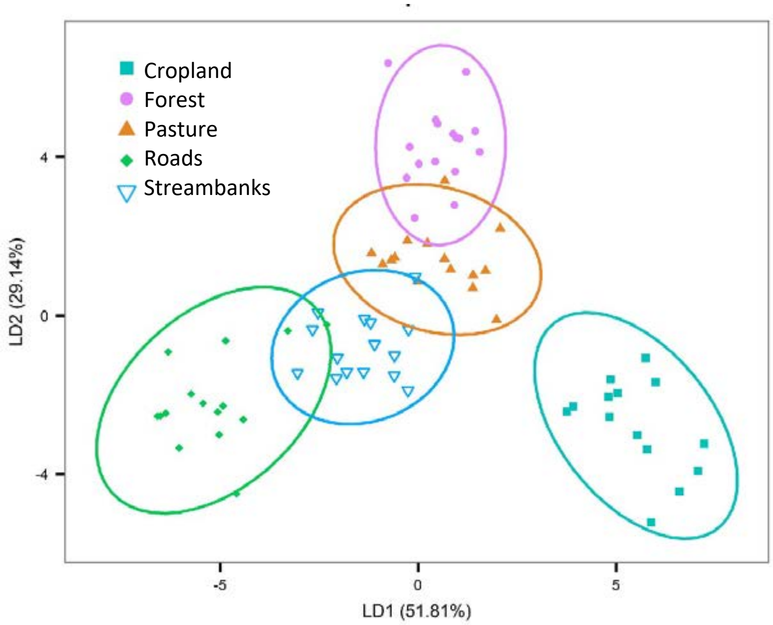

Figure 2. Preliminary source discrimination for September-October sediment from Black Creek gage site. LD1 is the indicator that provides the most differentiation (51.81%) among the sources - this is Zirconium. LD2 is the next most differentiating indicator - Tungsten. Eight critical indicators were identified.

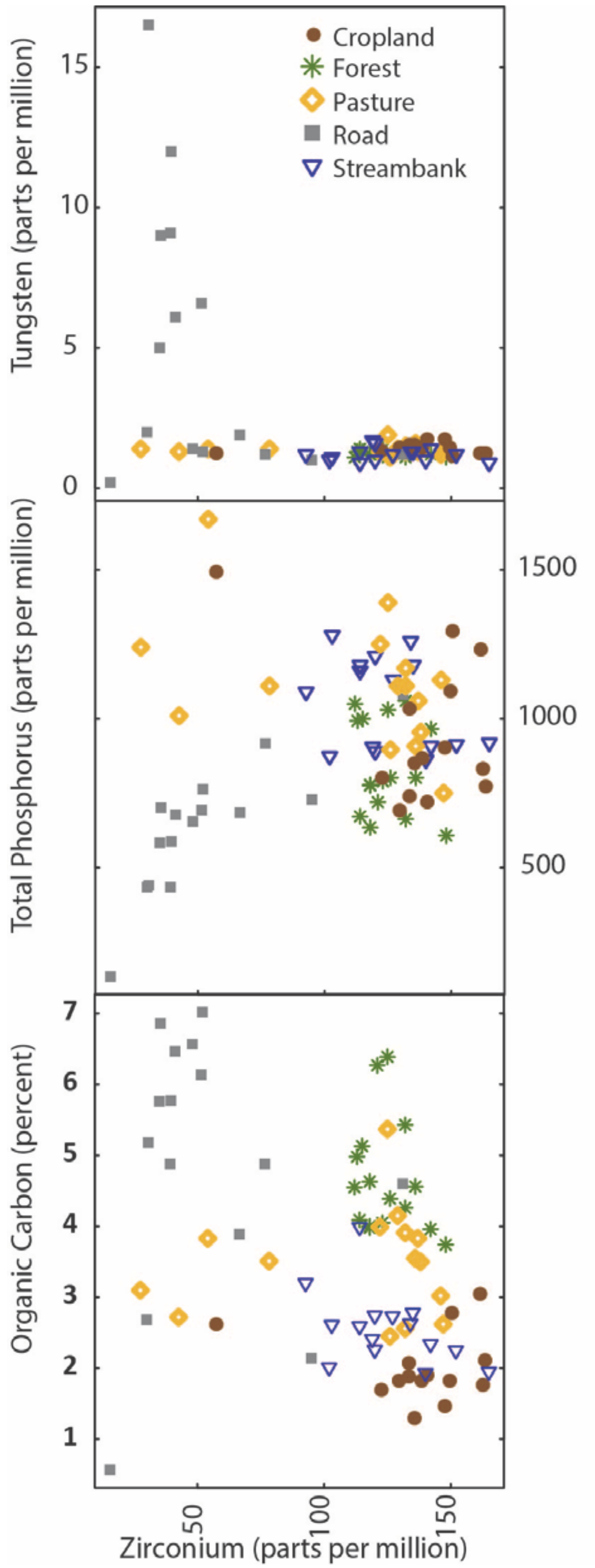

Figure 3. Concentrations of indicators. Preliminary analysis identified zirconium and tungsten as the two indicators that best separate the sources. Organic carbon and total phosphorus in sediment significantly improve this differentiation; their relative abundance reflects what we would expect from these five environments.

