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Winter wheat filter strip for in-field ditches to reduce nutrient and sediment runoff – A new best management practice

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Summary

Although only 9.5% of Louisiana, the Sportsman's Paradise, is considered a water resource, it supports a diverse array of wildlife and outdoor activities. Many of these activities are dependent (both directly and indirectly) on the water quality of the rivers, lakes, and streams. Aquaculture and fisheries (fresh and saltwater) account for $549,574,042 of the total gross farm value in Louisiana. Crawfish, alligators, oysters, turtles, game and fish are an integral portion of the state's economic infrastructure in addition to the production aspects related to irrigation and agricultural production. Louisiana watersheds represent a significant portion the Mississippi River watershed and directly contributes to water quality issues in the Gulf Coast. Land management of surrounding areas has the potential to contribute to the influx of nutrients, chemicals, and other pollutants, ultimately resulting in the declining quality of water in lakes, rivers, and streams. As a direct response, the Natural Resources Conservation Service (NRCS) has developed multiple best management practices (BMPs) with the ultimate goal to reduce nonpoint source (NPS) pollutants and improve water quality in impaired watersheds. The establishment of vegetation, typically a cover crop, planted over in-field drainage ditches is one such BMP, designed to slow drainage water as it moves though the ditch and act as a filter aiding in the removal of sediment and nutrients. In the fall of 2014, nine in-field ditches were established in a soybean field and divided into three treatments: bare ground (control), over seeded with wheat (*Triticum aestivum*), and over seeded with cereal rye (*Secale cereale*). In fall 2015 and 2016, treatments were adjusted to examine the effectiveness of in-field ditches over seeded with wheat at 4.6 or 9.1 meter borders. Automated water samplers (ISCO 6700) were installed at the terminal end of each drainage ditch to collected water samples following precipitation events after planting through termination of the cover crop. Regardless of cover crop, filters reduced total suspended solids (TSS, 57%), orthophosphate-P (37%), and total Kjedahl nitrogen (39%) compared to the bare ground controls. Low rainfall (2015 & 2016) and excessive rainfall (spring 2015) resulted in poor sampling conditions for those two years. Despite only a small number of samples collected, first flush samplers demonstrated a decrease in TSS (54%), orthophosphate-P (50%), total P (44%), and ammonium-N (65%) regardless of filter width.

Introduction

Approximately 60% of Louisiana's agricultural income stems from row crop agriculture (sugarcane, soybeans, rice, cotton, and corn) and in many cases is reliant on irrigation (flood or drip) during drier months. Louisiana is also well known for its aquaculture systems including crawfish, alligators, oysters, turtles, game fish, etc. In row crop production, use of chemical and organic fertilizers, pesticides, and herbicides are common, and these inputs have an increased potential to move throughout watersheds when used improperly. Flood irrigation is highly inefficient, and contributes significantly to outputs through runoff, carrying sediment and nutrient loads from surrounding fields into local water bodies. Best management practices (BMPs) are routinely implemented to aide in the reduction of nutrients and sediments in runoff, potentially improving surface water quality. The objective for this project was to evaluate use of modified in-field filter strips on runoff and determine if the filters were effective in reducing pollutant loads.

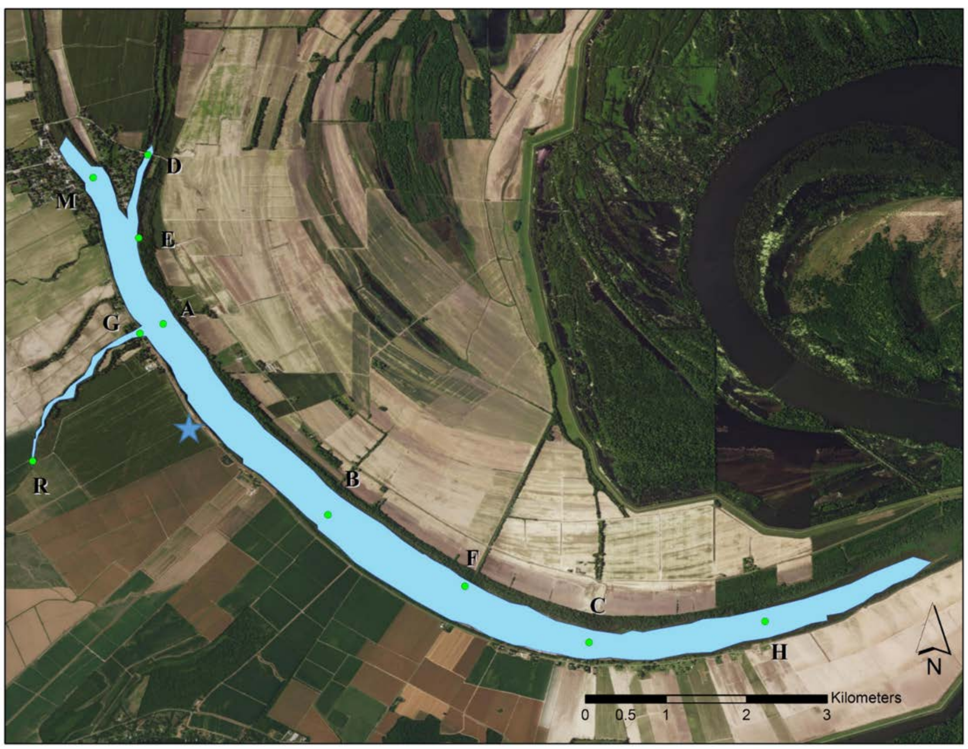

Figure 1. Farm location marked with blue star. Blue area represents Lake St. Joseph with green points representing water sample locations for monitoring water quality in the lake.

