ISA Final Report (FY24)

Project Title- Regenerative agricultural production systems to promote reliable yields, improved soil health and sustained environmental resilience

This report summarizes the Iowa Soybean Association supported research at the LAiYERS (Land mAnagement for improved Yield, Environmental Resilience, and Sustainability) plots from 2022-2024 with an emphasis on the most recent year (2024) of sample collection and analysis. This study evaluates the impact of poultry manure vs synthetic fertilizer, both with and without winter cereal rye cover crop, on water quality, soil health, and crop yield. The 0.1-hectare (1/4-acre) plots were established with tile line installation at each plot completed spring of 2021 and the first treatments were initiated in the fall of 2021 with cover crops planted to the designated plots (Systems 1, 3, 4, 6, 8) and the early winter and balanced poultry manure treatments applied (Systems 4, 5, 8, 9). The spring fertilizer and poultry manure treatments were applied in 2022 (year 1) for the corn year of the rotation. Poultry manure and synthetic fertilizer were not applied for the 2023 (year 2) soybean year, but cover crops were planted based on the treatment design. The second application of poultry manure and synthetic fertilizer was applied for the 2024 (year 3) corn year on November 15th, 2023 (early winter manure) and the spring treatments were applied in late May, 2024.

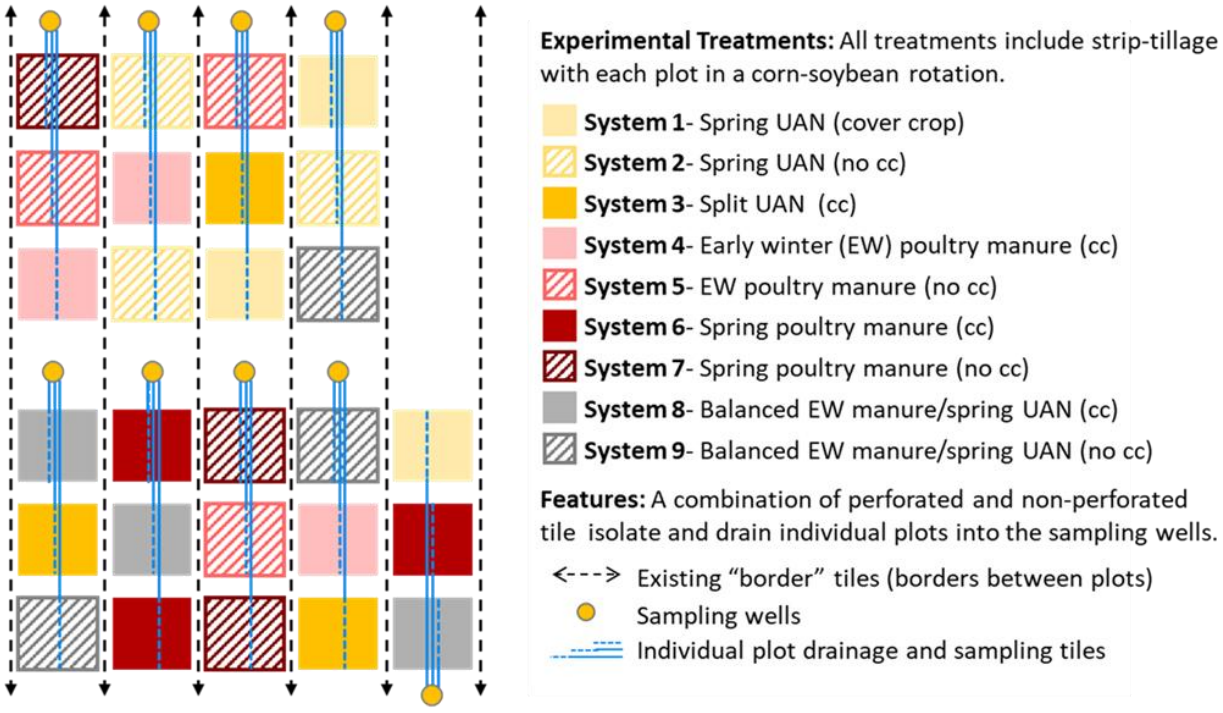

Figure 1. LAiYERS site experimental design. Each system- treatment is assigned to the 27 quarter-acre plots in triplicate. The N-management treatment is applied in the early winter or spring for the upcoming corn year.

