

# Short- and long-term legacies of carbon sequestration, and nutrient burial in floodplain wetlands of agricultural and forested catchments, Indiana, United States

Christopher Craft<sup>1</sup>  | Shanze Li<sup>2</sup> 

<sup>1</sup>O'Neill School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana, USA

<sup>2</sup>State Key Laboratory of Simulation and Regulation of Water Cycle in River Basin, China Institute of Water Resources and Hydropower Research, Beijing, China

## Correspondence

Shanze Li, State Key Laboratory of Simulation and Regulation of Water Cycle in River Basin, China Institute of Water Resources and Hydropower Research, Beijing 100038, China.  
Email: [lishanze@126.com](mailto:lishanze@126.com)

## Funding information

Young Elite Scientists Sponsorship Program, Grant/Award Number: 2022QNRC001; National Science Foundation, Grant/Award Numbers: OCE-062059, OCE-1237140, and OCE-1832178

## Abstract

Soil organic carbon (C) sequestration and nitrogen (N) and phosphorus (P) burial were measured in two floodplain wetlands' soils of the West Fork of the White River watershed (Indiana, United States) whose catchments differed in land use to better understand how land use practices affect wetland C and nutrient retention. The catchment of one floodplain, Upper West Fork, is dominated by row crop agriculture (61%) whereas the second catchment, Beanblossom Creek, is mostly forested (85%). Soils (0–30 cm) of the two floodplain wetlands had similar bulk density (1.23 g/cm<sup>3</sup>). Soil organic C and N were low in both floodplains but the percent organic C and N was two times greater (3.3% C, 0.22% N) in the agricultural floodplain than in the floodplain in the forested catchment (1.5% C, 0.14% N). Soil P was three times greater in the agricultural (1100 µg/g) than in the forested floodplain (350 µg/g). Recent soil accretion based on <sup>137</sup>Cs which provides a historical record since 1964 (60 years), was two times greater in the agricultural floodplain (2.2 mm/year) than in the forested catchment (1.0 mm/year). Sediment deposition (2500 g/m<sup>2</sup>/year), C sequestration (90 g/m<sup>2</sup>/year), and N burial (7.5 g/m<sup>2</sup>/year) were three times greater in the agricultural floodplain and P burial was seven times greater (3.0 vs. 0.41 g/m<sup>2</sup>/year). Long-term measurements (100 years) based on <sup>210</sup>Pb did not show large differences in C sequestration and N burial between the two floodplains though soil accretion and sediment deposition were greater in the forested floodplain. We attribute these higher rates to greater erosion in the watershed before 1950 when the catchment had more agricultural land and before instruction on best management practices to reduce soil erosion. These findings confirm previously published studies that show that P enrichment and accumulation in floodplain soils represent legacy effects of agricultural land use in the catchment.

## KEYWORDS

carbon sequestration, land use, organic matter, soil accretion, wetlands

## 1 | INTRODUCTION

Wetlands are important sinks for sequestering carbon (C) and removing nutrients, nitrogen (N), and phosphorus (P). Because of the connectivity to aquatic ecosystems, floodplain riparian wetlands are especially important. Floodplain wetlands, with their large areas inundated for long durations, also trap sediment and P that mainly originate

from erosion upriver (Noe et al., 2022; Wiener et al., 2022). The deposited sediment subsequently buries substantial amounts of C and N (Craft et al., 2022).

The ability of floodplain wetlands to filter pollutants depends on proximity to sources, especially agricultural land use (Zhang et al., 2023). Floodplains in agricultural watersheds are well suited to intercept large quantities of sediment, N and P because of their proximity to cultivated

This is an open access article under the terms of the [Creative Commons Attribution](https://creativecommons.org/licenses/by/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2024 The Authors. *River* published by Wiley-VCH GmbH on behalf of China Institute of Water Resources and Hydropower Research (IWHR).

land (Craft et al., 2018). In contrast, floodplains in predominantly forested catchments are less suited to remove such pollutants (Craft et al., 2022) because they are not intimately connected to the nutrient source(s).

We compared sediment deposition, C sequestration, and N and P burial in two floodplain forests of the agricultural Midwest, also known as the Corn Belt. The floodplain forest of the agricultural catchment, hereafter referred to as the *agricultural floodplain*, is located on the upper West Fork of the White River. The floodplain of the forested catchment, Beanblossom Creek, hereafter referred to as the *forested floodplain*, is part of the same West Fork White River watershed. We hypothesize that the floodplain wetland of the agricultural catchment will trap more sediment and remove more P than the floodplain wetland of the forested catchment based on published studies. We further hypothesize that, with greater rates of sediment deposition, the floodplain in the agricultural catchment will bury more N and sequester more C than the floodplain in the forested catchment.

## 2 | METHODS

### 2.1 | Site description

We collected soil cores from two floodplain wetlands, Upper West Fork and Beanblossom Creek, within in the West Fork White River watershed in central Indiana

(Figure 1). The agricultural floodplain, Upper West Fork, is located north of Indianapolis in Hamilton County. At this point, the river is a third-order stream that drains Killbuck, Pipe, Duck, and Stony Creeks. The geology is primarily glacial outwash derived from Silurian limestone and dolomite with a relatively flat landscape (0%–2% slope). Widespread conversion of forest and prairie to agriculture began in this area from 1850 to 1880 (Quarrier et al., 2022; Thaler et al., 2022). Today row crops, agriculture consisting of mostly corn and soybeans, comprise 61% of the land use in the watershed (Tedesco et al., 2011).

