# Indiana Corn Marketing Council and Soybean Alliance Research Grant

# Final Technical Report

**Project Title:** Indiana Watershed Initiative (IWI): Continued quantification of water quality and economic benefits from the watershed-scale pairing of cover crops and the two-stage ditch

**Grant Period:** 1st May 2017 – 30th April 2018

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## Project Overview

The overall aim of this ongoing project is to quantify the water quality and soil benefits from the watershed-scale implementation of winter cover crops and the two-stage ditch in two Indiana watersheds. Funds supplied to farmers in the watersheds (Shatto Ditch and Kirkpatrick Ditch) through the USDA Regional Conservation Partnership Program (2015-2019) have been allocated to enable the widespread planting of cover crops and installation of new two-stage ditch along the stream channels draining each watershed. These Best Management Practices (BMPs) were chosen because they provide a practical solution to nutrient and sediment loss from farmland while maintaining productive and profitable agriculture operations. A key component of our project is accurately documenting the effect of these practices on water and soil quality and estimating the benefits and costs for public and private interests using that information. To that end, we are conducting high resolution monitoring of water and nutrient fluxes, sampling soils, and collecting agronomic data provided by producers and partners. These data are supporting our statewide and regional outreach activities while also providing input for modeling efforts to forecast the effectiveness of these conservation practices at the state and regional scale.

### *BMP Overview*

During this grant period, each watershed contained ~0.5 miles of two stage ditch. In Shatto Ditch Watershed (SDW) the amount of cover crop planting was increased from 12% of the watershed cropland in Fall 2012 to 67% in 2013, and has remained at 60-70% each Fall since (see Figure 1). Kirkpatrick Ditch Watershed (KDW) is our newer research watershed; it expands the geographic scope of the project and provides a point of comparison with SDW. In Fall 2014, only 5% of KDW cropland was planted with cover crops. The percentage planted in Fall 2015-2017 (during this grant period) was 23%-24%.

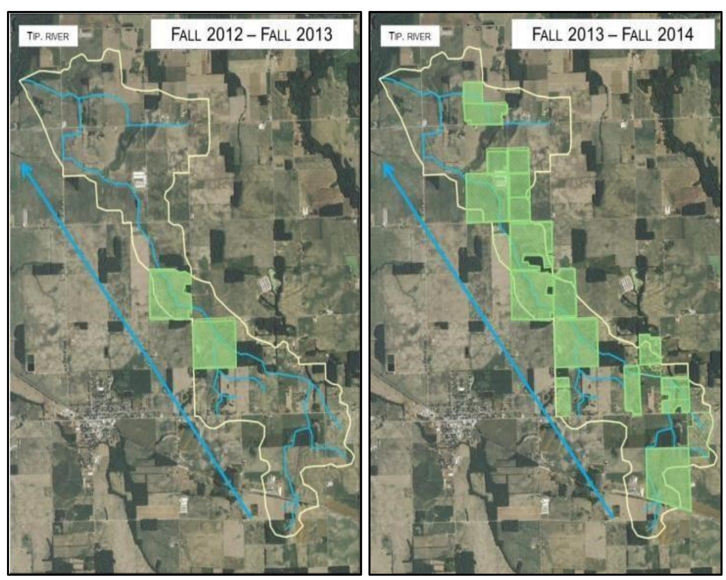


**Figure 1.** Location of cover crop parcels (shaded in green) in the Shatto Ditch Watershed during the pre-treatment year (left-2012-2013) and Year 1 (Right-2013-2014, with similar coverage each subsequent Fall).

## Project Objectives

**1.** We will quantify the water quality and quantity benefits of pairing cover crop and the two-stage ditch implemented at the watershed scale, through monitoring of the Shatto Ditch Watershed (SDW) located in Kosciusko County (3300 acres) and Kirkpatrick Ditch Watershed (KDW) in Jasper, Newton and Benton Counties (6373 acres).

**2.** We will quantify the benefits of winter cover crops in improving soil health through increased nutrient retention as well expected improvements of soil organic matter content over four years.

**3.** With our partners at the USDA Agricultural Research Service (ARS), we will use the process-based Soil Water Assessment Tool (SWAT) model to predict the benefits of watershed-scale cover crops and the two-stage ditch implemented across other watersheds in the region.

**4.** We will quantify the economic benefits for producers and the environment of the watershed-scale implementation of the cover crop/two-stage ditch pairing including the ecosystem service of increased watershed nutrient retention as well as the costs and benefits to the producers.

These objectives apply to the entirety of the ongoing project, known as the Indiana Watershed Initiative. The research grant from Indiana Corn Marketing Council and Indiana Soybean Alliance during this grant period was used to support activities under all four objectives.

## Objective 1: Actions and Outputs

### *Actions*

In order to quantify the water quality and quantity benefits of cover crop and two-stage ditch implementation, we have continued to use a combination of measurement and monitoring techniques and tools. In both watersheds this monitoring was the continuation of work begun with previous grants, including a grant from Indiana Corn Marketing Council and Indiana Soybean Alliance that ran from July 2015 to June 2016.

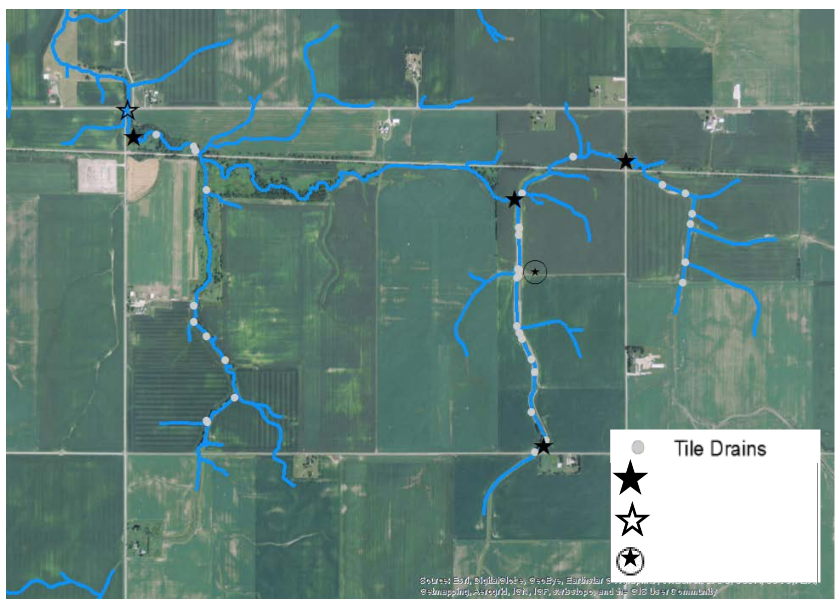


**Figure 2.** Kirkpatrick Ditch with tile drain and USGS gage locations.

Our sampling teams visited each watershed every two weeks for the entire reporting period. In SDW we continued to monitor 10 in-stream sampling locations and a representative subset of 25 tile drain outlets. In KDW we continued to monitor six in-stream sampling locations and 38 tile drain outlets distributed across ~10 fields (see Figure 2). We collected water samples from these sites and we also measured stream and tile drain flow and other water quality parameters (e.g. pH, conductivity). We then analyzed water samples for the following nutrients: ammonium ($NH_4^+$), nitrate ($NO_3^-$), soluble reactive phosphorus (SRP), and dissolved organic carbon (DOC). We continued to collect data from the real-time sensors and gauges deployed in 2015 (USGS stream gauges at the outlet of each watershed and weather stations in each watershed) and a real-time SUNA nitrate sensor deployed in August 2016 at the outlet of each watershed. In Spring 2017, we also began quantifying silica (Si) concentrations at the base of each watershed. Silica affects local water quality, and its ratio to nitrogen and phosphorus can help predict what species of algae may bloom. Our hope is the addition of silica data will be useful in managing for downstream harmful algal blooms that can introduce toxins into water supplies.

