ISA FY21 Final Technical Report

Indiana Watershed Initiative

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Overview: Indiana croplands play a crucial role in feeding the country and the world, but runoff of excess nitrogen (N), phosphorus (P), and sediments can impact both local and downstream water quality by causing harmful algal blooms and degrading freshwater habitat. Furthermore, storm frequency and intensity are expected increase under future climate regimes, which will exacerbate nutrient runoff. In addition to water quality problems, loss of fertilizer from fields can reduce farmers' productivity by compromising soil quality and potentially reducing crop yields and profitability. In order to effectively reduce nutrient loss to adjacent water bodies, we need effective conservation implementation that also meets the economic needs of the agricultural community. **It is imperative that we expand research in "real world" settings to provide reliable data about conservation effectiveness and the impact farmers are making through voluntary implementation, with or without federal incentives.**

The practices: Winter cover crops and the two-stage ditch are two conservation practices that, individually, can reduce nutrient and sediment export from agricultural watersheds and provide additional gains when paired together. **Cover crops,** planted after cash crop harvest, reduce soil erosion, decrease soil compaction, and suppress weed growth while also increasing soil organic matter and soil water-holding capacity. In addition, cover crops increase soil nutrient uptake during winter and spring, when fields are normally bare, reducing potential losses, especially through subsurface tile drains. The **two-stage ditch** is an alternative way to manage traditional agricultural drainage ditches, which often have unstable banks that are prone to slumping, and require routine maintenance to remove accumulated sediments. The two-stage ditch is a physically stable design that allows storm water to flow onto vegetated floodplains, which slows water velocities and reduces bank stress. Indiana leads the way in implementation of the two-stage ditch and our work has shown improved bank stability with fewer failures, thus reducing the need for costly maintenance.

The project: Since 2014, the **Indiana Watershed Initiative (IWI)** has documented water quality and soil health benefits of watershed-scale implementation of these two practices. During the October 2018 – October 2019 water year, the IWI Regional Conservation Partnership Program (RCCP) project paid out the last of its funds to farmers for incentivized conservation, having grown a model platform with unprecedented conservation adoption.

Over the five-year IWI RCCP project, we sustained use of cover crops on ~70% of row-crop acres in Shatto Ditch Watershed (SDW) and grew adoption to 32% of croppable acres in Kirkpatrick Ditch Watershed (KDW; Fig. 1). Additionally, in SDW we now have a total of 4.1 miles of two-stage ditch. We have quantified the water quality and soil health benefits of the watershed-scale implementation of winter cover crops and the two-stage ditch in these two Indiana watersheds, have shared data with diverse stakeholders via outreach activities, and have participated in management discussions about using monitoring data to facilitate the adoption of watershed-scale conservation to improve water quality.

With widespread adoption and evidenced-based monitoring data, cover crops and the two-stage ditch could help farmers meet the current goals for the reduction of nutrient loading to local or downstream surface waters. Through this project, we achieved sustained nutrient loss reductions, and built communities of trust in both study watersheds that have

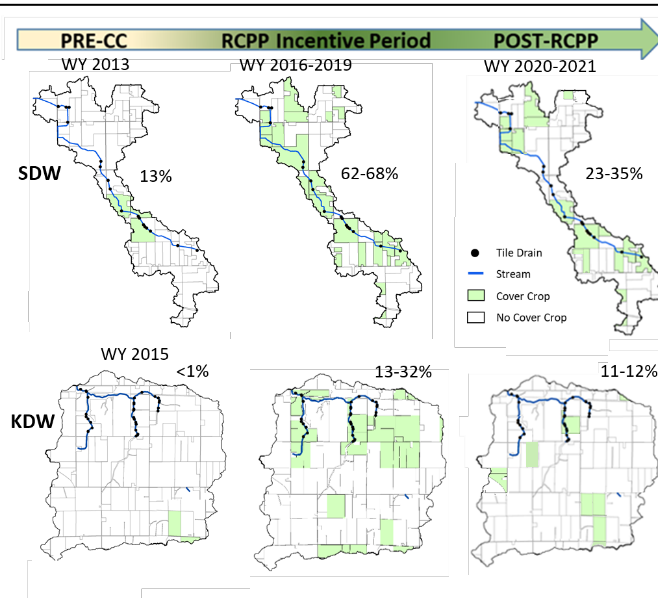

Figure 1: Map showing the variation in cover crop coverage in both IWI watersheds from the pre-incentive (WY2013 in SDW; WY2015 in KDW) through to the post-incentive period (WY2020-21).

enabled long-term studies of conservation practices on "working lands." Our work to date has generated important data and insights, but also has identified critical questions that influence the willingness of farmers to adopt cover crops and the two-stage ditch.

Progress on Objectives:

Objective 1: We have quantified the water quality benefits from paired watershed-scale cover crops and two-stage ditch through continued monitoring of SDW (3300 acres in Kosciusko County) and KDW (6373 acres in Jasper and Benton Counties). In addition, we have shown that storms are critical periods for nutrient runoff.