The forested floodplain, Beanblossom Creek, is a third-order stream located in Monroe County (Figure 1). The watershed is made up of ridges with steep slopes (25%–75%) and narrow valleys. The rocks are Mississippian and mostly siltstone rich in silica. Approximately 85%–90% of the watershed upstream of the site is forested (Hoosier Environmental Council, 2008). Both wetlands are inundated for several weeks to months during winter and spring, usually to a depth of 0.5–1 m.

(Soils of Beanblossom Creek are classified as Bonnie silt loam (fine-silty, mixed, acid mesic typic fluvaquents) <https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx>, <https://www.nrcs.usda.gov/resources/data-and-reports/official-soil-series-descriptions-osd>). Soils of the Upper West Fork are classified as Genesee silt loam (fine loamy, mixed, superactive mesic fluventic eutrudepts), indicative of the effects of tillage on the soil profile.



**FIGURE 1** Location of Upper West Fork (agricultural floodplain) and Beanblossom Creek (forested floodplain) wetlands in the West Fork White River, Indiana, United States.

The land use history of the forested catchment (and floodplain) is more complex than that of the agricultural catchment, which has been under intensive cultivation since the late 1800s. Portions of the forested catchment also were farmed beginning in the late 1800s, but because of the hilly terrain and shallow soils compared to the agricultural catchment, much of the land was and still is forested. Before 1950, in areas that were farmed, soil conservation practices such as terracing, contour plowing, conservation tillage (no-till), use of cover crops, and buffer strips were in limited (or no) use, leading to widespread soil erosion (Steiner, 1987; Trimble, 1985) compared to today's agricultural practices. The forested floodplain, Beanblossom Bottoms, also was farmed in the late 1800s but by 1950, farming was abandoned and forest regrowth began. Vegetation in the agricultural floodplain is dominated by an aggrading stand of red maple (*Acer rubrum*), cottonwood (*Populus deltoides*), and sycamore (*Platanus occidentalis*) that are approximately 50 years old. The forested floodplain is dominated by a community consisting of wetland oaks (Pin oak [*Quercus palustris*], Swamp white oak [*Q. bicolor*], Shellbark history [*Carya laciniosa*], black gum [*Nyssa sylvatica* var. *biflora*], and red maple [*Acer rubrum*]) that are approximately 75 years old.

## 2.2 | Soil sampling and analysis

We collected two 8.5 cm diameter by 30 cm deep soil cores from the agricultural floodplain and two 50 cm cores from the forested floodplain. Cores were sectioned in the field into 2-cm increments and transported to the lab where they were air-dried, weighed for bulk density, ground, and sieved.

Soil from each depth increment was packed into 50 mm diameter × 9 mm deep Petri dishes and analyzed for  $^{137}\text{Cs}$  and  $^{210}\text{Pb}$ . Cesium-137 was measured using gamma analysis of the 661.62 keV photopeak (Craft et al., 2003) to estimate accretion over the past 60 years since 1964—the year of maximum deposition of atmospheric  $^{137}\text{Cs}$  from above-ground nuclear testing (Ritchie & McHenry, 1990). Thus, the  $^{137}\text{Cs}$  maximum or peak in the soil serves as a marker horizon for the year 1964, where the soil surface was located at that time. Total  $^{210}\text{Pb}$  was measured using a gamma analysis of 46.5 keV photopeak (Craft et al., 2003). Excess  $^{210}\text{Pb}$  was calculated using the difference between total and background  $^{210}\text{Pb}$  which was determined from constant  $^{210}\text{Pb}$  from the deeper increments of each core. Accretion rates from  $^{210}\text{Pb}$  were calculated using the constant activity

(CA) model (Oldfield & Appleby, 1984) to estimate long-term (approximately 100 years) rates of soil accretion. The CA model is based on a consistent annual input of atmospheric or excess  $^{210}\text{Pb}$  from the decay of Uranium-235 from the earth's crust over time. The CA model describes the exponential decay of  $^{210}\text{Pb}$ , a daughter product of the U-235 decay scheme with age. The model assumes an exponential decrease in  $^{210}\text{Pb}$  with soil depth, leading to monotonic decrease in concentration as seen in Figure 4a,c. The model also assumes a constant accretion rate based on the regression of excess  $^{210}\text{Pb}$  versus depth.

Each depth increment (0–30 cm) also was analyzed for bulk density, organic carbon, total nitrogen, and total phosphorus. Bulk density was calculated from the dry weight per unit volume for each depth increment (Blake & Hartge, 1986). Organic carbon and total N were determined using a Perkin Elmer 2400 CHN analyzer (PerkinElmer). Total P was measured as phosphate in  $\text{HNO}_3\text{-HClO}_4$  digestions (Sommers & Nelson, 1972). An internal wetland soils standard yielded a 96% recovery rate for C and N and a 90.5% recovery rate for P. Percent mineral matter was calculated as 100–% organic matter which was assumed to be two times organic C content (Craft et al., 1991).

Mineral sediment deposition, C sequestration, and N and P burial were calculated using  $^{137}\text{Cs}$ - and  $^{210}\text{Pb}$ -derived vertical accretion rates, bulk density, and concentrations down to and including the increment of maximum  $^{137}\text{Cs}$  activity or extent of excess  $^{210}\text{Pb}$ . Mineral sediment deposition was calculated based on accretion, bulk density, and mineral content.