In addition, we carried out habitat surveys in SDW in Fall 2016, Spring 2017, and Fall 2017. The habitat survey data has been compared against historical data and has shown an improvement in benthic habitat quality since the introduction of the two-stage ditch. We also carried out habitat surveys in KDW in Fall 2016 and this will become an annual occurrence. These will allow us to assess the impact of our project work on geomorphology and biodiversity as well as water quality.

Colleagues at Grace College and USDA ARS (Agricultural Research Service) have provided us with datasets from other geographically close watersheds which have not had focused efforts on BMP implementation. We have been using these as references to compare to our Shatto and Kirkpatrick datasets and this will help us corroborate that the changes we are seeing are occurring because of the BMPs rather than as a result of other factors.

***<u>Outputs</u>***

The outputs of our activities include a wealth of data that enable us to empirically demonstrate the impacts of the BMPs on water quality and quantity.

*Nitrate ($NO_3^-$) in stream and tile drains (Figures 3 and 4)*

As part of ongoing work in both watersheds, we are now in the 5th consecutive year of cover crop planting in SDW at a coverage of ~70% of croppable acres. Before cover crops, we showed that the highest dissolved N and P concentrations enter the adjacent ditch via tile flow during winter and spring when fields are fallow. Since cover crop planting, we have shown that Spring nitrate-N mass losses from tiles draining fields with cover crops are 80% lower than N mass loss from tile drains without cover crops (2013-17). Our results for concentration are also in agreement with model simulations made at 41 Midwestern sites where cover crops reduced nitrate concentrations in tile flow by an estimated 42% (Malone et al. 2014). Results from our watershed-scale implementation on “working lands” (i.e., SDW) are therefore comparable to modeled values and are also transferrable to other watersheds. Our first manuscript, describing four years of sampling in SDW, has been published in Agriculture, Ecosystems & Environment (Hanrahan et al. 2018).

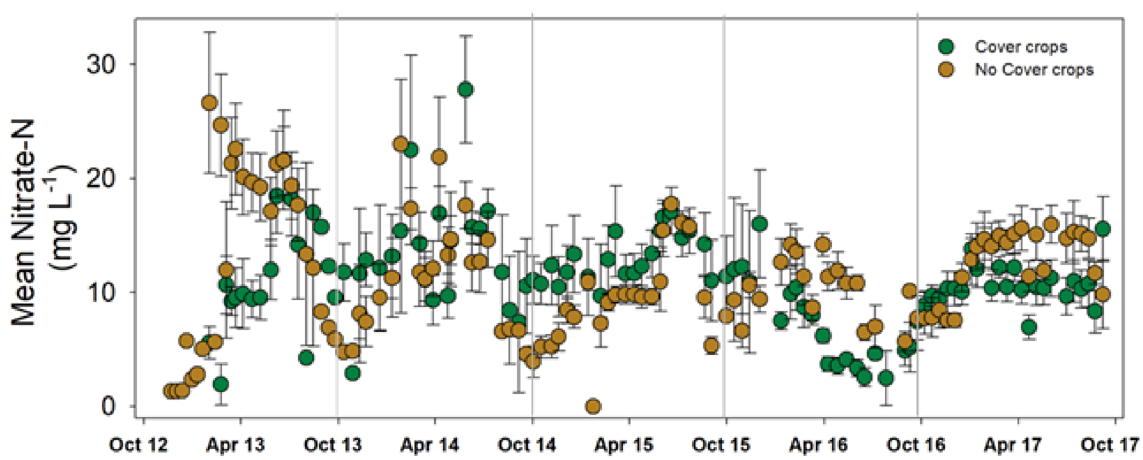


Figure 3. SDW tile drain nitrate concentrations have been lower since saturating the watershed with cover crops in October 2013. In Spring 2017, tiles draining cover crops were lower than previous years.

Since we expanded our project work to KDW, we have sustained cover crops at ~25% of croppable acres for two years, and we have seen similar and immediate results in the reduction of tile drain nutrients. Thus far, tile drain nitrate concentrations averaged ~50% lower in fields with cover crops compared to those without (Figure 4.

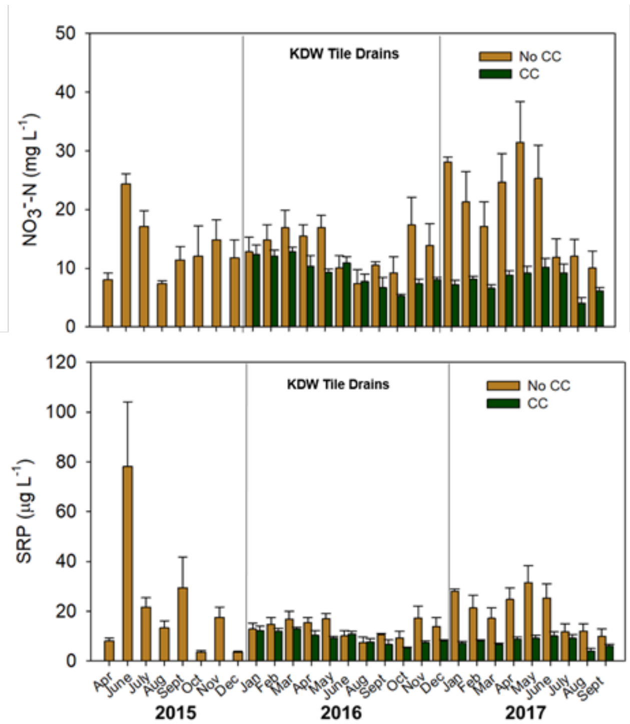


Figure 4. KDW tile drain nitrate (top) and soluble reactive phosphorus (SRP) concentrations varied seasonally and among years, with higher variation and mean concentrations for fields without cover crops than those with.

*Total watershed nutrient export (Figure 5 and Table 1)*

We used Loadflex in R (a computer programming language) to model nitrate export using the composite model and SRP using the interpolation model (Appling et al. 2015). We completed analysis of watershed N export for 10 water years at SDW, including 6 years prior to cover crop planting (Oct-2007 to Sep-2013) and 4 years at cover crop saturation (Oct-2013 to Sept-2017), and for 2 years at KDW (Oct-2015 to Sept-2017). Data collected during CIG-RCPP grant periods are shown below. Plots of cumulative export (Figure 4, left) show that while nitrate export was continuous, SRP export was intermittent with a large portion of the export occurring during short pulses.