Implementation and Monitoring Summary: We sustained implementation of cover crops via USDA funds paid to farmers through NRCS EQIP for six years in SDW (2013-2018; ~1650 acres, ~70% coverage) and 4 years in KDW (2015-2018; ~1582 acres, high of 32% coverage). In the first year after government incentives ended (starting Fall 2019), cover crops were retained at 22% coverage in SDW and 11% coverage in KDW. In the 2020-2021 water year, coverage increased to 35% in SDW and remained at 11% in KDW. While this reflects a decrease from peak coverage, it remains approximately double the acreage prior to the IWI RCPP project. For the two-stage practice, 0.5 miles were constructed in 2007 and 3.6 miles were constructed in 2017/2018 in SDW, making the 4.1 miles in SDW the longest two-stage ditch in the world. Throughout the grant period, we have continued year-round monitoring, including real-time stream flow gauging, and water sampling every two weeks to measure stream and tile drain nutrient losses, generating ~2000 water samples per watershed per year.

Results to Date:

***Tile Drain Nutrient Losses**:* In general, monitoring shows that cover crops consistently decreased tile drain losses of NO_3^- and reductions ranged from 28-72% for SDW and KDW combined (Fig. 2). Results for SRP loss have been more variable, with reductions in 4 of 6 study years, ranging from 7-58% (Fig. 2). Results from the first four years of sampling in SDW (2013-2016) have been published for NO_3^- and SRP by Hanrahan et al. in 2018 and 2021 respectively; results for the RCPP incentive period (2016-2019) are presented in Speir et al. (2021).

During the post-incentive period (2020-2021), tile drain losses of both NO_3^--N and SRP continued to be lower from fields planted with cover crops compared to those without (Fig. 2). Our preliminary examination of data for fields that switched from cover crops to no cover crops after incentives ended, showed that despite lower discharge during the post-incentive years, NO_3^--N loss increased by 15-24% while SRP mass loss increased by 30% in fields where farmers stopped planting cover crops in SDW. In KDW, one of the landowners who planted cover crops consistently during the incentive period, did not plant cover crops during water year (WY; Oct-Sept) 2020, the first year after incentives ended. This farmer resumed cover cropping during WY2021. We measured a significant decline in NO_3^--N losses of 68-83% when cover crop planting resumed in 2021 relative to the period with no cover crops in 2020. *Next steps* are to expand our analysis of individual fields that "switched" between cover crops and no cover crops to include more fields and years, normalizing for tile flow to account for differences in discharge related to variation in precipitation across years.

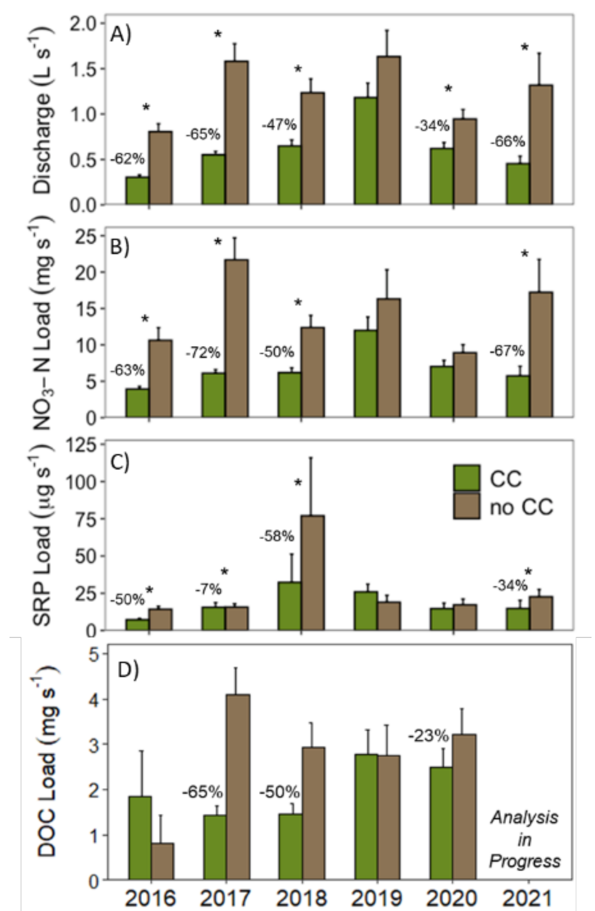

Figure 2. Cover crops reduce tile drain losses of (A) water, (B) NO_3^-, (C) SRP, and (D) DOC in two watersheds during RCPP incentives (WY2016-2019) and post-incentives (WY2020-2021).

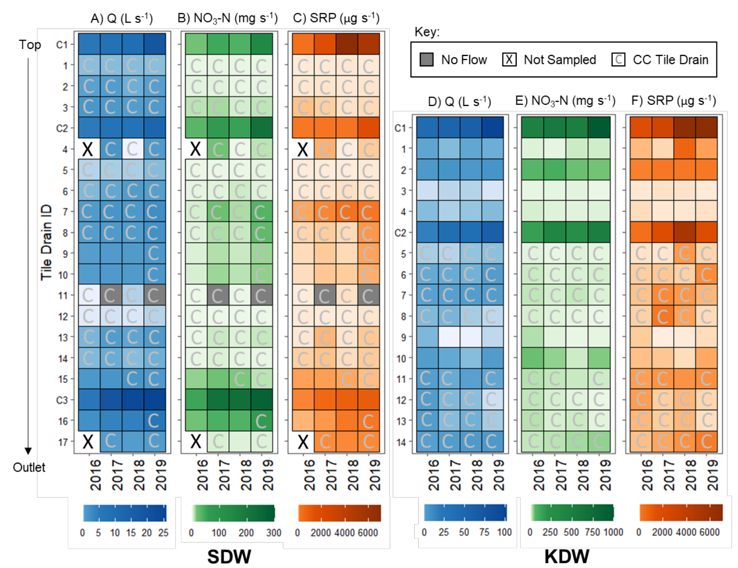

Figure 3. Grid plots showing spatial heterogeneity in discharge (Q), NO_3^--N loss, and SRP loss from tile drains across water years in SDW and KDW. (Speir et al. 2021)