Materials and Methods

Site Selection and Monitoring Plan

A soybean (*Glycine max*) field located at 32.044788°N and 91.219787°W, south of Newellton, Louisiana (Figure 1) was used for this experiment. Nine in-field ditches were established following soybean harvest each year of the study to allow for 3 replications of each treatment. The project was first initiated in the fall of 2013. Due to a cold winter in 2013, and severe bird damage resulting in a late re-planting (December), the wheat (*Triticum aestivum*) did not provide an adequate stand for evaluation. Following soybean harvest in 2014, in-field ditches were placed throughout the field and treatments were established (Figure 2). Treatments consist of 12.2 meter wide strips of wheat, cereal rye (*Secale cereale*), and a bare ground control seeded long the in-field ditch. The 12.2 meter wide strips provide 6.1 meter border of cover on either side of the in-field ditches. The treatments were planted on 28-Oct-2014 at a rate of 101 kg seed ha^{-1}. In fall 2015 and 2016 treatments were adjusted to include a bare ground control, a 4.6 meter border of wheat, and a 9.1 meter border of wheat, each replicated three times. Wheat was planted at 101 kg seed ha^{-1}. The orientation of the in-field ditches was also adjusted (Figure 3) to better follow the natural change is elevation within the field and typical producer practices. Figure 4 illustrates the vegetative growth of the different treatments.

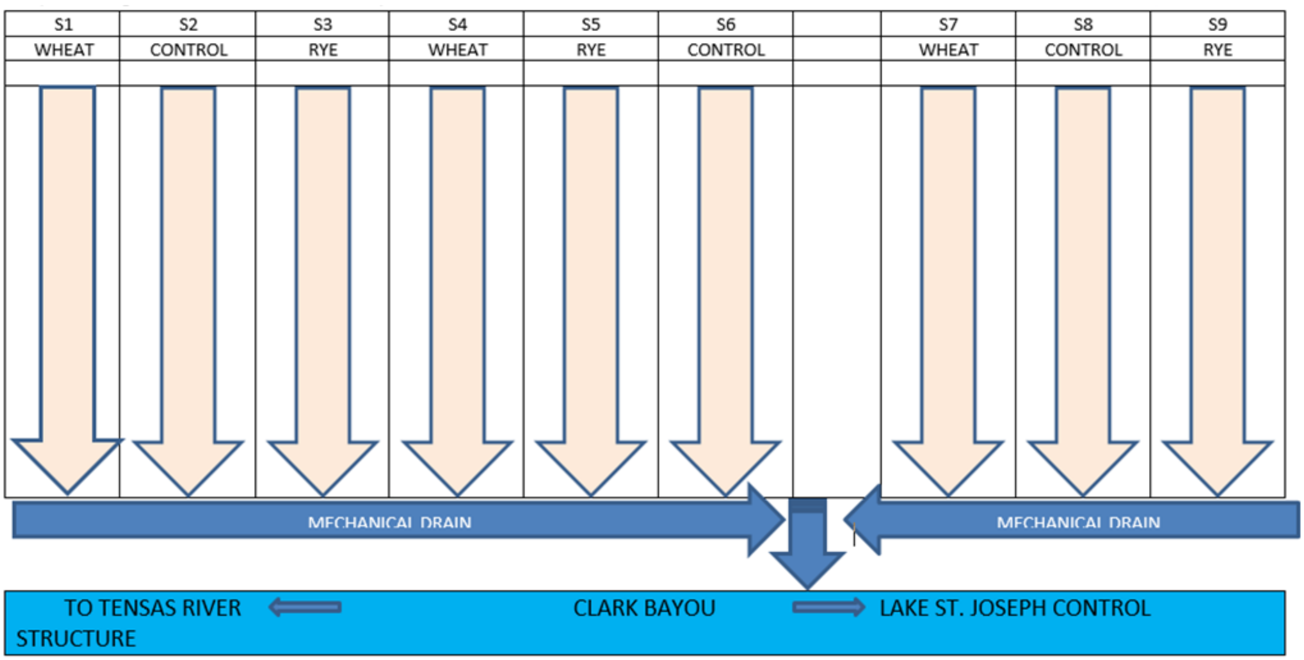

Figure 2. Modified in-field filter strips of wheat, cereal rye, and bare ground (control). Arrows indicate direction of flow to automated ISCO 6700 samplers. Wheat and cereal rye were planted on 29-Oct-2014 at 101 kg ha^{-1}.