For **SDW**, export during elevated flows was 18-22% lower for nitrate (Hanrahan et al. 2018) and 30% lower for SRP (Hanrahan et al. in preparation) during the first 3 years with watershed scale cover crop planting (2014-2016) compared to years without (2007-2012). However, in 2017 storms were more frequent and both runoff and nitrate export were ~40% higher than in the water year prior to cover crop saturation (2013). For **KDW**, annual export of water, nitrate, and SRP were higher than for SDW, likely due to KDW having both 2x higher watershed area and less cover crops (<25% of watershed area) than SDW.

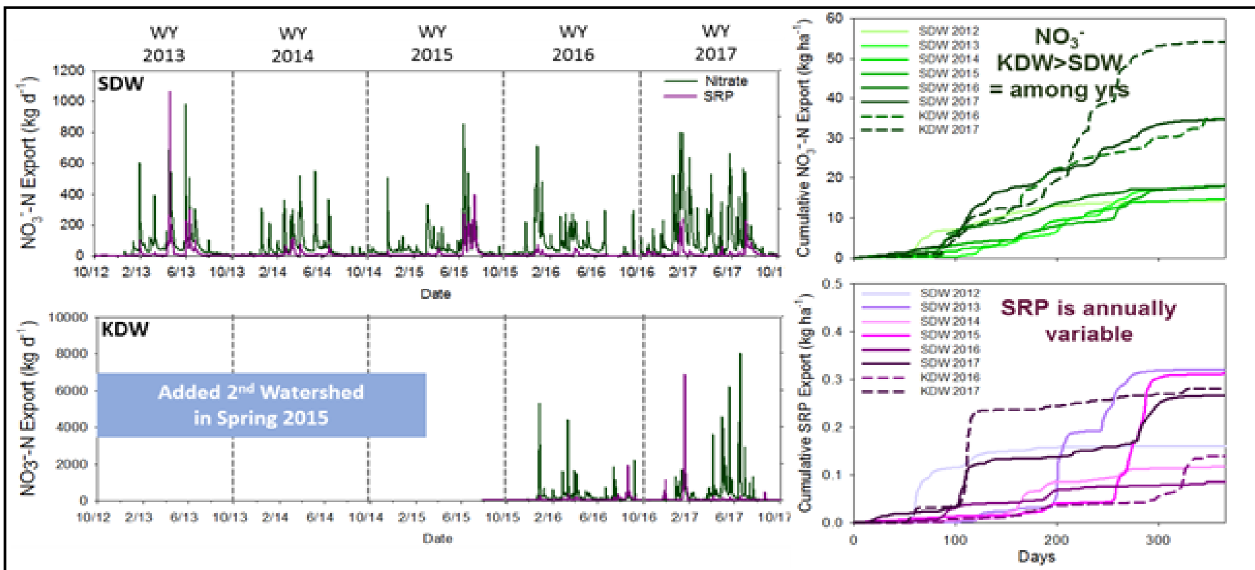


Figure 5. Nitrate and SRP export shown as a time series (left) and as total cumulative export for each water year (right) for the Shattto Ditch (SDW) and Kirkpatrick Ditch (KDW) Watersheds.

Table 1: Precipitation, total runoff, and modeled watershed export of both nitrate and SRP export for each year of the CIG-RCPP projects at SDW and KDW.

| Watershed | Water Year | Precipitation (mm) | Total Runoff (mm) | Modeled Nitrate Export (kg $ha^{-1}$) | Modeled SRP Export (kg $ha^{-1}$) |
|---|---|---|---|---|---|
| SDW | 2013 | 1162 | 270 | 17.95 | 0.32 |
| | 2014 | 942 | 250 | 14.64 | 0.12 |
| | 2015 | 944 | 292 | 17.72 | 0.31 |
| | 2016 | 949 | 314 | 17.82 | 0.09 |
| | 2017 | 941 | 381 | 25.26 | 0.21 |
| KDW | 2016 | 912 | 413 | 42.4 | 0.08 |
| | 2017 | 852 | 576 | 54.2 | 0.45 |

*Proportional Flow Duration Analysis (Figure 5)*

We examined N and P export during storm events, which has been a "frequently asked question" during many of our presentations. We found that storms do contribute significantly to N and P export; however, cover crops greatly reduced the amount of N and P export during winter and spring storms. For nitrate, there was low interannual variation in the proportion of export that occurred in each flow category even in wet years (08, 09, 17) and that SDW was similar to KDW. We found that ~80% of annual nitrate export occurred during storms (moist + high flows). Days with the top 10% of flows each year contribute 40-50% of nitrate export. Inter-annual variation for proportional export was higher for SRP than for nitrate. For both watersheds, base flow contribution to SRP export was minimal (<10%). The top 10% of flows had a much larger contribution to SRP export (~70%).

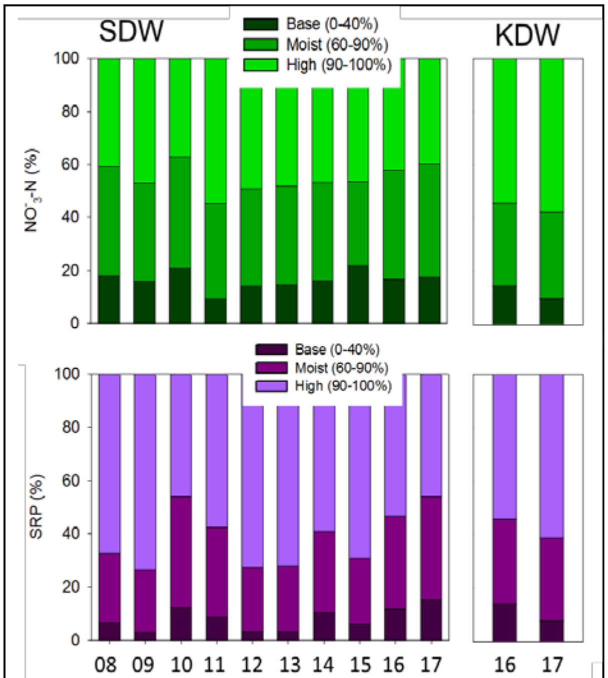

Figure 6. Proportional flow duration analysis showing the proportion of total annual nitrate and SRP export that occurs during different flow categories.

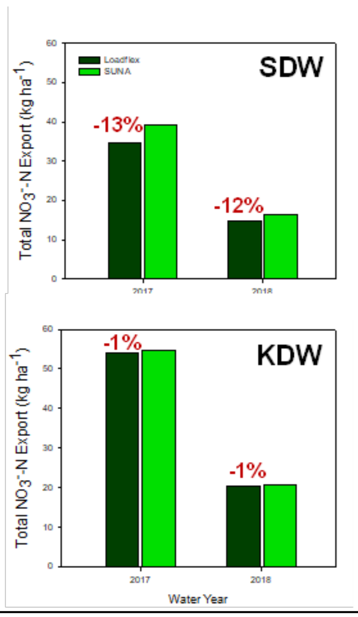

Figure 7. Comparison of total nitrate export calculated from SUNA data vs. export modeled using grab samples.