Given year to year variation, we examined the role of precipitation in mediating the effect of cover crops on tile drain flow and SRP loads. We found that tile flow and SRP losses were directly related to precipitation; however, cover crops have the potential to significantly decrease spring tile drain SRP export, and these effects are resilient to a wide range of precipitation (Trentman et al. 2020). We also found that tile drain losses were spatially and temporally heterogeneous, likely due to variation in soil conditions, management, and precipitation (Fig. 3. Speir et al. 2021). In summary, planting cover crops consistently buffers against NO_3^- loss, especially in wet years, while effects on SRP depend on precipitation, flow paths, and soil health.

We are still exploring the fate of the carbon fixed by the cover crop biomass, but our results show that cover crops did not increase DOC loads from tile drains (Fig. 2, bottom) and suggest potential for incorporation into soil organic matter. This has positive implications for cover crops as a "natural climate solution" given their potential for sequestering atmospheric carbon dioxide as soil organic matter. We are currently working on a publication summarizing these findings and the implications of cover crop planting on carbon export.

Annual watershed nutrient losses: *During the incentive period***,** with sustained cover crop use on 67% of row-crop acres in **SDW**, we saw a reduction in spring NO_3^- export from the watershed in 4 out of 6 years, ranging from 2-29% versus years prior to cover crop use (Fig. 4, top left). However, in 2017 and 2019, we found no reductions due to exceptionally high storm runoff. At KDW, cover crop use ranged from 13-32%, and we found reduction in spring NO_3^- export during 3 of 4 years, ranging from 17-70% (Fig. 4, top right) which is of a similar magnitude to SDW, despite fewer acres in cover crops at KDW. The effect of cover crops on spring SRP export were greater than for NO_3^- export, and we saw spring reductions in 8 out of 10 watershed-years, ranging from 31%-88% (Fig. 4, bottom row).

Reduction in cover crop acreage during the post-incentive period did not result in a significant increase in annual export of NO_3^--N or SRP at the outlet (when expressed as nutrient yield), likely due to the exceedingly dry conditions in the 2020 and 2021 water years (Fig. 4).

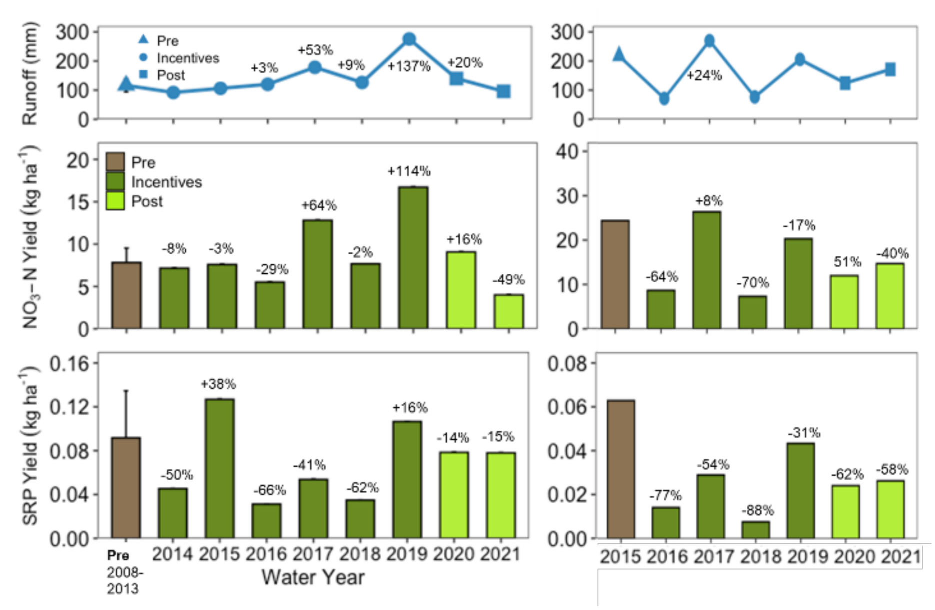

Figure 4. Cover crops decreased spring export (April-June) of NO_3^- (top) and SRP (bottom), and patterns mirror spring watershed runoff, especially for NO_3^-. Export was generally lower both during the incentive period (2014-2019) and the post-incentive period despite reductions in coverage after incentives ended (2020-2021).

However, when we normalized for runoff, we did observe some increases in export during select seasons. There was an average 9% increase in NO_3^--N export during the winter post-incentive period in KDW. However, that pattern did not occur in SDW, where trends in NO_3^--N export tend to link directly to patterns in streamflow. For SRP, export increased after incentives ended during the spring in both watersheds, despite decreased runoff during both the 2020 and 2021 spring seasons. We observed increases in spring SRP export ranging from 7-16% post-incentives, and when normalizing for runoff, that translated to a 12-34% increase. With more fields now fallow in the winter and spring, there is evidence of some increases in export during these seasons compared to winter and spring during the incentive period.