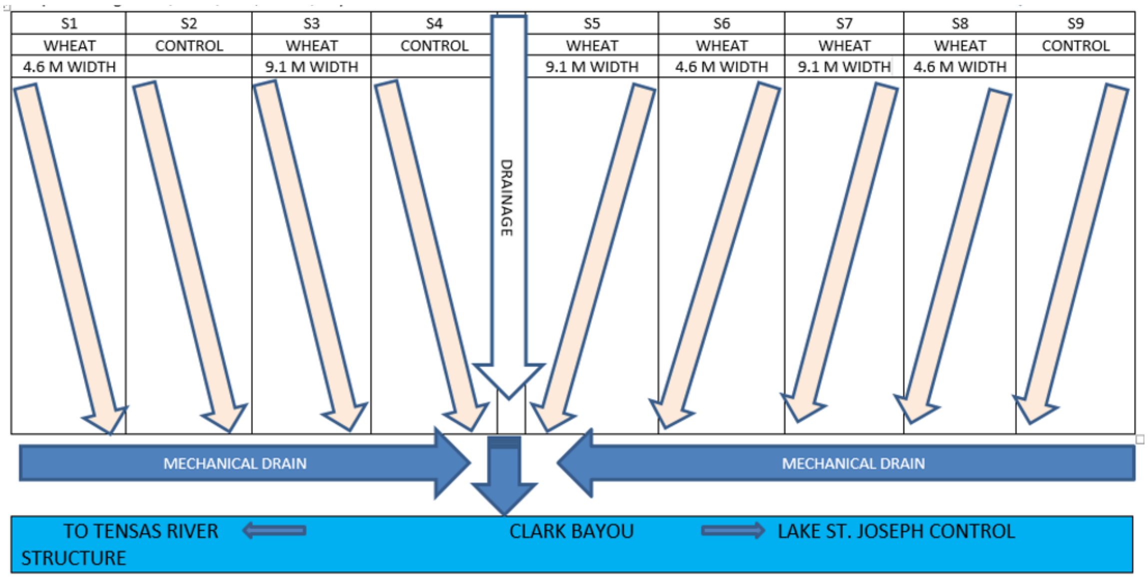

Figure 3. Modified in-field filter strips with treatments including bare ground, 4.6 meter wheat borders, or 9.1 meter wheat borders. Ditches were cut at a 45-degree angle from the mechanical drain. Wheat was planted at 101 kg ha^{-1} October 2015 and 2016. Arrows indicate direction of flow with arrow head marking location of automated ISCO 6700 samplers.

Table 1. Treatments for each location.

Replicate	**2014 Treatment**	**2015 & 2016 Treatment**
S1	Wheat	4.6 meter
S2	Control	Control
S3	Cereal rye	9.1 meter
S4	Wheat	Control
S5	Cereal rye	9.1 meter
S6	Control	4.6 meter
S7	Wheat	9.1 meter
S8	Control	4.6 meter
S9	Cereal rye	Control