## 3 | RESULTS

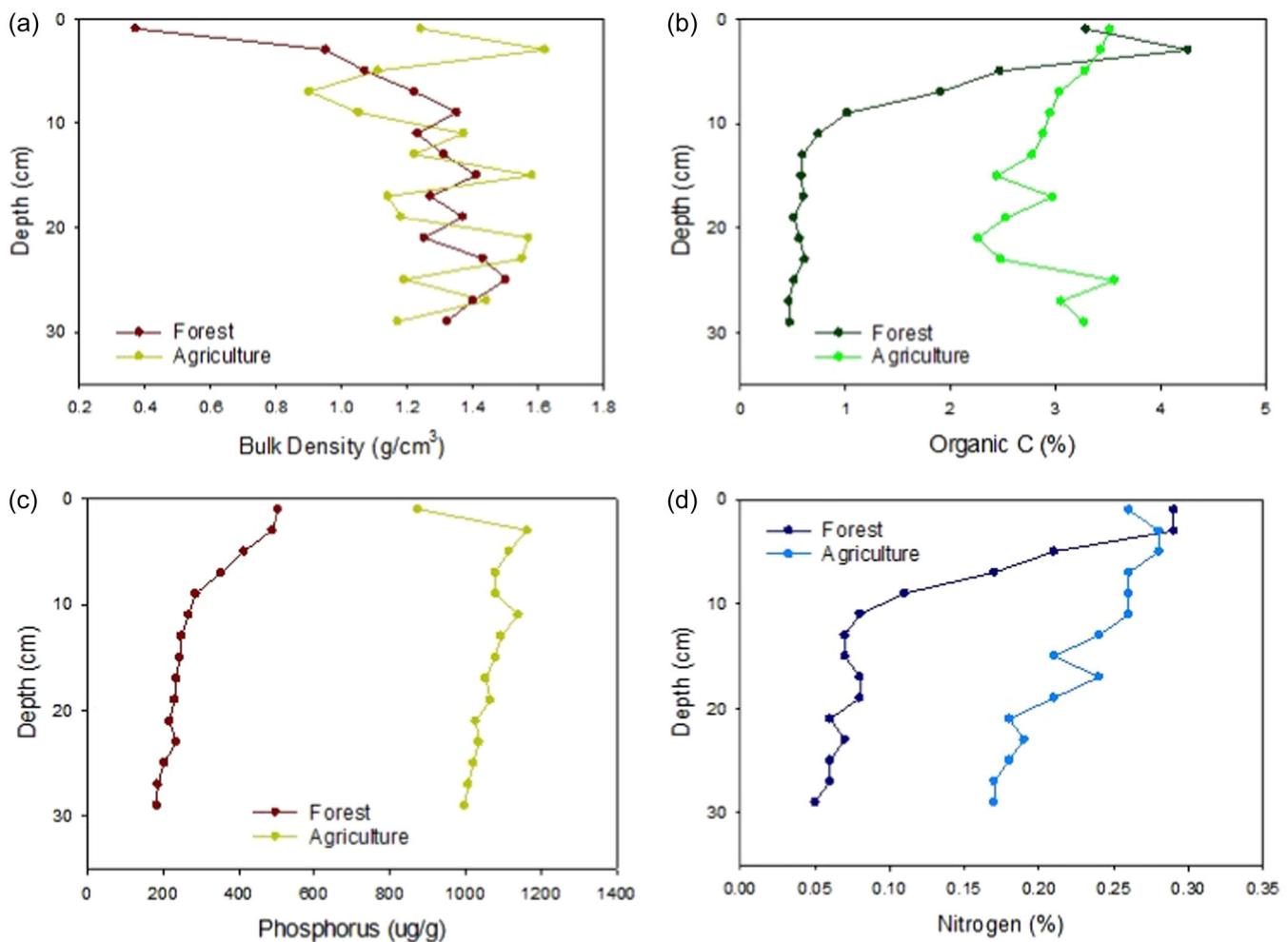
### 3.1 | Soil bulk density and nutrients

Floodplain soils (0–30 cm) were mineral in nature with high bulk density ( $>1\text{ g/cm}^3$ ) and low organic C (1%–3%) and N ( $<0.15\%$ ) (Table 1). They varied substantially in P, ranging from 300  $\mu\text{g/g}$  in soils of the forested catchment to 1100  $\mu\text{g/g}$  in soils of the agricultural catchment.

Bulk density, percent C and N, and total P also differed with depth among the two floodplain soils. The forested floodplain had low bulk density ( $<1\text{ g/cm}^3$ ) in surface soil (0–5 cm) that quickly increased with depth whereas percent C and N sharply decreased with depth (Figure 2), from 4% to 0.5% for C and from 0.28% to 0.05% for N. In contrast, soils of the agricultural floodplain exhibited a more uniform distribution with

**TABLE 1** Mean bulk density, organic C, total N, and total P (0–30 cm) in soils of the two floodplain forests of the White River, Indiana, United States ( $N = 2$  cores per site).

	Bulk density ( $\text{g/cm}^3$ )	Organic C (%)	Total N (%)	Total P ( $\mu\text{g/g}$ )
Agricultural floodplain	$1.23 \pm 0.01$	$3.31 \pm 0.35$	$0.22 \pm 0.01$	$1106 \pm 29$
Forested floodplain	$1.23 \pm 0.02$	$1.49 \pm 0.26$	$0.14 \pm 0.01$	$349 \pm 62$



**FIGURE 2** Change in (a) bulk density, (b) organic C, (c) total P, and (d) total N with depth in soil cores collected from the agricultural and forested floodplains.

depth. Bulk density was relatively constant (Figure 2) and consistently greater than  $1 \text{ g/cm}^3$ . Soil organic C (2%–3%) did not vary much with depth in the agricultural floodplain either. Soil N, however, exhibited a consistent decrease with depth, from 0.25% at the surface to 0.17% at 30 cm. Soil P in the two floodplains generally decreased with depth though concentrations throughout the 0–30 cm profile were much higher in the agricultural floodplain (Figure 2).