We also have documented that *storms are critical and often dominate annual nutrient export signatures*. Using flow duration analysis for SDW and KDW over four water years (2016-2021), we determined the majority of NO_3^--N (Fig. 5, left) and SRP (Fig. 5, right) export occurred during storms. For example, on average, the highest flows (top 10%) contributed about 60% of NO_3^--N export, while a single storm in Feb 2018 accounted for 14-28% of annual NO_3^--N loss in the two watersheds; the export patterns for SRP were even more strongly influenced by high flows (Speir et al. 2021). However, we found that **cover crops slowed cumulative SRP loss from the watershed and reduced SRP export in extreme events** (Hanrahan et al. 2021).

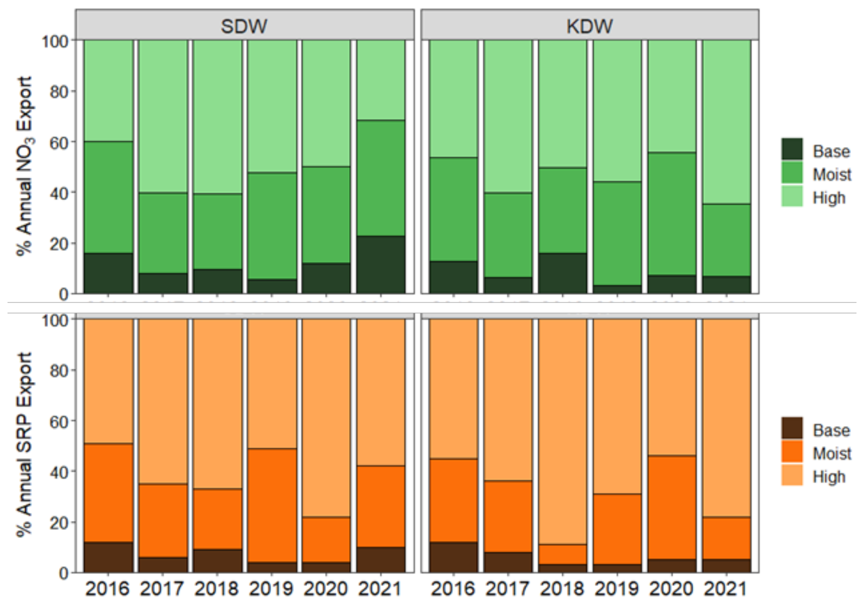

Figure 5. Flow duration analysis for SDW and KDW over four water years (2016-2019). The majority of NO_3^--N (left) and SRP (right) export occurred during storms (High=top 90-100[th] and Moist=60-90[th] percentiles of flows).

Our analysis of high frequency data from nitrate sensors at the watershed outlets also yielded a recent publication that documented the magnitude of the ecological challenge presented by storm-driven nutrient export in agricultural watersheds, and highlights the challenges of mitigating diffuse nutrient pollution, given anticipated shifts in hydrology associated with changing climate (Speir et al. 2021).

In addition to examining the effects of storms on temporal variation in export, we conducted a spatial analyses to quantify subwatershed leverage and identify areas within SDW and KDW that were hotspots for NO_3^--N and SRP export during the fallow season (Speir et al 2021). We found that subwatersheds with higher cover crop use were often smaller sources, or even sinks, for NO_3^--N and SRP. Additionally, we found that SRP leverage was positively correlated with percent cover crop use (Speir et al. 2021). **This indicates that, within SDW or KDW, areas with more cover crops typically contributed less to export at the watershed outlet compared to those areas with fewer cover crops**.

<u>**Objective 2:**</u> **We quantified the effect of cover crops on improving soil health,** via increased nutrient retention as well as expected improvements in soil organic matter with sustained planting of cover crops over multiple years. Organic matter content is often used as a litmus test for cover crop-induced improvements, but changes soil organic matter can be slow and challenging to detect, leading to questions about cover crop benefits for soil health.

<u>Results to Date:</u> We have sampled soils in fields with and without cover crops twice per year since Fall 2013 in SDW and since Spring 2015 in KDW, analyzing all samples for N species, P species, and organic matter content (% OM). We have synthesized soils data from four years of the *RCPP incentive-period* for both watersheds, and a

manuscript on the effects of cover crops on soil N, P and organic matter content was published in the Journal of Environmental Quality (Christopher et al. 2021). Our data show that soil NO_3^--N was consistently lower in cover crop fields compared to those without cover crops in both SDW and KDW (Fig. 6, top row). Christopher et al. (2021) also found that soil NO_3^- correlated with cover crop biomass, and that even modest growth of winter cover crops reduced soil nitrate, suggesting that nitrogen is incorporated into cover crop tissue, which decreases the potential for leaching to waterways via tile drainage. In contrast, soil P patterns differed among watersheds, where cover crops generally decreased water extractable P (WEP) in SDW (Fig. 6, bottom left), but the effect of cover crops was variable in KDW (Fig. 6, bottom right).