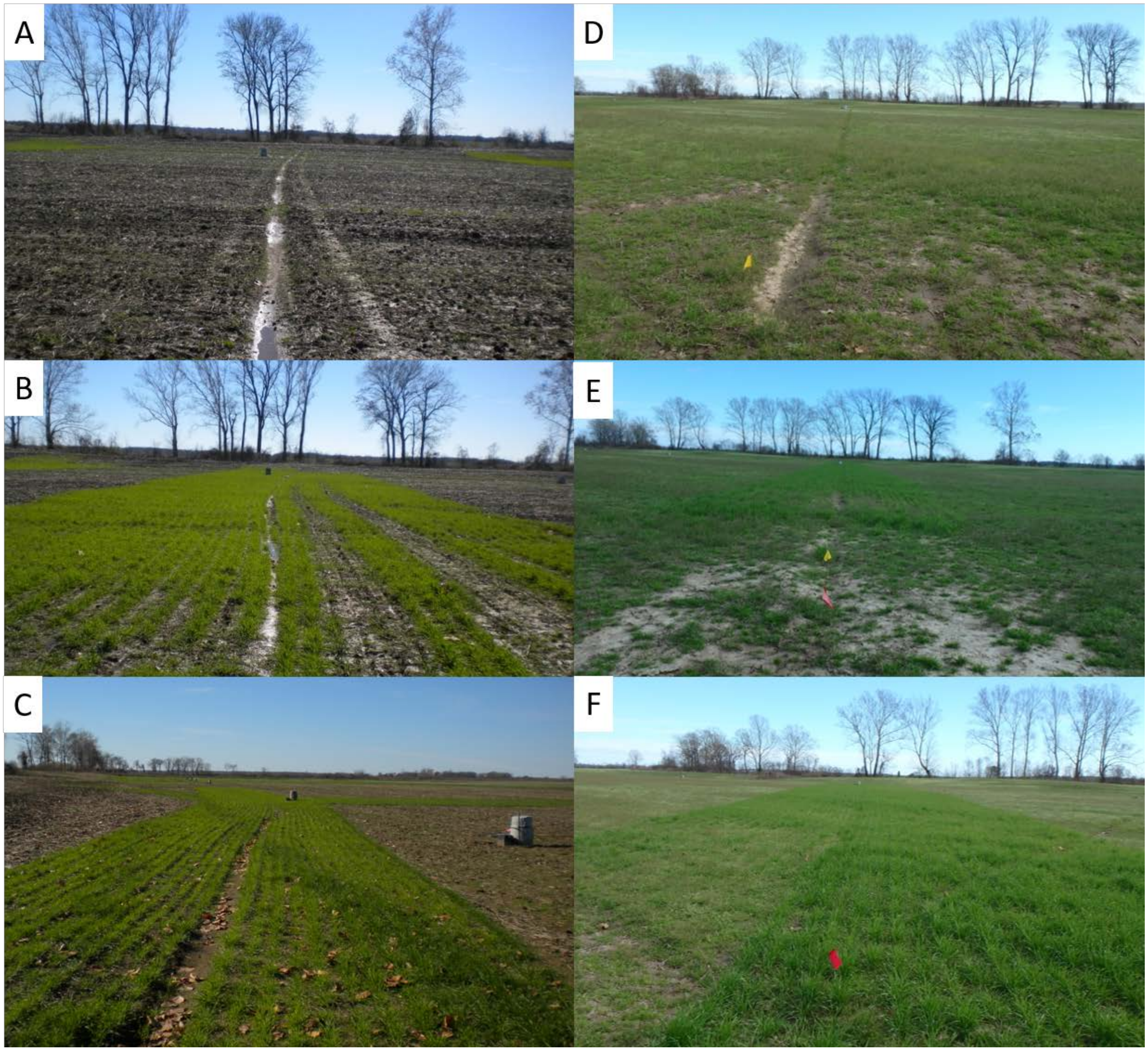

Figure 4. In-field ditches planted in 2014 under treatments of control (A), wheat (B), or cereal rye (C). All 2015 in-field ditch treatments included a control (D), a 4.6 meter wheat border (E), or a 9.1 meter wheat border (F).

Water Samples

Following planting of covers, flumes and automated ISCO 6700 (Teledyne ISCO, Lincoln, NE) were installed at the terminal end of each ditch to collected any runoff following rainfall events each year (Figure 5). Following late planting in 2013, four ISCO samplers were installed, however no samples were obtained for analysis. Following installation of samplers in 2014, samples from the control and at least either the wheat or the rye filter strips, however there were several occasions where no sample was produced (Appendix A). For this reason, in 2015 and 2016 storm water first flush samplers with 1 L sample containers (Nalgene 1100-1000

HDPE) were also installed at the terminal end of each treatment. The storm water sampler collects a maximum of 1 L grab sample at which point the float within the cap closes, preventing any dilution with further runoff. Samples were retrieved as soon as possible (typically < 24-hrs) following collection and transported to the LSU AgCenter – Northeast Research Station at St. Joseph, Louisiana, placed in a Styrofoam cooler with a layer of ice, and then shipped to the W.A. Callegari Environmental Center (Callegari) in Baton Rouge, Louisiana for analysis.

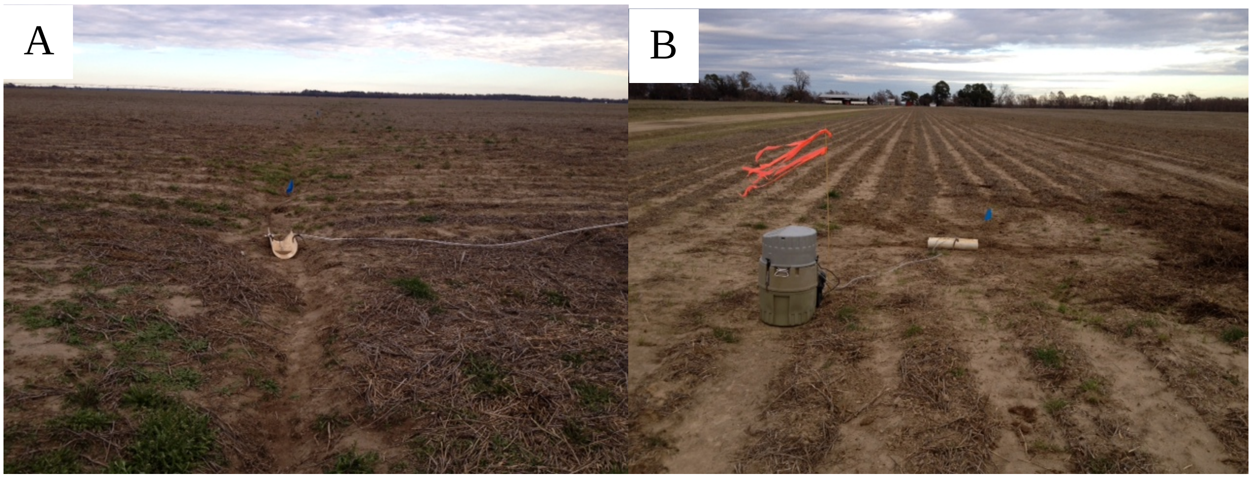

Figure 5. Images of (A) in-field ditch with a ditch flume for water sample collection and (B) installed ISCO 6700 sampler located adjacent to the installed flume.