*Real Time Monitoring (Figures 6, 7, and 8)*

Since August 2016, we have deployed a Submersible Ultraviolet Nitrate Analyzer (Satlantic SUNA V2) at the base of each watershed, allowing us to monitor trends in $NO_3^-$ concentrations and flux continuously. In general, nitrate export based on the Loadflex composite model matches SUNA export well. Loadflex composite model estimates were closer to SUNA data at KDW (~1% difference) than at SDW (~12-13% difference). Estimates of export derived from Loadflex vs. the SUNA are likely closer at KDW due to the watershed's greater discharge having a greater impact on export in comparison to the changes in concentration during storms. Additionally, KDW is flashier, with rapid rising and falling limbs during storms. In contrast, the falling limb in SDW storms presents a more gradual return to baseflow (especially when the Tippecanoe River backs up).

*Storm nutrient export (Figures 8 and 10)*

To delve deeper into storm export dynamics, we explored the SUNA and discharge data during spring storms in both 2017 and 2018. We found that nitrate concentrations often increase with runoff during storms (as seen in the first three storm peaks in 2017 and the first two peaks in 2018). However, depending on antecedent moisture conditions and storm size, nitrate concentrations may also be diluted as flow increases. We found that hysteresis occurred during the two storms indicated by blue arrows in figure 10 (where each storm accounted for ~11% of total annual watershed export which amounted to 5,500 kg $NO_3^-$-N (4.1 kg/ha) for SDW and 15,400 kg $NO_3^-$-N (5.9 kg/ha) for KDW. *High frequency data can provide insight into storm dynamics, which could be important when management is targeting runoff during storms.*

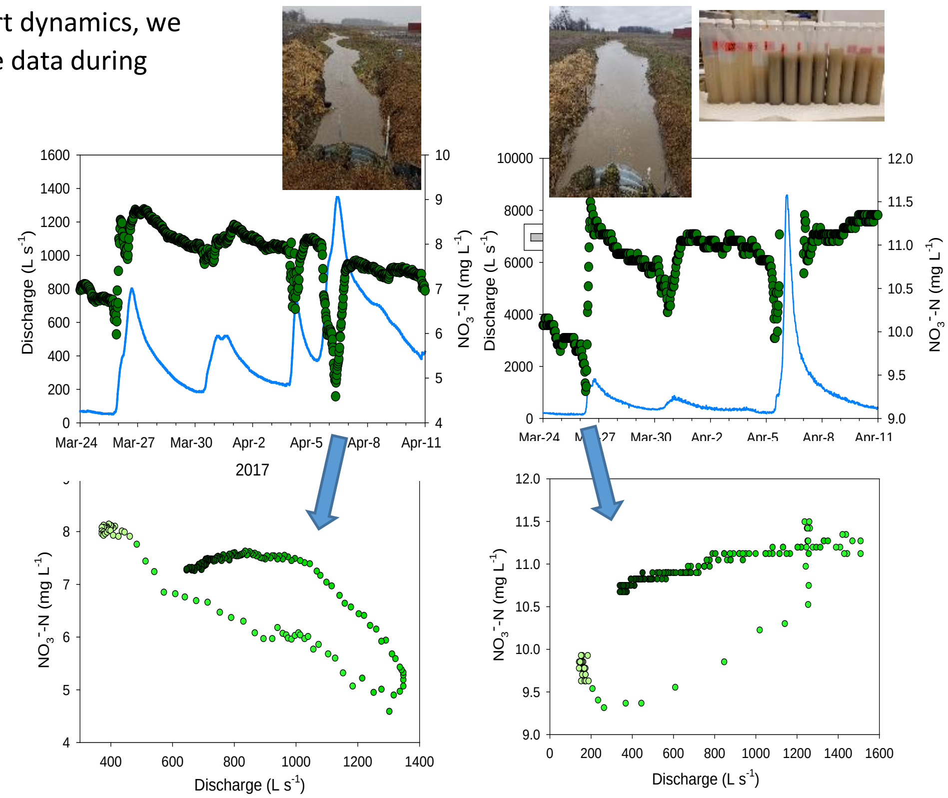


Figure 8. Trends in mean daily nitrate concentration (green dots) and discharge (blue line) show that concentrations can either increase with or be diluted by discharge during a storm and that hysteresis may occur, whereby patterns on the ascending and descending limbs of a storm may differ.


Figure 9. Images of SUNA nitrate sensor deployment..

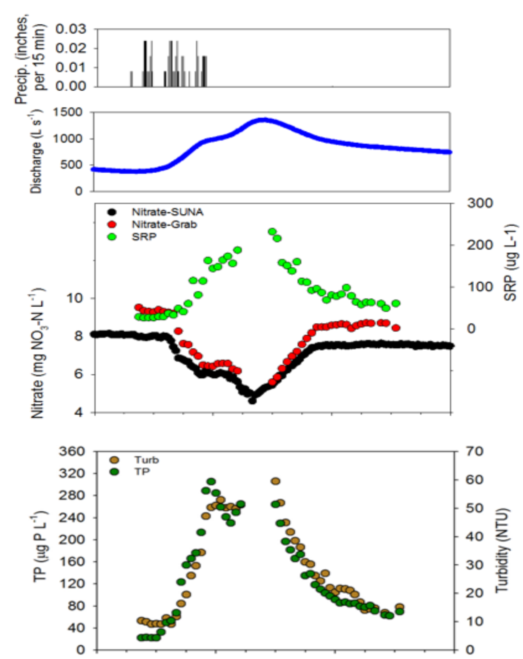


Figure 10. Precipitation, hydrograph, nutrient, and turbidity values for a storm at the outlet of SDW on April 5, 2017

We have also targeted storms for sampling with ISCO automated samplers at SDW to capture $NO_3^-$, SRP, total phosphorus (TP), and turbidity dynamics. One storm, from April 5, 2017 in SDW shows different patterns between SRP and $NO_3^-$, with SRP increasing in concentration while $NO_3^-$ was diluted (Figure 11). Also, during this storm TP was highly correlated with turbidity.

## Objective 2: Actions and Outputs

### *Actions*

In order to assess the changes in soil health from the planting of cover crops, we continued our soil sampling schedule by conducting soil surveys in Fall 2017 and Spring 2018 in both watersheds. In SDW we sampled 10 fields with cover crops and 3 fields without; in KDW we sampled 4 fields with cover crops and 4 fields without. Within each field we sampled soil along three transects that were perpendicular to the tile drain outlet (~ 20, 40, and 60 m from the edge of the field) as well as three transects parallel with the tile drain outlet. We collected soil at 0-5 cm and 5-20 cm depths at 6 points along transects and homogenized 2 samples per transect from each depth and each field for a total of 12 samples per field. Samples were analyzed for dry bulk density, pH, soil moisture, organic matter content, and total P. We also measured soluble species of Mehlich III phosphorus, water extractable phosphorus, soil nitrate-N, ammonium-N, and total dissolved N. For statistical analysis, we performed a randomized analysis of variance (ANOVA) to test the hypothesis that differences in nitrogen and phosphorus were due to differences between treatments (cover crop versus no cover crop).