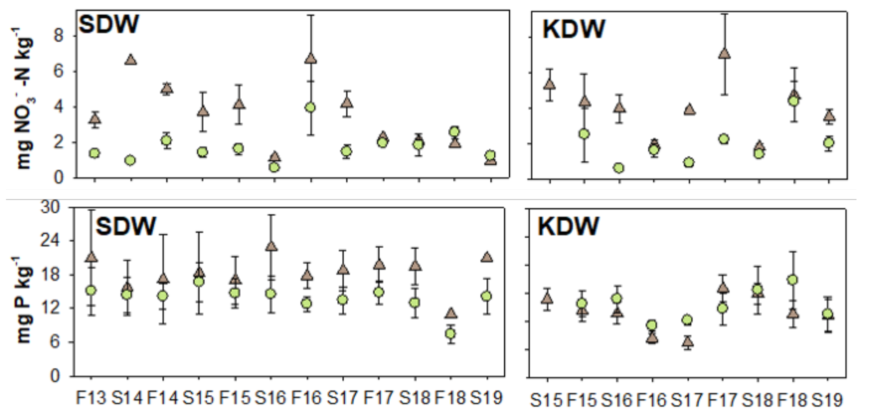

Figure 6. Changes in soil nitrate and water extractable phosphorus (WEP) due to cover crops in both study watersheds. Brown and green symbols are fields without and with cover crops, respectively. (Christopher et al. 2021 JEQ)

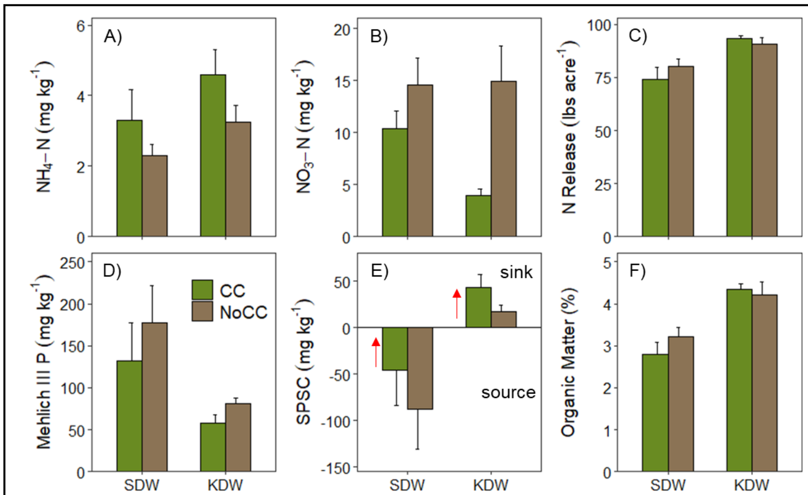

Figure 7. Soil Nutrients. Results from Fall 2020 (0-5 cm depth shown here) for A) NH_4^+-N, B) NO_3^--N, D) Mehlich III P, E) soil P storage capacity (SPSC), and F) % organic matter in fields with (CC) and without (NoCC) cover crops.

Post incentive period: Analysis of Fall 2020 data indicates that soil NO_3^--N was consistently lower in cover crop fields compared to those without cover crops in both SDW and KDW (Fig. 7). This suggests that cover crop biomass was taking up N from the soil that would otherwise be available for loss to waterways, especially in the more "leaky" forms (e.g., NO_3^--N). Importantly, soil analyses also showed that estimated N release (based on soil organic matter content) was not different between cover cropped and no cover crop fields (Fig. 7). These data will reassure producers that use of cover crops does not reduce N release from soil organic matter, which can provide necessary N for cash crop growth.

Fall 2020 sampling also showed that soil P patterns differed among the two watersheds. Cover crops generally decreased Soil Test P (i.e., Mehlich III P) in soils at SDW, but the effect of cover crops was more variable in KDW (Fig. 7). Additionally, we examined soil P storage capacity (SPSC) and found that fields with cover crops were either less of a source (SDW) or more of a sink (KDW) for P; this soil metric emphasizes that the "soil setting" is quite different between the two watersheds, but that cover crops had a similar directional improvement, reducing the potential for P loss from fields to waterways.

We have also recently completed laboratory analyses for soil samples from Spring 2021, and preliminary data analysis suggests that the spring data support the patterns for Fall 2020 (described above). We have also begun analyses to examine changes in soil chemistry across individual fields that switched from cover crops to no cover crops following the end of the incentive period (n= 10 fields). For fields where management changed, our preliminary results show that soil NO_3^--N was 90% to 700% higher during periods with no cover crops compared to the period with cover crops (Fig. 8). Our next step is to examine the effects of discontinuing cover crops on soil P. We will also explore field-specific changes in soil organic matter over time, to see if the cover crop signature is more evident in fields that remain consistently in cover crops. Dr. Shannon Speir will take the lead on a second soils manuscript exploring the effect of cover crops on the interactions of soil P and cations, which is expected to be completed by February 2022.

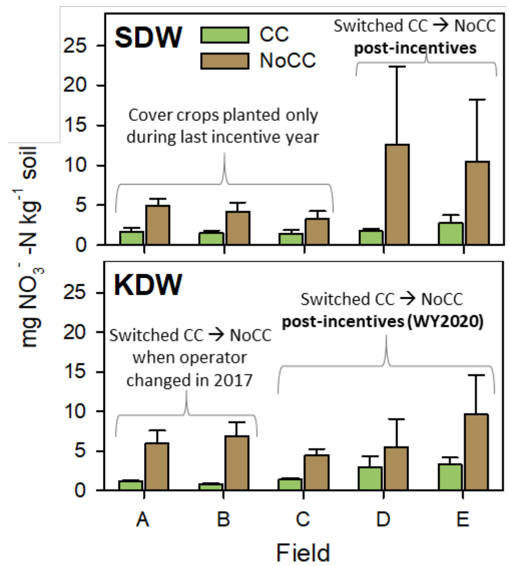

Figure. 8. For fields that "switched" from CC to NoCC after incentives ended, mean soil nitrate (+/-SE) for each field was consistently lower for years when cover crops were planted (CC) *vs.* years when fields were bare during the fallow period. (NoCC).