Laboratory Methods

Samples were analyzed in the Callegari laboratory. Analyses were conducted based on the EPA-approved methods listed in Table 2. Laboratory analyses were reanalyzed if a spike recovery fell below 80% or above 120%.

Table 2. Methods used by Callegari laboratory (Baton Rouge, Louisiana) for sample analysis.

Laboratory analysis	**Method**
Ammonia nitrogen (NH_3-N)	SM 4500-NH3-E
Anions (Br^-, Cl^-, Fl^-, NO_3^--N, PO_4^{3-})	EPA 300.0
Total dissolved solids (TDS)	EPA 160.1
Total suspended solids (TSS)	EPA 160.2
Total solids (TS)	EPA 160.3
Total Kjeldahl nitrogen (TKN)	EPA 351.4
Total phosphorus (TP)	EPA 365.3
Turbidity	EPA 180.1

Statistical Analysis

Each planting event (2014-2015, 2015-2016, and 2016-2017) was analyzed separately. Statistical analysis included ANOVA to determine if there was any difference as result of treatment, time, or an interaction of treatment and time. In the case were time was not a factor results were averaged within a treatment season.

Results and Discussion

Variation in precipitation across all years of the study resulted in zero runoff collections over winter in 2013-2014, ten runoff sample events in 2014-2015, seven runoff collection events in 2015-2016, and only one runoff collections in 2016-2017. Significant precipitation in early 2016 resulted in some sample loss due to flooding and submerging of the ISCO 6700 samplers. On average, the presence of cover crops planted over in-field ditches reduced TSS, TDS, orthophosphate-P, and total P. The magnitude of the measured decrease varied across runoff events.

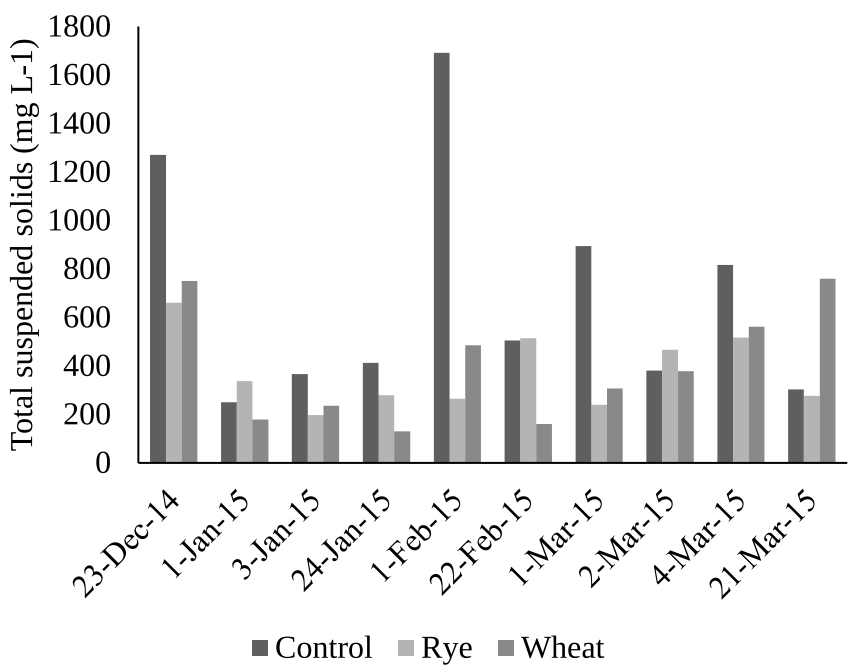

Figure 6. Total suspended solid concentrations measured in samples collected following runoff events starting in December 2014 through burn-down of covers in March 2015.

Total suspended solids in runoff were significantly lower in all but two samples collected from either in-field ditches over seeded with cereal rye or wheat (Figure 6). There was no consistent difference between over seeding with cereal rye or wheat, but on average the presence of a cover crop reduced TSS by 57%. The variation between the two cover treatments likely stems from the difference in growth characteristics and ground cover at the time of runoff. Similar to TSS, orthophosphate-P concentrations decreased an average 37% relative to the control samples. Unlike TSS, however, this decrease was primarily attributed to two significant events on 23-Dec-2014 and 1-Feb-2015. In general, while orthophosphate-P concentrations were lower after filtering through the over seeded in-field ditches, concentrations were similar, for most runoff events. This may be due to low levels of orthophosphate-P available in these fields. Total Kjeldahl nitrogen concentrations were also lower after filtering through in-field ditches over seeded with cereal rye or wheat (avg 2.04 mg L^{-1}) relative to the control samples (3.03 mg L^{-1}) resulting in a 41% decrease over the fallow season. Total dissolved solids and total P while not significant, tended to be lower in samples collected from the cereal rye and wheat treatments, however there was large variation in concentrations over time (Table 3).