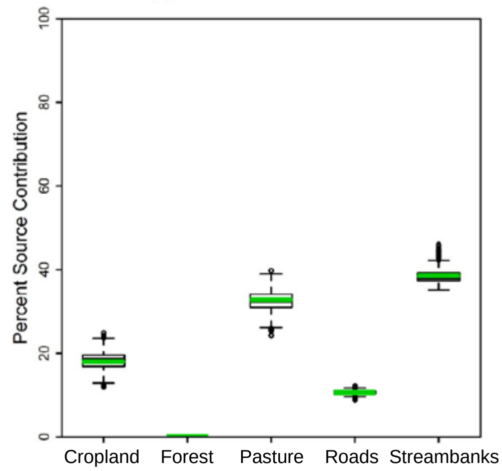

Figure 4. Preliminary source allocation for sediment from September-October 2017 Black Creek gage site.

When active erosion off the agricultural fields is considered, preliminary results show that ^{7}Be activity density in suspended sediment is similar from both the control and the pre-BMP field at the Indiana edge-of-field site, indicating similar erosion processes. The soil inventories from before the event show a range of depth profiles from the two fields, with ^{7}Be accumulation in organic matter at the soil surface and almost no ^{7}Be activity below the surface soil (Figure 5). A preliminary difference between the Black Creek, IN and Plum Creek, WI fields is in the baseline ^{7}Be profile. This difference reflects field management: the Indiana site is no-till and the Wisconsin site is conventional tillage, resulting in direct contact of precipitation with an irregular surface, exposed soil in cracks, and clods of soil that are left at the surface. Over time, this results in ^{7}Be being incorporated deeper into the soil at the Wisconsin site, with a more gradual decrease in ^{7}Be activity over the plow-layer depth.

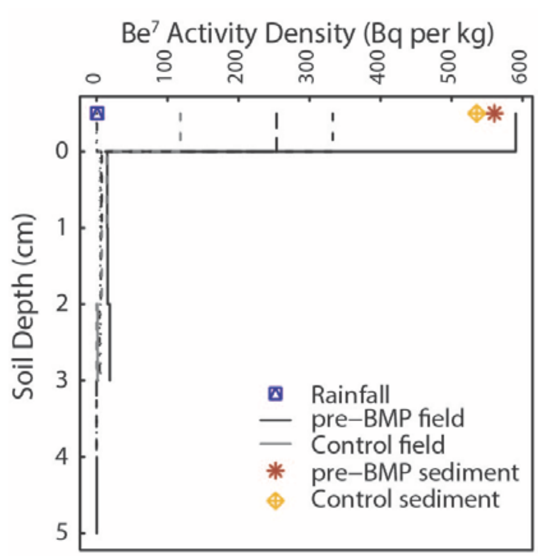

Figure 5. Preliminary ^{7}Be results from the Indiana edge-of-field sites for the 3/30/2018 event. Pre-event cores indicate ^{7}Be is only in the organic-litter layer and very near the surface in the soil profiles in these fields, with no ^{7}Be measurable below 5 cm. Differences among individual cores could be due to particle size and organic matter content differences as well as gamma counting differences for low-mass organic samples on the top of the profiles.

Summary

The strength of this sediment source tracking study lies in the inclusion of a pre-BMP period, including paired edge-of-field sites in Indiana that will enable ongoing comparison between BMP and control conditions. At the field scale, this will provide information on how the cover-crop BMP changes the source of sediment in both overland and tile-drain flow at the Indiana edge-of-field site, in addition to how it changes the abundance of overland flow and concentration of suspended sediment. Incorporation of ^{7}Be analysis will help document how BMP implementation alters both surface and deeper-soil erosion as a function of storm type and field conditions. The ability to quantify the effect of individual BMPs in terms of sediment source, abundance, and link to nutrient concentrations will provide a way of valuing these field-management strategies to water quality in both the focus basins of Black Creek, IN and Plum Creek, WI as well as the western Lake Erie and Lake Michigan basins.

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