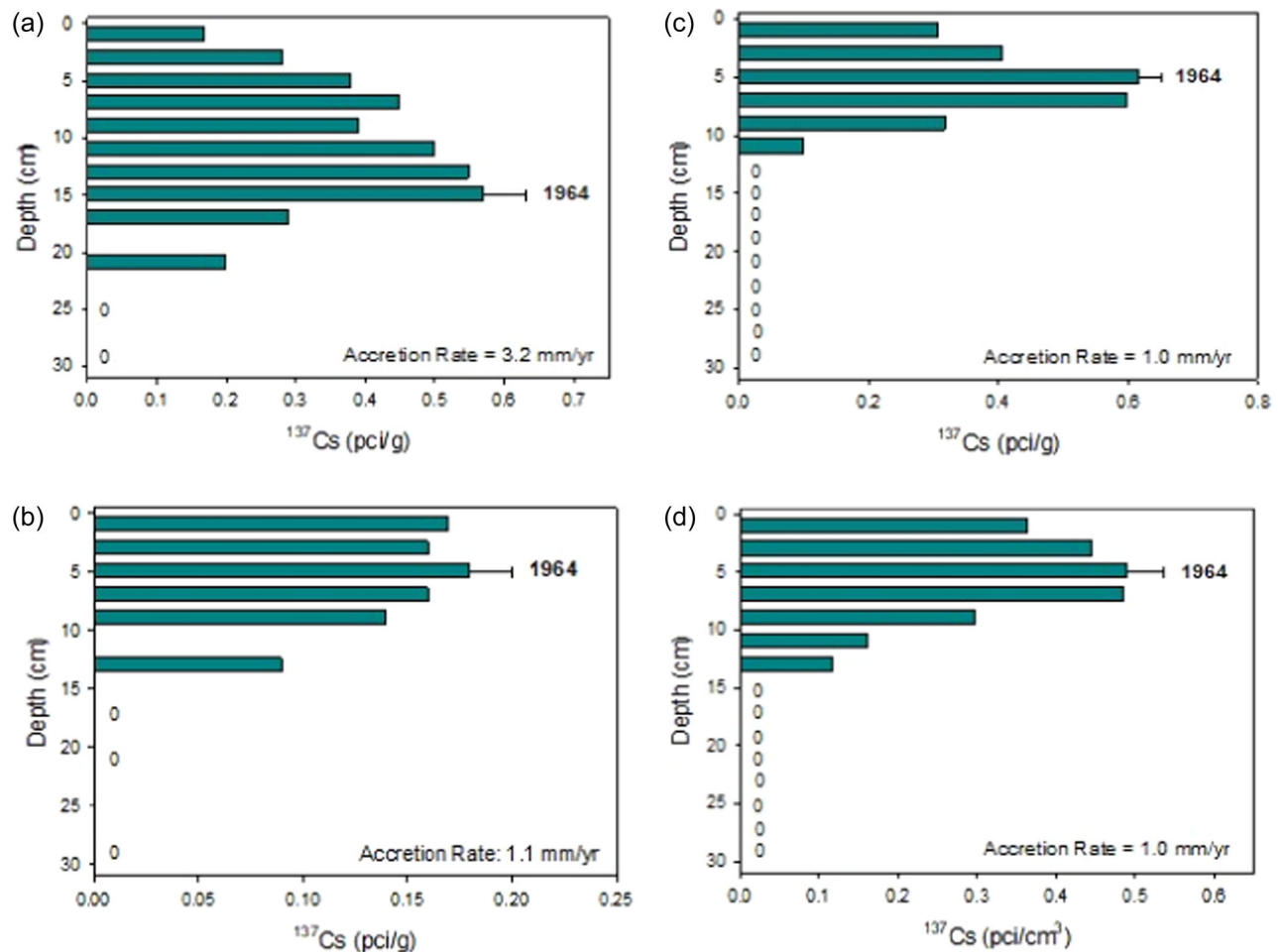
### 3.2 | Soil accretion and accumulation

Soil cores exhibited generally well-defined  $^{137}\text{Cs}$  peaks with the  $^{137}\text{Cs}$  maxima occurring at depths between 5 and 15 cm (Figure 3). Accretion rates based on  $^{137}\text{Cs}$  ranged from 1.0 mm/year in the forested floodplain to 3.2 mm/year in soils of the agricultural floodplain. Pb-210 profiles were interpretable in only one of the two cores from each floodplain. In these cores, total  $^{210}\text{Pb}$  exhibited an exponential decrease with depth down to background activities of 4–6 dpm/g (Figure 4). Accretion based

on  $^{210}\text{Pb}$  was 2.2 mm/year in the forested floodplain and twice the rate measured using  $^{137}\text{Cs}$ . In the agricultural catchment,  $^{210}\text{Pb}$  accretion was 1.0 mm/year and less than the rate measured using  $^{137}\text{Cs}$  (2.2 mm/year).

Deposition of mineral sediment based on  $^{137}\text{Cs}$  ranged from 740 to 3790  $\text{g/m}^2/\text{year}$ , with two to five times higher deposition occurring in the agricultural floodplain (Table 2). Carbon sequestration and N burial were three times greater (64–123  $\text{g C/m}^2/\text{year}$ , 7.5  $\text{g N/m}^2/\text{year}$ ) in soils of the agricultural floodplain than in the forested floodplain (27–34  $\text{g C/m}^2/\text{year}$ , 2.3  $\text{g N/m}^2/\text{year}$ ). Nitrogen and P burial also were considerably greater in the agricultural floodplain (Table 2).