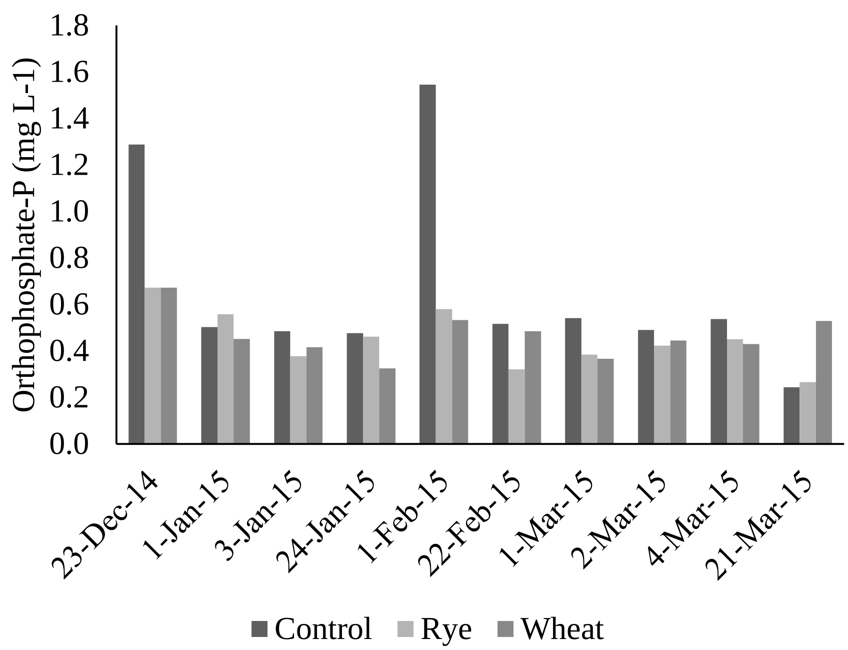

Figure 7. Orthophosphate-P concentrations measured in samples collected following runoff events starting in December 2014 through burn-down of covers in March 2015.

Table 3. Measured parameters from samples collected following over seeding of in-field ditches in 2014-2015. No significant treatments were observed; however, concentrations did vary over time.

Date	Total dissolved solids	Total P	Total Kjedahl N
		mg L^{-1}	
23-Dec-14	600	1.73	5.34
1-Jan-15	2,541	0.76	2.17
3-Jan-15	2,324	0.69	1.56
24-Jan-15	175	1.04	3.79
1-Feb-15	1,032	2.13	0.97
22-Feb-15	178	0.27	1.73
1-Mar-15	210	1.06	2.85
2-Mar-15	177	0.75	3.17
4-Mar-15	384	1.19	3.31
21-Mar-15	3,978	0.99	0.69

Based on results obtained comparing cereal rye relative to wheat over seeding, it was determined that either would serve as a suitable cover crop. Using wheat, the width of the over seeded patch by either straddling the ditch for one pass (4.6 meter borders) or two passes (one on each side of the ditch) for 9.1 meter border was done in October 2015 and 2016. Lower precipitation over the winter resulted in significantly fewer runoff collection events. Additionally, a significant rainfall event in March 2016 resulted in flooding of the research location and the submergence of the ISCO 6700 samplers for approximately 20 days, the loss of the runoff samples, and one ISCO 6700 unit. No significant differences were observed between treatments in TSS and TDS, chloride, fluoride, orthophosphate-P, or total P concentrations (Appendix B) from samples collected from the ISCO 6700 samplers. Nitrate-N and ammonium-N were the same in the wider (9.1 meter) and control treatments (0.09 mg L^{-1}) relative to the 4.6 meter borders (0.23 mg L^{-1}). Despite this difference it is worth noting that of the 17 samples obtained in 2015-2016, approximately half of them resulted in nitrate-N concentrations below detection limits with the highest concentration obtained following a runoff event in December 2015. Ammonium-N followed a similar pattern with concentrations averaging 0.16 mg L^{-1} in the 9.1 meter and control treatments which was lower than that measured in the 4.6 meter treatment. (0.32 mg L^{-1}). While fewer first flush samples were obtained due to their delayed installation, lower concentrations of TSS and TDS, nitrate- and ammonium-N, total Kjedahl N, orthophosphate-P, and total-P were measured (Table 4).

Table 4. Parameters measured from first flush samplers installed in January 2016.

	Total suspended solids	Total dissolved solids	Chloride	Fluoride	Ortho-phosphate P	Total P	Total Kjedahl N	Nitrate N	Ammonia N
	---mg L-1								---
Control	1527	865	3.47	0.24	2.55	3.89	2.47	1.21	0.36
4.6 meter	826	799	3.65	0.24	1.66	2.53	1.70	0.59	0.19
9.1 meter	926	771	4.89	0.24	1.42	2.46	2.36	0.29	0.17

Following the award of a no-cost extension, treatments established in 2015 were repeated in 2016. However, a relatively dry winter coupled with early cover crop termination (February 2017) resulted in limited retrieval of water samples (Table 5). With no replicate samples obtained for each date or treatment is it not possible to determine if any statistical difference exists between treatments. On average, concentrations tended to be lower in samples obtained from the over seeded in-field ditches with the exception of total P which increased significantly in samples obtained on 27-Feb-17. In preparation for planting corn the land owner had applied poultry litter prior to a precipitation event resulting in increased potential nutrient loss.