### *Outputs: Soil results from both watersheds*

Cover crops reduced soil N content in both watersheds but had limited effects on other soil properties (Fig. 11). ***For both watersheds***, we found that soil $NO_3^-$N was consistently lower at both depths (0-5cm and 5-20cm) in cover crop fields compared to those without cover crops (Figure 14, ANOVA, p=<0.05), suggesting that N may be tied up in cover crop tissue during Fall and Spring. _In ***SDW***, WEP was also generally lower in fields with cover crops than those without, but differences were only significant during two seasons (Spring 2016 and 2017) and this trend was not observed at ***KDW***. We also found that loss of soil N and P during the fallow period (based on the decrease in soil N and P between Fall and Spring sampling) tended to be higher in fields without cover crops. However, cover crops did not significantly alter other soil properties such as organic matter and cation exchange capacity, which can influence whether N and P will remain bound to soils or leach during storms.

This is consistent with previous studies that have shown it can take years of cover cropping to see accumulation of organic matter and changes in soil chemistry. These data support the hypothesis that, even before long term changes in soils occur, cover crops can store nutrients over the fallow period then release nutrients that can be used by cash crops after cover crop termination.

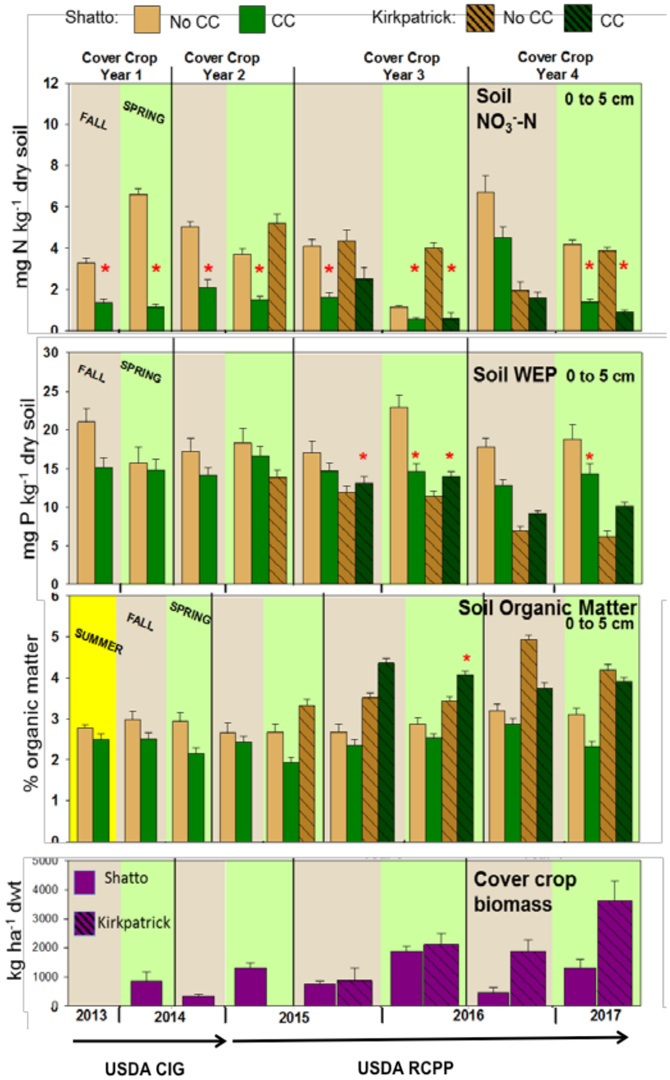


Figure 11. Variation in soil nitrate ($NO_3^-$-N), water extractable phosphorus (WEP), and organic matter OM) at 0-5 cm depth and cover crop biomass in fall and spring over 4 years at SDW and KDW. An * indicates significant differences (P<0.05).

In addition, buried bags tests showed that soil nitrification and mineralization were significantly higher in soils with cover crop residues

As with the water results, the outcome of these results is that we are able to contribute further data to understanding how cover crops retain nutrients in the field and return them to the soil after termination, thereby reducing the loss of nutrients through tile drains and the impact of agriculture on the environment.

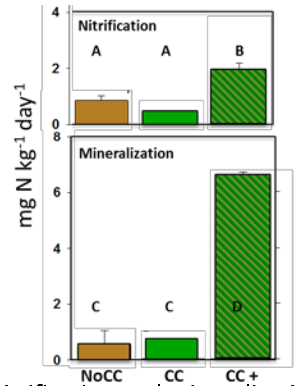


Figure 12. Rates of nitrification and mineralization for fields without cover crops (NoCC) and for fields with cover crops both without (CC) and with (CC+) cover crop residue added to soils.

## Objective 3: Actions and Outcomes

We have been working on ways to predict the wider impacts of both cover crops and the two-stage ditch using the Soil Water Assessment Tool (SWAT), a widely-used model that predicts water quality responses to agricultural land management activities. With SWAT, we can scale-up our results to address regional-scale questions, test various scenarios, and generate new hypotheses.

To parameterize the SWAT model for both the cover crop and two-stage ditch analysis, we have collated and processed field data derived from SDW and KDW to be used for calibration and validation. We have also reconditioned digital elevations models (DEMs) and prepared soils data and land use coverage data. The soil and land use data was first used for input to the Agricultural Conservation Planning Framework (ACPF) tool, which is used to assess nitrate leaching and runoff risk. We used the tool to evaluate the nutrient reduction potential of various SDW land use scenarios (including current cover crop coverage) and estimate annual cost across a series of cover crop scenarios. The scenarios from this tool are used as input to the SWAT model.

In addition, for the two-stage ditch component, we have worked with partners at the USDA Agricultural Research Service (ARS) to develop a new module for the SWAT model (there was no pre-existing two-stage ditch module). This module predicts nitrate and total phosphorus reduction resulting from two-stage ditches. Data from 9 Midwestern two-stage ditches were used for the module creation phase. In 2017 our team published a manuscript in the journal Ecological Engineering, entitled “Modeling nutrient removal using watershed-scale implementation of the two-stage ditch” (Christopher et al. 2017).

The modeling component of our project is being fed directly into the economic analysis because the model simulations are used as factors in this analysis. Future SWAT model simulations will allow for more refined analysis, determination of cost-effectiveness evaluations relative to nitrate and sediment reductions, and incorporation of aggregative field-level net profitability data. We will conduct further ACPF and SWAT analyses in both watersheds.

## Objective 4 Outputs and Outcomes

Our final objective is to quantify the economic benefits, for both producers/land managers and the environment, of the watershed-scale implementation of the cover crop/two-stage ditch pairing, including the ecosystem service of increased watershed nutrient retention as well as the costs and benefits to the producers. In order to expand our capacity and expertize in this area, Dr. Adriana Valcu-Lisman joined our team in January 2017, working with Dr. John Tyndall at Iowa State University. Dr. Valcu-Lisman is an environmental and natural resource economist.