Pb-210 sediment deposition, C sequestration, and N and P burial, however, were inconsistent with measurements based on  $^{137}\text{Cs}$  as sediment deposition was greater in the forested floodplain compared to the agricultural catchment (2340 vs. 930  $\text{g/m}^2/\text{year}$ , respectively). Furthermore, whereas the agricultural floodplain exhibited higher C sequestration and nutrient burial,  $^{210}\text{Pb}$ -based C sequestration and N and P burial were similar among the two floodplain forests (Table 2).



**FIGURE 3** Depth distribution of  $^{137}\text{C}$  in soil cores collected from soils of (a, b) agriculture land and (c, d) forested floodplains.

## 4 | DISCUSSION

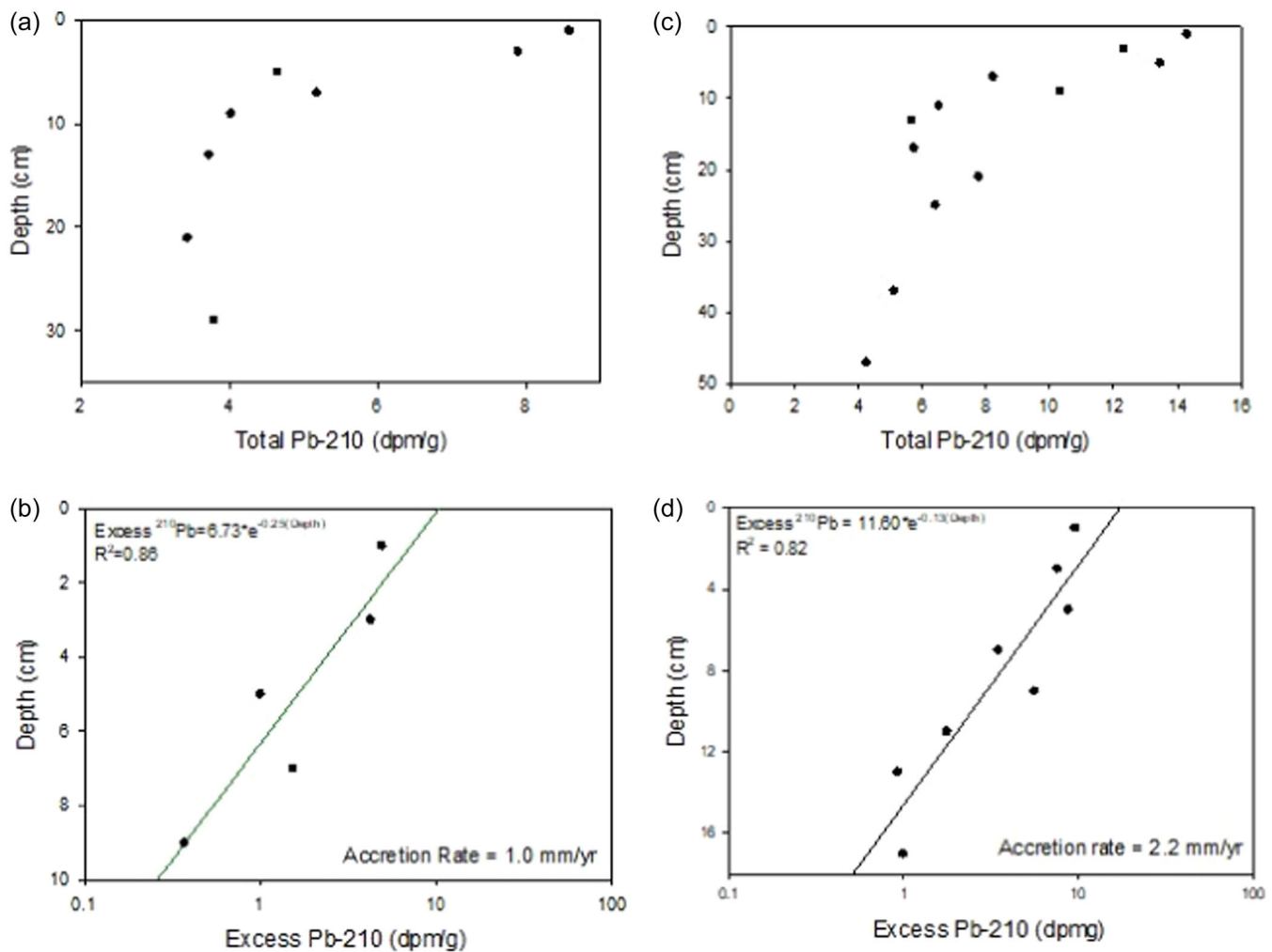
The agricultural floodplain contained higher soil P and greater  $^{137}\text{Cs}$  accretion, sediment deposition, and P burial than the forested floodplain (Tables 1 and 2, Figure 2). Published studies of wetlands in agricultural catchments also exhibit greater soil accretion, elevated soil P and greater C sequestration, and N and P burial relative to wetlands that do not receive agricultural drainage (Craft & Richardson, 1993; Graham et al., 2005) as agricultural catchments export large amounts of sediment and P via eroded soil. The hypothesis of greater sediment deposition, C sequestration, and N and P burial in wetlands with agricultural catchment is thus supported by the findings.

Soil organic C, N, and P also varied with depth among the two catchments. Phosphorus was consistently greater at all depths of the agricultural floodplain (Figure 2). Percent C and N were similar in surface (0–5 cm) soils of the two floodplains, but the agricultural catchment contained greater C and N below this depth. The relatively uniform concentrations of C, N, and P in the upper 30 cm of the agricultural floodplain likely reflect the history of row crop agriculture and its ploughing that homogenizes the surface soil while the high soil P concentration also reflects the

legacy effect of P inputs from long-term agriculture in the catchment. In contrast, percent C and N in the floodplain of the forested catchment were greatest at the surface and declined strongly with depth, indicating the reforestation of the floodplain after agriculture was abandoned on site in the mid-20th century (discussed in detail below).