__Objective 3:__ **We are using the process-based Soil Water Assessment Tool (SWAT) to predict the benefits of watershed-scale cover crops and the two-stage ditch** implemented regionally across other watersheds to enhance conservation scenario planning. The SWAT module for cover crops is based on data collected from experimental farms. Given our multi-year dataset, we have been uniquely positioned to 1) validate the cover crop module at the watershed scale using real-world data from working lands in Indiana, and to 2) conduct scenario analyses that test the benefits of cover crops under future precipitation regimes. SWAT modeling is the go-to tool for assessing conservation impacts on non-point source pollution. With SWAT, we can scale-up our research from small experimental watersheds to larger spatial scales in order to forecast potential regional benefits of conservation in larger river basins, under both historical and projected future climate.

__Results to Date:__ Our initial work focused on developing a two-stage ditch module for SWAT, and results have been published in Christopher et al. (2017), which modeled reductions in N and P export under multiple two-stage ditch implementation scenarios for the River Raisin in the Western Lake Erie Basin. Next, for cover crops, we used a small watershed SWAT model to simulate the impact of the cover crops in SDW, based on actual implementation data from 2014-2018. Watershed export varied annually due to variation in storms, but on average, using cover crops on 67% of the row-crop acres reduced NO_3^--N export by 42% and SRP export by 36% during the fallow period (when cover crops are present), which resulted in annual export reductions of 36% for NO_3^--N and 9% for SRP (Table 1). As a second step, we used the validated model to run scenarios with coverage ranging from 10-100%, which resulted in 6-50% reductions in NO_3^--N export with cover crops implemented randomly on both corn and soy fields. Model runs with non-random implementation showed that planting cover crops on cornfields was

Table 1. The effect of cover crops on nutrient export using the SWAT Model in SDW. We contrast nutrient reductions for water year export (WY) to export during the cover crop growing season (October to April). Negative values indicate reduced nutrient loss to waterways.

	Water Year						Cover Crop Growing Season	
	No Cover Crop		67% Cover Crop		Impact of Cover Crop (WY)		Impact of Cover Crop (Oct-Apr)	
					Change in Load		Change in Load	
Water Year	NO_3-N (kg)	SRP (kg)	NO_3-N (kg)	SRP (kg)	NO_3-N (%)	SRP (%)	NO_3-N (%)	SRP (%)
2014	9864	160	5657	123	-43%	-23%	-53%	-38%
2015	23919	223	21218	326	-11%	46%	-22%	-26%
2016	17251	134	9987	108	-42%	-19%	-48%	-41%
2017	23327	220	14548	162	-38%	-26%	-39%	-38%
2018	14439	218	7896	175	-45%	-19%	-50%	-37%
Average:	**17760**	**191**	**11861**	**179**	**-36%**	**-9%**	**-42%**	**-36%**

twice as effective as planting on soy fields, likely because N fertilizer is only applied to corn fields, which increases the cover crop impact on NO_3^--N.

Recently, we explored the same implementation rates under multiple climate change scenarios using data from regionally-downscaled global climate models (GCMs). Our results show that, without cover crops, climate change strongly increased nutrient export, but the effectiveness of cover crops in reducing nutrient export also increased under climate change, producing greater percent reductions in export compared to retrospective simulations of historical conditions (Fig. 9). Assuming no other climate-induced changes in management, these results show that conservation practices based on cover crops will likely increase the climate resilience of the Midwestern agroecosystem. While cover crops can also pay dividends under the current climate, it may be that agroecosystems of the future will be more sustainable under a warmer and wetter future climate when cover crops are part of a management system. We are currently preparing two SWAT-related manuscripts including: 1) watershed-scale validation of the cover crop module in SWAT, 2) exploring resilience of agroecosystems to climate change impacts using cover crops.