Deriving a benefit-cost ratio requires an economic valuation of the benefits and costs. The costs of the practices are a known value in this project. The primary benefits include avoided fertilizer loss and prevented water pollution, which is being measured under Objective 1. Another potential benefit of cover crops is improved soil quality and increased crop yield. Soil data is being collected under Objective 2 but information on soil changes can also be obtained directly from producers. The other key information required is the land managers' costs and returns associated with their farm management practices including their use of cover crops. Survey data collected from SDW land owners/producers in previous years has been used for preliminary analysis but we have also been making the necessary preparations for conducting a new survey, written specifically to collect the essential data needed for our economic analyses and guided by the experience of our Iowa State University team members. This survey was distributed in August 2017 and will allow us to estimate direct, indirect and opportunity costs for producers associated with cover crop/two-stage ditch pairing.

Table 1. Average model financial parameters, as per farmer management records in SDW. Data: 2016/2017. n=4 farms[1].

| Average yields | BU/ac |
|---|---|
| Soybeans | 57.5 |
| Corn | 187 |

| Average cover crop cost/ acre | NRCS EQIP payment [2] |
|---|---|
| $42.21 | $36.07 |

| Average yield effects, % change | | Yield effect bu/acre | $/acre[3] |
|---|---|---|---|
| Soybean | 2.5 | 1.4375 | $14.62 |
| Corn | 0.5 | 0.935 | $3.30 |

| Average Change in Inputs | Soybean ($/acre) | Corn ($/acre) |
|---|---|---|
| Herbicide | +$1.00 | +$2.65 |
| Insecticides | +$1.00 | +$1.00 |
| Fungicides | $0.00 | $0.00 |

Average reduction in erosion costs/ acre = $5.00[4]

1. Data should be used with caution as the sample size it too small to capture reasonable variation. Results here in this report are meant for demonstration purposes at this time.

2. 2017/2018 NRCS Indiana EQIP is paying $36.07/acre for all cover crop species and termination methods.

3. Crop prices used for this analysis were 2018 futures at $10.17/bushel for soybeans, $3.53/ bushel for corn.

4. The average reduction in erosion costs represent costs prevented due to reducing erosion such as machinery costs to repair erosion in the field or ditches. The $5.00/acre savings was an average derived from a recent series of similar analyses (NACD, 2017).

The modelling work described under Objective 3 is a key part of the economic analysis because the models are used to simulate various watershed scenarios, setting up the environmental context of the analysis. Farm-scale (e.g., field-level nutrient retention and reduced erosion) and watershed benefits (e.g., reduced nutrient transport and sedimentation), as characterized by SWAT modeling, are being framed in economic terms and monetized. This work will continue through the next phase of the project.

<u>Results to date</u>: Analyzing the private and public benefits of long-term winter cover crop usage is very challenging. In a *private* context, the economic implications of cover crops on individual farms, in terms of long-term soil health, seasonal nutrient and moisture dynamics, and yearlong cash crop yield implications are idiosyncratic and complex. They are also highly dependent on farm-related factors such as cropping systems, field characteristics, soil type, cover species, pest pressure, cover management/termination, as well as exogenous factors such as weather. <u>As such, generalizable information about the net private economic benefits of cover crops is decidedly scarce.</u> To fill this gap, working closely with farmer participants, we have created working-farm partial budgets to track

changes in costs and revenues between rotations, and rank-specific factors by net change in profit. This farm-level economic data will be incorporated into the various watershed-scale cover crop scenarios so as to estimate aggregate privately experienced economic outcomes.

During Summer-Fall 2017, we developed a survey tool to aid our farmer cooperators in comprehensively tracking changes in costs and revenues between rotations associated with their use of cover crops, and rank specific factors by net change in revenue per acre. The survey was developed, and delivered, and analysis is ongoing in accordance with Institutional Review Board (IRB) approved protocols in place to protect individual farmer data and ensure quality control in data collection. We sent out surveys in both SDW (n=23) and KDW (n=30), and surveys are still being received and processed; we anticipate an above-normal response rate, but reminder cards have been sent to those cooperators who have yet to respond.

The survey data are being entered into a database and will be used to model net changes in revenue per acre in fields utilizing cover crops, using Cover Crop Economic Analysis Tool (Version 2.1), a model developed by USDA NRCS. For all cooperators, we are creating partial budgets that track the ranges and average financial effects of cover crop use, capturing short and long-term financial outcomes on working farms. For each cooperator financial model, we are using the following variables: 1) direct cover crop establishment and management costs; 2) yield increase/decrease in cash crop following cover crop; 3) other operation specific changes in costs such as changes in fertilizer (e.g., nutrient credits), herbicide, pesticide, fungicide inputs. Additionally, we asked farmers to qualitatively describe erosion reduction so that we can attempt to monetize reductions in erosion repair costs and equipment maintenance, and estimate effects to long-term on-site soil fertility.

Using a subset of data from the surveys in SDW, we summarize *very preliminary* results of this financial analysis (Table 1 presents average model parameters based on farmer survey responses). On average, farmers paid about $42/ acre to establish and terminate cover crops and they received the standard NRCS EQIP cost share payment of $36.07/ acre. Soybean rotations experienced a 2.5% increase in yields following cover crops and corn rotations a 0.5% increase; these yield changes were worth $14.62 and $3.30 per acre respectively. Reported changes in cash crop inputs due to cover crop usage were minimal in this subset of data, amounting to an average $1/acre increase in herbicide costs in soybean rotations and a $2.65/ acre increase in corn as well as a $1/acre increase in insecticide costs in both soy and corn crops. This analysis used a $5.00 per acre reduction in erosion related costs (e.g., fixing gullies, reduced equipment usage, cleaning out tile inlets/drainage ditches) derived by averaging the findings from a recent series of similar analyses (NACD 2017).

Table 2. Average net benefits per crop in a two-crop, corn-soybean rotation in SDW (n=4 respondents).

| Cover Crop - Soybean rotation | | Cover Crop - Corn rotation | |
|---|---|---|---|
| Total Cost ($/ac)[1] | $42.22 | Total Cost ($/ac) | $42.22 |
| Total Benefit ($/ac)[2] | $50.80 | Total Benefit ($/ac) | $40.42 |
| Net Benefit ($/ac) | $8.59 | Net Benefit ($/ac) | -$1.79 |

[1.] Total cost includes direct establishment, termination costs of cover crops plus any increases in cash crop inputs.

[2.] Total benefits includes EQIP payment, yield increases, reductions in cash crop inputs, and reductions in machinery costs due to reduction in erosion.

For the farms represented in this subset of data, we found that soybean fields experienced an average net benefit of $8.59 per acre (note: result is largely due to one farm experiencing fairly large increases in yields across two crop years that they attributed to the use of cover crops). Corn fields experienced an average net benefit of -$1.79 per acre (largely due to slightly increased cash crop input costs attributed to cover crop usage). See Table 2 for summary.