In contrast to  $^{137}\text{Cs}$ , which showed consistently greater soil accretion, sediment deposition, and C, N, and P accumulation in the agricultural floodplain, measurements based on  $^{210}\text{Pb}$  did not. Except for P burial, which was marginally greater in the agricultural floodplain, soil accretion, and sedimentation were double in the forested floodplain (Table 2).  $\text{Pb-210}$  C sequestration and N burial did not strongly differ between the agricultural and forested floodplains despite accretion rates that were double (Table 2). The similarity in  $^{210}\text{Pb}$ -based C sequestration and N burial among the two catchments was the result of consistently greater percent C and N with depth in the agricultural floodplain relative to the forested floodplain where percent C and N strongly decreased with depth (Figure 2).

Greater  $^{210}\text{Pb}$  accretion and sedimentation in the forested floodplain likely reflect agricultural activities in the catchment that occurred in the past, before about 1950.



**FIGURE 4** Depth distribution of total and excess  $^{210}\text{Pb}$  in soil cores collected from soils of (a, b) agricultural and (c, d) forested floodplains.

**TABLE 2** Soil accretion (mm/year) and sediment, organic C, N, and P accumulation ( $\text{g}/\text{m}^2/\text{year}$ ) in two floodplain forests of the White River, Indiana, United States.

	Accretion	Organic C	N	P	Sediment
$^{137}\text{Cs}$ ( $n = 2$ cores per site)					
Agricultural catchment	$2.1 \pm 1.0$	$93 \pm 29$	$7.5 \pm 3.0$	$3.0 \pm 1.3$	$2550 \pm 1230$
Forested catchment	$1.0 \pm 0.0$	$31 \pm 3$	$2.3 \pm 0.2$	$0.41 \pm 0.04$	$755 \pm 15$
$^{210}\text{Pb}$ ( $n = 1$ core per site)					
Agricultural catchment 1.0	1.0	42	2.9	1.12	930
Forested catchment	2.2	45	3.9	0.86	2350

The Beanblossom Creek floodplain was cleared and tilled beginning in the 1800s and continued into the 20th century (<https://members.wetlandsof distinction.org/woddirectory/Details/beanblossom-bottoms-nature-preserve-2016983>). After the Second World War, cultivation ceased and resulting reforestation of the floodplain has led to a 75 year-old hardwood forest that exists today (2024). In contrast to  $^{137}\text{Cs}$  which measures soil accretion from the past 60 years since 1964,  $^{210}\text{Pb}$  measurements describe conditions over the past 100–125 years, from about 1900

onward. In the agricultural Midwest, the first half of the 20th century was characterized by limited soil conservation practices such as terracing, contour plowing, conservation tillage (no-till), use of cover crops, buffer strips, and others (Steiner, 1987; Trimble, 1985). The conversion of native prairie and forest vegetation plus the lack of conservation practices led to severe soil erosion beginning in the second half of the 18th century and continued into the 20th century (Quarrier et al., 2022; Thaler et al., 2022). Furthermore, fertilizer application was quite limited until the

advent of widespread production of inorganic N and P fertilizer after the Second World War (Cao et al., 2018; Cordell & White, 2014).

It is likely that the higher rates of  $^{210}\text{Pb}$  soil accretion and sediment deposition in the forested floodplain in the past are also a result of the steeper sloped landscape (25%–75%) in addition to the lack of conservation tillage practices. Overall the steep slopes historically provided a rich source of eroded sediment to the wetland. In contrast, the catchment of agricultural wetland lies on the till plain of the Wisconsinian glacier of the Ice Age 20,000 years ago (Hoosier Environmental Council, 2008) which, today remains a nearly flat (0%–2%), featureless landscape conducive for intense row crop agriculture if given adequate drainage.

Other published studies of floodplain C sequestration, N burial, and sediment deposition within the Midwest highlight the legacy of land usage on wetlands. Mean rates originate mostly from the United States and are based on  $^{137}\text{Cs}$  and  $^{210}\text{Pb}$  that are quite similar to each other unlike this study (Table 3). Cs-137 P burial was somewhat greater

(0.91 g/m<sup>2</sup>/year) than  $^{210}\text{Pb}$  (0.70 g/m<sup>2</sup>/year) which may be due to the increasing use of P fertilizers worldwide since the mid-20th century. N and P burial were greatest in a Wisconsin floodplain (2.6 g/m<sup>2</sup>/year) whose catchment was primarily in agriculture (Johnston et al., 1984). These rates were substantially greater than those measured in our study and others. Carbon sequestration was greatest in floodplains of Maryland, United States and Costa Rica (Table 3). Sediment deposition was also greatest in the Costa Rican floodplain.

There is much interest in soil C sequestration and the high rates of recent ( $^{137}\text{Cs}$ ) C sequestration in the floodplain of the agricultural catchment relative to the floodplain of the forested catchment suggests that sediment transport from farmed uplands promotes its burial. How much of the sequestered C is produced in situ versus transported by periodic flooding is unknown. Overall, catchment-scale C sequestration by floodplain wetlands depends mostly on the amount of floodplain habitat within the catchment, which generally is small since historically many were drained and converted to agriculture.

**TABLE 3** Carbon sequestration, nitrogen and phosphorus burial, and sediment deposition in floodplain soils based on  $^{137}\text{Cs}$  (first number) and  $^{210}\text{Pb}$  (second number).