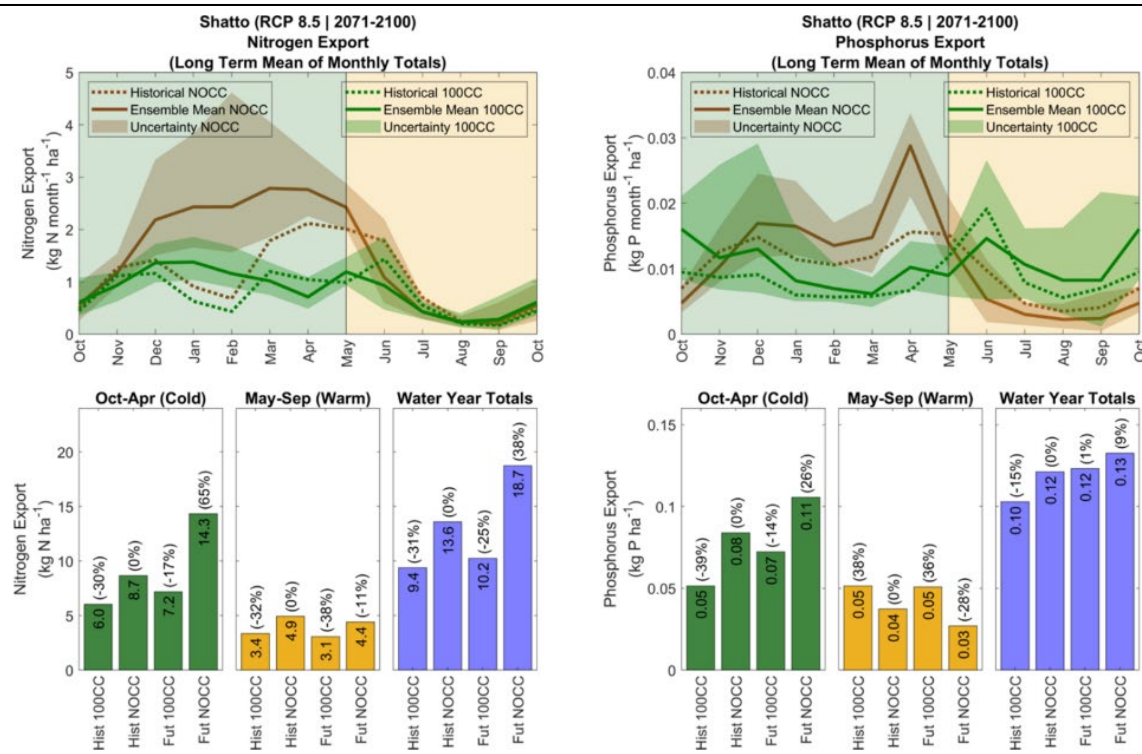

Figure. 9. Top panels: composite mean plots and range (shaded area) for different combinations of climate (historical and 2080s RCP8.5 future projections) and cover crop coverage (NOCC and 100CC) for Shatto. Lower panels: long-term-average total nutrient export as a function of season (Oct-Apr, May-Sept, Water Year), climate, and cover crop coverage. Ensemble mean values are used for the projected future values shown in the lower panels. The value and percent changes relative to the Hist NOCC values are shown as an inset number and number in parentheses respectively for each bar of the lower panels.

Sharing our outcomes:
The PIs have a long history working to quantify the effects of agricultural conservation on water quality in Indiana, building an excellent track record of training exceptional graduate students, and the consistent publication of their research in the peer-reviewed literature. The IWI project builds on the collaborative model established through our long-term work in SDW and developing partnerships in KDW. Our partners include the local Soil and Water Conservation Districts (SWCDs) and the producers/landowners in the two watersheds located in Kosciusko County (SDW) and Jasper/Newton/Benton Counties (KDW), their respective County Surveyors, The Nature Conservancy (TNC), The US Geological Survey (USGS), and researchers at the University of Notre Dame (ND) and Indiana University (IU). We have disseminated our project results widely by participating in a variety of outreach events at the local, national, and international level. **In FY21 alone, we participated in >28 outreach opportunities and**

reached nearly 1,000 people. We have also **published our work in the peer-reviewed literature** and have additional articles related to this work *in review* and in preparation with expected publication in 2022. **We will continue to communicate outcomes to stakeholders, and to other researchers through presentations at scientific meetings and publications.**

Peer-reviewed Publication from the IWI Project during FY21 project period (2020-2021):

Christopher, SF, Tank, JL, Mahl, UH, Hanrahan, BR, Royer, TV. **2021**. Effect of winter cover crops on soil nutrients in two row-cropped watersheds in Indiana (USA). Journal of Environmental Quality. https://doi.org/10.1002/jeq2.20217.

Dee, MM and Tank, JL. **2020**. Inundation time mediates denitrification end products and carbon limitation in constructed floodplains of an agricultural stream. Biogeochemistry 149: 141-158.

Hanrahan, BR, Tank, JL, Speir, SL, Trentman, MT, Christopher, SF, Mahl, UH, Royer, TV. **2021**. Science of the Total Environment, Vol: 801. https://doi.org/10.1016/j.scitotenv.2021.149501

Sethna, LR, Royer, TV, Speir, SL, Mahl, UH, Trentman, MT, Hagemeier, LP, Tank, JL ***In review***. Examining controls on silicon concentrations and stoichiometry in two agricultural watersheds: implications for management and downstream water quality. Biogeochemistry

Speir, SS, Tank, JL., Mahl, UH. **2020**. Quantifying denitrification following floodplain restoration via the two-stage ditch in an agricultural watershed. Ecological Engineering 155, 105945.

Speir, SS, Tank, JL, Bieroza, M, Mahl, UH, Royer, TV. **2021**. Storm size and hydrologic modification influence nitrate mobilization and transport in agricultural watersheds. Biogeochemistry. DOI10.1007/s10533-021-00847-y

Speir, SS, Tank, JL, Trentman, MT, Mahl, UH, Sethna, LR, Hanrahan, BR, Royer, TV. **2021**. Cover crops control nitrogen and phosphorus transport from two agricultural watersheds at multiple measurement scales. Agriculture, Ecosystems and Environment *In press*.

Trentman, MT, Tank, JL, Jones, SE, McMillian, SK, Royer, TV. **2020.** Seasonal evaluation of biotic and abiotic factors suggests phosphorus retention in constructed floodplains in three agricultural streams. Science of the Total Environment. 729, 138744.

Trentman, MT, Tank, JL, Royer, TV, Speir, SL, Mahl, UH, and Sethna, LR. **2020**. The role of cover crops and antecedent precipitation on soluble reactive phosphorus losses via tile drain flow in an agricultural watershed. Hydrological Processes. 34: 4446-4458.

Trentman, MT, Tank, JL, Braund, D, Entrekin, SA. **2021** Agricultural layering explains variation in sediment P dynamics in streams draining two distinct agricultural biomes. Aquatic Sciences 83: 1-11.