Extending the analysis over a 15-year period for these farmers by assuming continual cover crop usage, continual EQIP payments, consistent input costs and crop prices (in real terms, ignoring inflation), and corn-bean rotations, we tested the financial effects of expected long-term enhancement of soil organic matter. Assuming a 1% increase in soil organic matter by Year 10, available N and P will increase 20 and 2 lbs/acre respectively (in addition to any reported nutrient reductions; Reeves 1994). As such, the net present value of benefits for this subset of respondents fluctuates between about $8/acre and -$1/acre (depending on rotation) until Year 11 when the emergent benefits of additional nutrients increases the net-benefits to an average of just under $25/ acre through Year 15 (Table 3). <u>This preliminary analysis emphasizes the long-term nature of economic outcomes associated with cover crop usage. As additional surveys are incorporated into our database, we will add them to this analysis.</u>

<u>Next steps:</u> We will layer the net-financial effects information into the ACPF GIS framework and SWAT so that total experienced and expected financial outcomes of various cover crop scenarios can be tracked and better utilized in cost-effectiveness assessments. Our subsequent SWAT model simulations will allow for more refined analyses, determination of cost-effectiveness evaluations relative to nutrient and sediment reductions, and incorporation of aggregative field-level net profitability data.

Table 3. 15-year net present value of continuous cover crop usage in SDW using 2%, real discount rate on n=4 farms.

| Year | Costs ($/ac) | Benefits ($/ac) | Net Benefit ($/ac) |
|---|---|---|---|
| 2017 | $42.22 | $50.80 | $8.59 |
| 2018 | $41.39 | $39.63 | -$1.76 |
| 2019 | $40.58 | $48.83 | $8.25 |
| 2020 | $39.78 | $38.09 | -$1.69 |
| 2021 | $39.00 | $46.93 | $7.93 |
| 2022 | $38.24 | $36.61 | -$1.62 |
| 2023 | $37.49 | $45.11 | $7.62 |
| 2024 | $36.75 | $35.19 | -$1.56 |
| 2025 | $36.03 | $43.36 | $7.33 |
| 2026 | $35.33 | $33.82 | -$1.50 |
| 2027[1] | $34.63 | $63.73 | $29.09 |
| 2028 | $33.95 | $54.13 | $20.18 |
| 2029 | $33.29 | $61.25 | $27.96 |
| 2030 | $32.64 | $52.03 | $19.39 |
| 2031 | $32.00 | $58.87 | $26.88 |

1. Assumes a total nutrient benefit per 1% increase in SOM ($/ac) of $14.38 due to an increase of 20 and 2 pounds per acre respectively in available nitrogen and phosphorus (Reeves 1994).

## Project Outreach

This project builds on the collaborative model established through our long-term work in SDW and developing partnerships in KDW. It leverages a significant monetary investment through the USDA RCPP program. Our partners include the Soil and Water Conservation Districts (SWCDs) and local producers/landowners in each of the two watersheds located in Kosciusko and Jasper/Newton/Benton Counties, their respective County Surveyors, the Indiana Chapter of The Nature Conservancy (TNC), The US Geological Survey (USGS), and researchers at the University of Notre Dame (ND), Indiana University (IU), and Iowa State University (ISU). We remain committed to sustained outreach activities to educate stakeholders about the benefits of pairing cover crops with the two-stage ditch at the watershed scale. We continue to host multiple stakeholder meetings within and across watersheds to coordinate monitoring and implementation efforts, and to disseminate our ongoing results. We are disseminating our project results widely by participating in a variety of outreach events at the local, national and international level. Since the start of the IWI RCPP project (May 2015), we have presented and/or participated in 24 agricultural/field day events, given 64 conference presentations and hosted 9 watershed tours. In June 2017, PI Jennifer Tank organized and chaired a special session on "Quantifying water quality outcomes of watershed-scale conservation projects" at the annual conference of the University Council in Water Resources (UCOWR) in Colorado; all of the students participating in the IWI RCPP presented their research and had an opportunity to interact with invited speakers from around the nation. In September 2017, we also hosted a tour for 30+ NRCS Engineers at the SDW after the recent implementation of an addition 2.4 miles of two-stage ditch, making SDW the longest continuous two-stage in the world at 2.9 miles in total. Team members also gave invited talks at the AGU Chapman Conference in Puerto Rico, and at the 2017 ASLO Aquatic Sciences Meeting in Hawaii. We also continue to maintain our online presence via our website and social media accounts which provide a place to share results, updates, and project resources including one-page data summaries. We continue to use these opportunities to discuss the benefits of cover crops and the two-stage ditch on water quality/quantity and soil health (**Objectives 1 and 2**) and results from model parameterization and economic analysis (**Objectives 3 and 4**). An outreach summary is provided in Table 2 and a full list is provided in Appendix 1.

Two new manuscripts describing our work were recently published: (1) a manuscript describing our work on creating a new two-stage ditch module for the SWAT model (using data from this project for calibration) is now available in Ecological Engineering, and (2) a manuscript (led by former PhD student Brittany Hanrahan) the first 4 years of stream and tile drain results from the SDW is now available in Agriculture, Ecosystem & Environment, which is a high impact journal with an international audience.

- S.F. Christopher, J.L. Tank, U.H. Mahl, H Yen, J.G. Arnold, M.T. Trentman, S.P. Sowa, M.E. Herbert, J.A. Ross, M.J. White, T.V. Royer. Modeling nutrient removal using watershed-scale implementation of the two-stage ditch*. Ecological Engineering* 108 (B):358-369.
- Winter cover crops reduce nitrate loss in an agricultural watershed in the central U.S. 2018. B.R.Hanrahan, J.L.Tank, S.F.Christopher, U.H.Mahl, M.T.Trentman, T.V.Royer. Agriculture, Ecosystems & Environment. Volume 265, 1 October 2018, Pages 513-523. https://doi.org/10.1016/j.agee.2018.07.004

In addition, Sheila Christopher is working on a manuscript describing the changes we have measured in watershed soils as a result of cover crop planting and Brittany Hanrahan is working on a manuscript describing the changes we have measured in phosphorus export at field and watershed scales.

We continue to have open dialogue between the County Soil and Water Conservation Districts (in each watershed), the Nature Conservancy, and the University of Notre Dame, Indiana University and Iowa State University researchers, which is essential for the success of conservation practice implementation and data collection.

| Outreach Events/Activities | Total This Reporting Period |
|---|---|
| **All** | **34** |
| **Agricultural Meetings** | **1** |
| **Farmer Outreach** | **2** |
| **Hosted Tours** | **0** |
| **Presentations** | **27** |
| **Communications & Media** | **4** |
| **Other** | **0** |

**Table 2.** Summary of Outreach Events and Activities**PENDIX 1**

| CATEGORY | TITLE/DESCRIPTION | DATE | LOCATION | TEAM ATTENDEE(S) | AUDIENCE | TALK TITLE |
|---|---|---|---|---|---|---|
| Presentations | Good Shepherd Montessori School Junior High Academic Conference | 5/5/2017 | South Bend, IN | Jennifer Tank | 30 junior high students | |
| Communications and Media | Webinar: Water Quality Targeting Success Stories Report Launch | 5/24/2017 | Washington DC and https://www.farmland.org/initiatives/water-quality-targeting-success-stories | Jennifer Tank | 245 (online and in-person at launch event) | |
| Presentations | Society for Freshwater Science annual meeting | 6/5/2017 | Raleigh, North Carolina | Shannon Speir | 110 | Real-time nitrate data provide insights into nitrate-n export during storms in two contrasting agricultural watersheds |