Observation of the treatments over time suggest that having some vegetation in place aided in the maintenance of the integrity of the in-field ditches. While not quantitative, it does suggest that these in-field ditches or other soil structures over seeded with cover crops may resist erosive forces to a greater degree than their bare ground counterparts. The lack of sufficient samples may stem from low precipitation events in general. It is also possible that the presence of vegetation, whether it is native vegetation in the control plots of the over seeded cover crops resulted in decreased runoff as the water was held in place by the vegetation. Because flow and total runoff volume was not collected it is not possible to verify this hypothesis, but warrants further investigation.

Table 5. Measured concentrations of water quality parameters from first flush samplers collected in February 2017. Rep = rep ID; ND = below detection limit

Rep - Treatment	Collection date	Total suspended solids	Total dissolved solids	Ortho-phosphate P	Total P	Total Kjeldahl N	Nitrate N	Ammonia N
		-- mg L-1 ---						
S2 - Control	20-Feb-17	587	3930	5.87	8.21	172.20	1.72	192.41
S3 - 9.1 meter	20-Feb-17	137	1585	27.65	36.50	34.23	ND	9.94
S9 - Control	21-Feb-17	177	545	10.45	11.70	20.07	5.88	2.79
S8 - 4.6 meter	21-Feb-17	187	1045	18.92	26.70	25.52	2.49	4.96
S5 - 9.1 meter	21-Feb-17	232	1785	3.99	5.24	42.84	2.55	42.21
S9 - Control	27-Feb-17	177	1595	36.62	45.20	37.70	4.52	10.84
S8 - 4.6 meter	27-Feb-17	322	1765	14.05	43.40	36.44	5.83	10.94

Conclusions

While no distinct differences were observed between over seeding cereal rye versus wheat, or varying the width of the vegetation filter strips, the presence of vegetation resulted in decreased suspended solids and nutrient concentrations in runoff samples. Having vegetation in place provided a sink for nutrients and sediments. The vegetation also acted as ground cover potentially increasing the stability of the in-field ditches. Late planting (after November) and unpredictable precipitation may hinder the effectiveness of the over seeded in-field ditches as was observed in 2013-2014. However, having the covers over seeded by the end of October resulted in sufficient stands to cover the soil surface and reduce losses of TSS and orthophosphate-P.

Appendix A Measured parameters from samples collected following over seeding of in-field ditches in 2014-2015. Concentrations reported were averaged across treatments for each data of collection. Dashes indicate no samples was collected. ND = parameter was below detection limits.

Cover	Collection date	Total suspended solids	Total dissolved solids	Chloride	Fluoride	Ortho-phosphate P	Total P	Total Kjedahl N	Nitrate N	Ammonia N
		$mg\ L^{-1}$								
Control	23-Dec-14	1270	346	0.48	0.19	1.29	2.38	7.05	0.84	0.12
Rye	23-Dec-14	660	890	0.47	0.14	0.67	1.32	4.17	0.41	ND
Wheat	23-Dec-14	750	565	0.21	0.11	0.67	1.48	4.81	0.55	0.01
Control	27-Dec-14	-	-	-	-	-	-	-	-	-
Rye	27-Dec-14	337	2987	0.82	0.19	0.56	1.00	3.07	0.11	ND
Wheat	27-Dec-14	179	2840	0.86	0.22	0.45	0.74	2.11	0.84	ND
Control	1-Jan-15	250	2338	ND	0.27	0.50	0.86	2.53	0.08	0.24
Rye	1-Jan-15	198	2785	0.25	0.13	0.38	0.68	2.03	ND	ND
Wheat	1-Jan-15	236	2499	0.37	0.15	0.42	0.75	1.94	0.20	ND
Control	2-Jan-15	-	-	-	-	-	-	-	-	-
Rye	2-Jan-15	279	2660	0.17	ND	0.46	0.76	1.82	ND	ND
Wheat	2-Jan-15	-	-	-	-	-	-	-	-	-
Control	3-Jan-15	366	2157	0.38	0.13	0.49	0.81	1.84	0.08	ND
Rye	3-Jan-15	-	-	-	-	-	-	-	-	-
Wheat	3-Jan-15	130	2155	0.18	0.10	0.33	0.52	1.01	ND	ND
Control	12-Jan-15	-	-	-	-	-	-	-	-	-
Rye	12-Jan-15	265	3390	1.09	0.11	0.58	0.90	2.27	0.12	ND
Wheat	12-Jan-15	-	-	-	-	-	-	-	-	-
Control	22-Jan-15	-	-	-	-	-	-	-	-	-
Rye	22-Jan-15	-	-	-	-	-	-	-	-	-
Wheat	22-Jan-15	485	239	ND	ND	0.53	1.08	ND	0.28	ND
Control	24-Jan-15	413	112	ND	ND	0.48	1.00	3.79	ND	0.03
Rye	24-Jan-15	-	-	-	-	-	-	-	-	-
Wheat	24-Jan-15	-	-	-	-	-	-	-	-	-

Appendix A (Cont.)