	Organic C		Nitrogen		Phosphorus		Sediment	
This study (agricultural)	93	42	7.5	3.9	3.0	1.12	2550	930
(Forest)	31	45	2.3	2.9	0.41	0.86	755	2350
Georgia <sup>a</sup>	18	107	1.4	8.0	0.12	0.75	120	1300
Georgia <sup>b</sup>	40	60	3.1	4.7	0.52	0.80	1030	1890
Georgia <sup>c</sup>	60		4.1		0.75		1080	
Arkansas <sup>d</sup>							800	
Maryland <sup>e</sup>	240						1300	
Wisconsin <sup>f</sup>			12.8		2.6		2000	
Ohio <sup>g</sup>	130							
Indiana <sup>h</sup>	40	48	3.3	3.5	0.6	0.49	1400	2800
Alaska <sup>i</sup>	45	23	2.0					
Austria <sup>j</sup>	140							
Czech Republic <sup>h</sup>	19	86	1.3	6.1	0.11	0.46	90	290
Costa Rica <sup>k</sup>	232						4530	
Botswana <sup>k</sup>	56						1100	
Mean	90 ± 22	87 ± 28	4.7 ± 1.3	5.1 ± 0.0	0.91 ± 0.35	0.70 ± 0.1	1370 ± 360	1580 ± 370

<sup>a</sup>Craft and Casey (2000).

<sup>b</sup>Bannister et al. (2015).

<sup>c</sup>Craft et al. (2022).

<sup>d</sup>Kleiss (1996).

<sup>e</sup>Kroes and Hupp (2010).

<sup>f</sup>Johnston et al. (1984).

<sup>g</sup>Bernal and Mitsch (2012) based on  $^{137}\text{Cs}$  and  $^{210}\text{Pb}$ .

<sup>h</sup>Craft et al. (2018).

<sup>i</sup>Kaye (2003) (C and N were measured along a 50-year-old floodplain chronosequence).

<sup>j</sup>Zehetner et al. (2009) (measured using  $^{137}\text{Cs}$  and optically stimulated luminescence).

<sup>k</sup>Bernal and Mitsch (2013) based on  $^{137}\text{Cs}$  and  $^{210}\text{Pb}$ .

## 5 | CONCLUSIONS

Both catchment and wetland land use history produce legacies associated with long- and short-term agriculture. Recent ( $^{137}\text{Cs}$ , since 1964) rates of sediment deposition and C, N, and P burial were three to six times greater in the agricultural floodplain. Soil P enrichment and greater P burial in the agricultural floodplain is associated with the legacies of widespread fertilizer in this predominantly agricultural (61%) catchment since the mid-20th century while at the same time, the forested floodplain was an aggrading forest in a predominantly forested (85%–90%) catchment. However, long-term ( $^{210}\text{Pb}$ ) rates revealed evidence of agriculture (erosion and sediment deposition) in the forested floodplain pre-1950, when the floodplain and the catchment were tilled.

Disentangling the legacy effects of agriculture, including erosion and sediment deposition, fertilizer history, and implementation of conservation practices are key to explaining historical patterns of sediment, carbon, and nutrient retention in floodplain wetlands of the agricultural Midwest.

### ACKNOWLEDGMENTS

The authors would like to thank Madeleine Thompson for assisting with figures, tables, and manuscript edits. The work was supported by grants OCE-062059, OCE-1237140, and OCE-1832178 from the National Science Foundation, and the Young Elite Scientists Sponsorship Program by CAST (2022QNRC001). This is the University of Georgia Marine Institute Publication Number 1106.



### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

### ETHICS STATEMENT

The author states that the manuscript is original and has not been published elsewhere.

### ORCID

Christopher Craft  <http://orcid.org/0000-0003-3345-6592>  
Shanze Li  <http://orcid.org/0000-0003-3246-3571>