TABLE 2: FY21 Outreach Activities						
Category	**Event Name**	**Date**	**Location**	**Team Attendee(s)**	**Audience**	**Talk Title**
Presentation	American Geophysical Union, Annual Fall Meeting	Dec 2020	Web	Amelia Grose (Undergraduate)		Differences in groundwater contribution to streamflow versus watershed NO3--N export reveal importance of scale in evaluating agricultural conservation practices
Presentation	American Geophysical Union, Annual Fall Meeting	Dec 2020	Web	Shannon Speir (PhD Student)		Hysteresis patterns during storms suggest that vegetative cover mediates nitrate export in two agricultural watersheds
Presentation	Indiana Water Monitoring Council 2020 Annual Symposium; Breaking Down the Data Silos	Dec 2020	Web	Todd Royer (PI)	75	Use of monitoring data in academic research; examples of active and passive approaches
Presentation	2021 Upper Midwest Stream Restoration Symposium; Keynote Address	Feb 2021		Jennifer Tank (PI)	~150	**Keynote Address**. Indiana Watershed Initiative: The influence of floodplain restoration on water quality in agricultural streams
Presentation	Indiana University O'Neill School PhD Student Conference	March 2021	Web	Lienne Sethna (PhD Student)	15	Do winter cover crops alter N:P:Si ratios and risk for cyanobacterial blooms in streams draining intensive agriculture?
Presentation	Dissertation Defense	April 2021	Virtual	Shannon Speir (PhD Student)	90	Controls on Retention, Transformation, and Export of Nitrogen and Phosphorus in Agricultural Streams Across Spatial and Temporal Scales
Webinar	Dive into Sci-Comm Event held by University of Oklahoma	April 2021	Virtual	Shannon Speir (PhD Student)	50	Note: Discussed engagement with farmers and other stakeholders, as well as communication of project results to large audience
Presentation	International Association of Great Lakes Research Annual Meeting.	June 2021	Virtual	Shannon Speir (PhD Student)		Winter cover crops reduce nutrient losses from fields to waterways in two agricultural watersheds
Presentation	Society for Freshwater Science Annual Meeting.	May 2021.	Virtual	Shannon Speir (PhD Student)		Increased temperature and carbon availability enhances nitrous oxide production due to incomplete denitrification in river sediments.
Presentation	Society for Freshwater Science Annual Meeting.	May 2021.	Virtual	Lienne Sethna (PhD Student)		Does changing land cover alter N:P:Si ratios and risk for cyanobacterial blooms in streams draining intensive agriculture?
Presentation	Society for Freshwater Science Annual Meeting.	May 2021.	Virtual	Todd Royer (PI)		Effect of winter vegetative cover on dissolved organic carbon (DOC) input to streams draining intensively farmed watersheds

Presentation	Society for Freshwater Science Annual Meeting.	May 2021.	Virtual	Jennifer Tank (PI)		Winter cover crops reduce nutrient losses from fields to waterways in two agricultural watersheds
Presentation	Society for Freshwater Science Annual Meeting.	May 2021.	Virtual	Abagael Pruitt (PhD Student)		Land cover change reduces storm-driven sediment export in agricultural streams.
Presentation	Fourth International Workshop on High Temporal Resolution Water Quality Monitoring and Analysis.	June 2021	Virtual	Anna Vincent (PhD Student)		Influence of storms on ecosystem metabolism in two agricultural watersheds.
Presentation	Fourth International Workshop on High Temporal Resolution Water Quality Monitoring and Analysis.	June 2021	Virtual	Abagael Pruitt (PhD Student)		Winter cover crops reduce stream sediment export during storms.
Presentation	Fourth International Workshop on High Temporal Resolution Water Quality Monitoring and Analysis.	June 2021	Virtual	Shannon Speir (PhD Student)		Storm size and hydrologic modification influence nitrate mobilization and transport in agricultural watersheds
Presentation	ASLO 2021 Aquatic Sciences Virtual Meeting	June 2021	Virtual	Shannon Speir (PhD Student)		Storm size and hydrologic modification influence nitrate mobilization and transport in agricultural watersheds
Hosted Tours	Shatto tour for Kankakee River Basin Development Commission and other stakeholders	July 22, 2021	Shatto Ditch, IN	Todd Royer (PI), Ursula Mahl (staff)	20	Shatto Ditch tour; questions and answers about the implementation and effectiveness of the two-stage ditch as a conservation practice
Presentation	Indiana Water Summit	August 10, 2021	Indianapolis, IN	Todd Royer (PI)	200 (estimated)	
Media	CSA News magazine on Agronomy, Crop Science, and Soil Science Societies social media accounts https://doi.org/10.1002/jeq2.20217	August 2021	Web	Sheila Christopher (Associate Professor), Jennifer Tank (PI), Todd Royer (PI)		"Winter Cover Crop Promotes Nutrient Retention", Feature article promoting: Christopher, S.F., Tank, J.L., Mahl, U.H., Hanrahan, B.R., & Royer, T.V. (2021). Effect of winter cover crops on soil nutrients in two row-cropped watersheds in Indiana. Journal of Environmental Quality, 50, 667–679. https://doi.org/10.1002/jeq2.20217
Hosted Field Tour	Shatto Ditch Field Tour for Congresswoman Jackie Walorski	September 1, 2021	Shatto Ditch, IN	Jennifer Tank (PI)		
Media		September 1, 2021	Web			Rep. Walorski visits watershed initiative in rural Kosciusko County (https://wsbt.com/news/local/rep-walorski-visits-watershed-initiative-in-rural-kosciusko-county)
Presentation	KBS Field Station	September 14, 2021		Jennifer Tank (PI)	~40	