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|---|---|---|---|---|---|---|
| Presentations | Society of Wetland Scientists Annual Conference | 6/6/2017 | Puerto Rico | Sheila Christopher | 50 | Modeling nutrient removal using watershed-scale implementation of the two-stage ditch |
| Presentations | Society for Freshwater Science annual meeting | 6/7/2017 | Raleigh, North Carolina | Brittany Hanrahan | 100 | Comparing denitrification rates between restored and naturalized floodplains in agricultural ditches |
| Presentations | Society for Freshwater Science annual meeting | 6/8/2017 | Raleigh, North Carolina | Anna Kottkamp | 100 | Changes in benthic substrate in response to the restoration of inset floodplains in a midwestern agricultural stream |
| Presentations | Society for Freshwater Science annual meeting | 6/8/2017 | Raleigh, North Carolina | Jennifer Tank | 120 | Quantifying water quality benefits of floodplain restoration in agricultural streams at both the reach- and watershed-scale |
| Presentations | Universities Council on Water Resources 'Water in a Changing Environment' conference | 6/14/2017 | Fort Collins, CO | Brittany Hanrahan | 40 | Quantifying changes in nutrient export from an agricultural watershed following the planting of winter cover crops |
| Presentations | Universities Council on Water Resources 'Water in a Changing Environment' conference | 6/14/2017 | Fort Collins, CO | Ursula Mahl | 40 | Linking soil health to improved water quality via the planting of cover crops in two Indiana watersheds |
| Presentations | Universities Council on Water Resources 'Water in a Changing Environment' conference | 6/14/2017 | Fort Collins, CO | Kara Prior | 40 | Response in dissolved organic carbon dynamics and greenhouse gas emissions to watershed-scale implementation of winter cover crops |
| Presentations | Universities Council on Water Resources 'Water in a | 6/14/2017 | Fort Collins, CO | Shannon Speir | 40 | Real-time monitoring provides insight into nitrate- |

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| | Changing Environment' conference | | | | | n export during storms in two agricultural watersheds |
| Presentations | Universities Council on Water Resources 'Water in a Changing Environment' conference | 6/14/2017 | Fort Collins, CO | Matthew Trentman | 20 academics | Comparing the effectiveness of increased winter land cover on nutrient export across two Indiana agricultural watersheds |
| Farmer Outreach | Shatto Ditch Watershed Annual Town Hall meeting | 6/26/2017 | Mentone, IN | Jennifer Tank; Todd Royer; Kara Prior; Matt Trentman; Shannon Speir; Elizabeth Willows | 16: 2 SWCD partners, 1 NRCS partner, 1 County Surveyor, 1 TNC partner, 11 landowners | IWI RCPP Project: Shatto Ditch Update |
| Farmer Outreach | Kirkpatrick Ditch Watershed Annual Town Hall meeting | 6/27/2017 | Goodland, IN | Jennifer Tank; Todd Royer; Kara Prior; Elizabeth Willows; Shannon Speir; Matt Trentman | 11: 3 SWCD partners, 2 NRCS DCs, 1 TNC partner, 3 farmers, 2 county surveyors | |
| Presentations | Indiana Water Resources Association Symposium | 6/29/2017 | Turkey Run State Park, IN | Elizabeth Willows | 72 | Successes and challenges in quantifying the impact of watershed-scale conservation on working land |
| Communications and Media | Email communication with Jason Milks at TNC Arkansas Field Office on two stage ditch data | 9/12/2017 | | Jennifer Tank | | |
| Communications and Media | Email communication with Katie Burke at Kansas Department of Agriculture | 8/30/2017 | | Jennifer Tank | | |

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| | with One Pagers and IWI publications | | | | | |
| Communications and Media | Email communication with Dan Perkins at Harte Charitable Foundation on One Pagers and recent IWI-related publications | 8/30/2017 | | Jennifer Tank | | |
| Presentations | Engineers/CETS meeting--Northeast Area | 10/4/2017 | | Jennifer Tank, Todd Royer | | |
| Presentations | WaterSmart Innovations Conference and Exposition | 10/4/2017 | Las Vegas, NV | Matthew Trentman | 30 | The Impact of Winter Cover Crops on the Export of Phosphorus from Tile Drains in the Agricultural Midwest |
| Presentations | WaterSmart Innovations Conference and Exposition | 10/4/2017 | Las Vegas, NV | Shannon Speir | 30 | Real-time nitrate data provides insight into management of nitrate-N export during storms in agricultural watersheds |
| Presentations | Swedish University of Agricultural Sciences | 2/1/2018 | Uppsala, Sweden | Jennifer Tank | 40 | Quantifying the effects of floodplain restoration and winter cover crops on nutrient export from agricultural catchments |
| Presentations | Notre Dame Junior Parents Weekend | 2/17/2018 | South Bend, IN | Jennifer Tank | 50 | |
| Presentations | Environmental Studies Lecture Series | 4/17/2018 | Colby College, Waterville, ME | Jennifer Tank | 50 | Quantifying the effects of floodplain restoration and winter cover crops on nutrient export from agricultural catchments |
| Agricultural Meetings | SWCD Meeting | 5/1/2018 | Kosciusko County, IN | Jennifer Tank | 12 | Update on IWI activities |
| Presentations | School of Natural Resources Research Day | 5/3/2018 | University of Missouri | Jennifer Tank | 50 | Quantifying the effects of floodplain restoration and |

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| | | | | | | winter cover crops on nutrient export from agricultural catchments |
| Presentations | St. Joseph County Parks Department, Science at Sunset | 5/15/2018 | South Bend, IN | Jennifer Tank | 27 | Fighting for Farmers and Clean Water |
| Presentations | Society for Freshwater Science annual meeting | 5/21/2018 | Detroit, MI | Sarah Roley | 50 | Restoring stream ecosystem function on working lands to improve water quality |
| Presentations | Society for Freshwater Science annual meeting | 5/21/2018 | Detroit, MI | Jennifer Tank | 70 | The influence of elevated flows on nitrate and phosphorus export from two agricultural watersheds |
| Presentations | Society for Freshwater Science annual meeting | 5/21/2018 | Detroit, MI | Brittany Hanrahan | 50 | Land cover change through the planting of winter cover crops reduces phosphorus loss from an agricultural watershed |
| Presentations | Society for Freshwater Science annual meeting | 5/21/2018 | Detroit, MI | Matt Trentman | 50 | Comparing the role of biotic and abiotic factors influencing phosphorus cycling in constructed floodplains of multiple agricultural streams |
| Presentations | Society for Freshwater Science annual meeting | 5/22/2018 | Detroit, MI | Shannon Speir | 50 | The impact of substrate size and other drivers on nutrient uptake across a five-month biofilm colonization sequence in experimental streams at ND-LEEF |
| Presentations | Society for Freshwater Science annual meeting | 5/23/2018 | Detroit, MI | Lienne Sethna | 20 | Responses of silica stoichiometry to hydrologic and vegetation changes |

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| Presentations | Society for Freshwater Science annual meeting | 5/23/2018 | Detroit, MI | Anna-Sophie Hoppe | 20 | Comparing species richness and taxonomic diversity of aquatic invertebrates in restored and naturalized agricultural ditches |

Literature Cited


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