### REFERENCES

- Bannister, J. M., Herbert, E. R., & Craft, C. B. (2015). Spatial variability in sedimentation, carbon sequestration, and nutrient accumulation in an alluvial floodplain forest. In J. Vymazal (Ed.), *The role of natural and constructed wetlands in nutrient cycling and retention on the landscape* (pp. 41–56). Springer.
- Bernal, B., & Mitsch, W. J. (2012). Comparing carbon sequestration in temperate freshwater wetland communities. *Global Change Biology*, *18*, 1636–1647.
- Bernal, B., & Mitsch, W. J. (2013). Carbon sequestration in freshwater wetlands in Costa Rica and Botswana. *Biogeochemistry*, *115*, 77–93.
- Blake, G. R., & Hartge, K. H. (1986). Bulk density. In A. Klute, *Methods of soil analysis, Part I. Physical and mineralogical methods. Agronomy monograph no. 9* (2nd ed., pp. 363–375). American Society of Agronomy.
- Cao, P., Lu, C., & Yu, Z. (2018). Historical nitrogen fertilizer use in agricultural ecosystems of the contiguous United States during 1850–2015: Application rate, timing, and fertilizer types. *Earth System Science Data*, *10*, 969–984.
- Cordell, D. S., & White, S. (2014). Life's bottleneck: Sustaining the world's phosphorus for a food secure future. *Annual Review of Environment and Resources*, *39*, 161–188.
- Craft, C. B., & Casey, W. P. (2000). Sediment and nutrient accumulation in floodplain and depressional freshwater wetlands of Georgia, USA. *Wetlands*, *20*, 323–332.
- Craft, C. B., Li, S., & Xie, T. (2022). From the headwaters to the sea: The role of riparian, alluvial, and tidal wetlands to filter nutrients and ameliorate eutrophication. *River*, *1*, 133–141.
- Craft, C., Megonigal, P., Broome, S., Stevenson, J., Freese, R., Cornell, J., Zheng, L., & Sacco, J. (2003). The pace of ecosystem development of constructed *Spartina alterniflora* marshes. *Ecological Applications*, *13*(5), 1417–1432.
- Craft, C. B., & Richardson, C. J. (1993). Peat accretion and N, P and organic C accumulation in nutrient-enriched and unenriched everglades peatlands. *Ecological Applications*, *3*, 446–458.
- Craft, C. B., Seneca, E. D., & Broome, S. W. (1991). Loss on ignition and Kjeldahl digestion for estimating organic carbon and total nitrogen in estuarine marsh soils: Calibration with dry combustion. *Estuaries*, *14*, 175–179.
- Craft, C., Vymazal, J., & Kröpfelová, L. (2018). Carbon sequestration and nutrient accumulation in floodplain and depressional wetlands. *Ecological Engineering*, *114*, 137–145.
- Graham, S. A., Craft, C. B., McCormick, P. V., & Aldous, A. (2005). Forms and accumulation of soil P in natural and recently restored peatlands—Upper Klamath Lake, Oregon. *Wetlands*, *25*, 594–606.
- Hoosier Environmental Council. (2008). Watershed management plan for restoration and protection of Bean Blossom Creek and Lake Lemon. [https://ecm.idem.in.gov/cs/idcplg?IdcService=GET\\_FILE&dID=83085030&dDocName=83084963&Rendition=web&allowInterrupt=1&noSaveAs=1](https://ecm.idem.in.gov/cs/idcplg?IdcService=GET_FILE&dID=83085030&dDocName=83084963&Rendition=web&allowInterrupt=1&noSaveAs=1)
- Johnston, C. A., Bubenzer, G. D., Lee, G. B., Madison, F. W., & McHenry, J. R. (1984). Nutrient trapping by sediment deposition in a seasonally flooded lakeside wetland. *Journal of Environmental Quality*, *13*, 283–290.
- Kaye, J. P. (2003). Stable soil nitrogen accumulation and flexible organic matter stoichiometry during primary floodplain succession. *Biogeochemistry*, *63*, 1–22.
- Kleiss, B. A. (1996). Sediment retention in a bottomland hardwood wetland in eastern Arkansas. *Wetlands*, *16*, 321–333.
- Kroes, D. E., & Hupp, C. R. (2010). The effect of channelization on floodplain sediment deposition and subsidence along the Pocomoke River, Maryland. *Journal of the American Water Resources Association*, *46*, 686–699.
- Noe, G. B., Hopkins, K. G., Claggett, P. R., Schenk, E. R., Metes, M. J., Ahmed, L., Doody, T. R., & Hupp, C. R. (2022). Streambank and floodplain geomorphic change and contribution to watershed material budgets. *Environmental Research Letters*, *17*(6), 064015.
- Oldfield, F., & Appleby, P. G. (1984). Empirical testing of  $^{210}\text{Pb}$  models for dating lake sediments. In E. Y. Hayworth, & J. W. G. Lund (Eds.), *Lake sediments and environmental history* (pp. 93–124). University of Minnesota Press.
- Quarrier, C. L., Kwang, J. S., Quirk, B. J., Thaler, E. A., & Larsen, I. J. (2022). Pre-agricultural soil erosion rates in the midwestern United States. *Geology*, *51*, 44–48.
- Ritchie, J. C., & McHenry, J. R. (1990). Application of radioactive fallout Cesium-137 for measuring soil erosion and sediment accumulation rates and patterns: A review. *Journal of Environmental Quality*, *19*, 215–233.
- Sommers, L. E., & Nelson, D. W. (1972). Determination of total phosphorus in soils: a rapid perchloric acid digestion procedure. *Soil Science Society of America Journal*, *36*(6), 902–904.
- Steiner, F. (1987). Soil conservation policy in the United States. *Environmental Management*, *11*, 209–223.
- Tedesco, L. P., Hoffman, J., Bihl, L., Hall, B. E., Barr, R. C., & Stouder, M. (2011). Upper White River watershed assessment and

- planning report. <https://thewhiteriveralliance.org/wp-content/uploads/2018/08/Upper-White-River-Watershed-Regional-Plan.pdf>
- Thaler, E. A., Kwang, J. S., Quirk, B. J., Quarrier, C. L., & Larsen, I. J. (2022). Rates of historical anthropogenic soil erosion in the Midwestern United States. *Earth's Future*, *10*, e2021EF002396.
- Trimble, S. W. (1985). Perspectives on the history of soil erosion control in the eastern United States. *Agricultural History*, *59*, 162–180.
- Wiener, K. D., Schlegel, P. K., Grenfell, S. E., & van der Waal, B. (2022). Contextualising sediment trapping and phosphorus removal regulating services: A critical review of the influence of spatial and temporal variability in geomorphic processes in alluvial wetlands in drylands. *Wetlands Ecology and Management*, *30*, 737–770.
- Zehetner, F., Lair, G. J., & Gerzabek, M. H. (2009). Rapid carbon accretion and organic matter pool stabilization in riverine floodplain soils. *Global Biogeochemical Cycles*, *23*(4), GB4004.
- Zhang, Y., Li, Z., Wang, T., Wang, P., Xu, R., & Wang, J. (2023). Effects of source-sink landscape proximity on the spatial-temporal water quality from the perspective of cost distance in an agricultural watershed. *Journal of Hydrology*, *628*, 130569.

**How to cite this article:** Craft, C., & Li, S. (2024). Short- and long-term legacies of carbon sequestration, and nutrient burial in floodplain wetlands of agricultural and forested catchments, Indiana, United States. *River*, *3*, 38–46. <https://doi.org/10.1002/rvr.2.79>