Experimental Treatment Design

Each of the nine system treatments are replicated in triplicate. Treatment comparisons are illustrated by the flow chart in figure 2. The spring UAN treatments, with and without cover crops, serve as the experimental control. An additional UAN treatment includes a split UAN application with spring application and early growing season side dress to address concerns with yield loss due to potential low nitrogen availability with cover crops. Phosphorus and potassium are applied to the UAN treatment plots (Systems 1-3) in the fall. The manure application treatments allow for a side-by-side comparison of early winter and spring manure application with and without cover crops. We also include a balanced manure treatment with manure applied every 4 years (early winter application after soybeans in 2025 will be the next application).

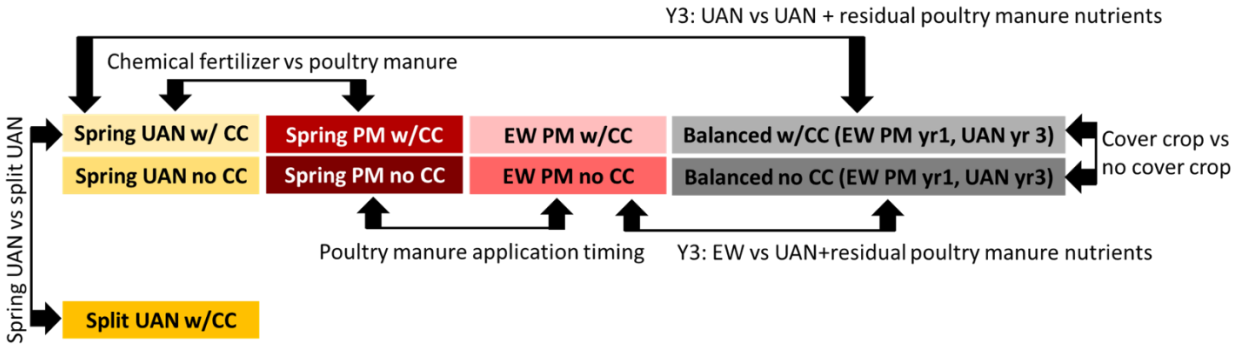

Figure 2. Experimental design with treatment comparisons.

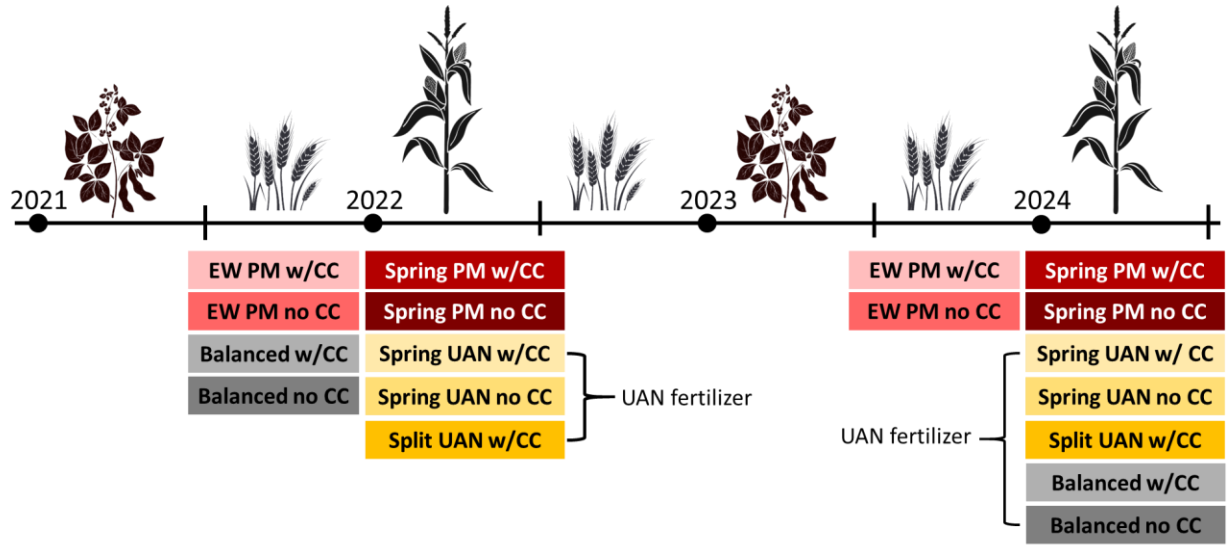

Figure 3. Treatment N application source and timing.