Cover	Collection date	Total suspended solids	Total dissolved solids	Chloride	Fluoride	Ortho-phosphate P	Total P	Total Kjedahl N	Nitrate N	Ammonia N
		-----	-----	-----	-----	-----mg L^{-1}-----	-----	-----	-----	-----
Control	1-Feb-15	1691	1581	ND	ND	1.55	2.24	0.95	0.12	0.12
Rye	1-Feb-15	514	484	ND	ND	0.32	2.03	0.99	ND	ND
Wheat	1-Feb-15	-	-	-	-	-	-	-	-	-
Control	16-Feb-15	-	-	-	-	-	-	-	-	-
Rye	16-Feb-15	-	-	-	-	-	-	-	-	-
Wheat	16-Feb-15	160	85	ND	ND	0.49	0.27	1.32	0.34	ND
Control	21-Feb-15	-	-	-	-	-	-	-	-	-
Rye	21-Feb-15	239	141	ND	ND	0.39	0.25	0.41	ND	ND
Wheat	21-Feb-15	-	-	-	-	-	-	-	-	-
Control	22-Feb-15	506	252	ND	ND	0.52	0.31	2.42	0.10	ND
Rye	22-Feb-15	466	186	ND	ND	0.42	0.27	2.48	ND	ND
Wheat	23-Feb-15	307	133	ND	ND	0.37	0.27	1.59	0.17	ND
Control	1-Mar-15	895	262	ND	ND	0.54	1.39	3.86	ND	ND
Rye	1-Mar-15	517	197	ND	ND	0.45	1.06	2.80	ND	ND
Wheat	1-Mar-15	379	173	ND	ND	0.45	0.72	1.90	0.14	ND
Control	2-Mar-15	381	177	ND	ND	0.49	0.75	3.17	ND	ND
Rye	2-Mar-15	-	-	-	-	-	-	-	-	-
Wheat	2-Mar-15	-	-	-	-	-	-	-	-	-
Control	4-Mar-15	816	569	ND	ND	0.54	1.35	3.99	ND	ND
Rye	4-Mar-15	-	-	-	-	-	-	-	-	-
Wheat	4-Mar-15	562	199	ND	ND	0.43	1.03	2.63	ND	ND
Control	21-Mar-15	303	4363	ND	ND	0.24	0.72	0.66	ND	ND
Rye	21-Mar-15	276	3062	ND	ND	0.27	0.81	0.81	ND	ND
Wheat	21-Mar-15	759	4511	ND	ND	0.53	1.42	0.59	ND	ND

Appendix B Measured parameters from ISCO 6700 samples collected following over seeding of in-field ditches in 2015-2016. Concentrations reported were averaged across treatments for each data of collection. Dashes indicate no samples was collected. ND = parameter was below detection limits.

Cover	Collection date	Total suspended solids	Total dissolved solids	Chloride	Fluoride	Ortho-phosphate P	Total P	Total Kjedahl N	Nitrate N	Ammonia N
		--mg L-1							--	
Control	13-Dec-15	331	349	0.60	0.24	1.53	1.78	3.99	ND	0.16
4.6 meter	13-Dec-15	141	253	2.63	ND	0.90	1.09	2.57	0.63	0.17
9.1 meter	13-Dec-15	288	184	0.77	0.25	1.34	1.62	3.05	0.10	0.17
Control	21-Dec-15	-	-	-	-	-	-	-	-	-
4.6 meter	21-Dec-15	831	505	1.26	0.22	1.83	3.02	3.92	0.21	1.17
9.1 meter	21-Dec-15	378	259	0.75	ND	1.60	1.95	2.36	ND	0.28
Control	19-Jan-16	213	88	0.14	0.21	1.62	2.29	0.92	ND	0.03
4.6 meter	19-Jan-16	618	153	0.37	0.14	1.48	2.61	2.12	0.11	0.07
9.1 meter	19-Jan-16	277	80	0.29	0.18	1.11	2.07	0.94	0.08	0.07
Control	21-Jan-16	192	51	0.39	0.16	1.19	1.45	ND	0.08	0.42
4.6 meter	21-Jan-16	150	26	0.54	0.10	0.88	1.00	0.39	0.08	0.04
9.1 meter	21-Jan-16	78	56	0.47	0.17	0.96	1.18	ND	0.09	0.14
Control	26-Jan-16	57	608	0.37	0.13	1.09	1.17	1.27	ND	0.09
4.6 meter	26-Jan-16	95	644	6.87	0.39	1.29	1.34	1.06	0.15	0.15
9.1 meter	26-Jan-16	59	869	0.98	0.23	1.17	1.11	1.32	ND	0.09
Control	23-Feb-16	157	1652	0.92	0.15	1.00	1.30	2.14	ND	ND
4.6 meter	23-Feb-16	547	1554	1.70	ND	0.92	1.12	1.11	ND	ND
9.1 meter	23-Feb-16	217	761	2.01	ND	0.85	1.09	1.04	ND	ND