The manure and synthetic fertilizer application timeline is shown in figure 3. The N-source treatments were initiated with early winter poultry manure (EW PM). The balanced treatments (shown in greys) received manure in early winter 2021 and UAN in spring 2024.

Preliminary sample collection and 2021 soybean yields

Although treatments were not established at the site until cover crop planting and early winter poultry manure application in 2021, soybeans were planted after tile installation was completed. Late planting and an extremely dry year resulted in low soybean yields in 2021. In addition, the dry conditions resulted in no tile flow for the season so we were unable to document plot level tile flow conditions before the experimental treatments were initiated.

Soil samples were collected in the fall to measure the initial soil conditions at the plots. The soil samples collected in fall of 2021 show some correlation with plot location and higher % organic matter and soil P levels. The plots along the west side of the site, where drainage was previously not well established, were susceptible to ponding. These plots had Mehlich 3-P levels 2-3 standard deviations above the average value of 28 ppm for the site and relatively high organic matter (ranging from 3.75 %-4.25%) compared to the overall average of 3.26%. The 2021 soil P levels and available nitrogen are included in table 2 with additional soil results discussion.

Poultry manure and fertilizer were applied for the 2022 and 2024 corn seasons.

Poultry manure and UAN (urea ammonia nitrate) were applied at the target agronomic rate for a corn-soybean rotation in Iowa of 150 lbs N/acre. Phosphorus (P_2O_5) and potassium (K_2O) were applied to the strictly UAN treatment plots (systems 1, 2, and 3) in the fall of 2021 and 2023 with strip tilling to ensure essential macronutrients to support crop growth.

The poultry manure required for a growing season (early winter and spring applications) was delivered and stockpiled before the early winter treatments for the 2022 and 2024 corn growing seasons. A composite sample was collected from the stockpile and analyzed for N content before application to estimate the required manure needed to meet the target N application rates. Additional samples were collected from the manure wagon at each plot at the time of application to determine the achieved nutrient application rates. The average values of the plot level analysis are reported as the application rates in Table 1. The stockpile N content was underestimated with the composite sample collected before early winter application for the 2022 season, resulting in a lower than the target 150 lbs N/acre application rate. The amount of manure applied was adjusted for spring 2022 to avoid underapplying the poultry manure. The early winter poultry manure applied for 2024 tested much higher at the plot level than the stockpile analysis, resulting in a higher application rate than the target rate.

Table 1. Select poultry manure analysis results and nutrient application rates.

Year	Treatment	N source	Manure Analysis				Application Rate			
			Moisture	N (TKN)	P2O5	K2O	Manure	PAN*	P2O5	K2O
			(%)	(lbs/ton)			(tons/acre)	(lbs/acre)		
2022	Systems 1 and 2	Spring UAN	-	-	-	-	-	150	91	91
	System 3	Split UAN	-	-	-	-	-	75/75	91	91
	Systems 4 and 5	EW poultry manure	46.0	50.6	84.5	48.7	4.25	123	90	52
	Systems 6 and 7	Spring poultry manure	45.9	49.6	97.9	43.8	6.00	170	147	66
	Systems 8 and 9	Balanced-EW poultry manure	46.0	50.6	84.5	48.7	4.25	123	90	52
2024	Systems 1 and 2	Spring UAN	-	-	-	-	-	150	94	94
	System 3	Split UAN	-	-	-	-	-	75/75	94	94
	Systems 4 and 5	EW poultry manure	27.3	94.0	73.6	70.5	4.00	214	74	71
	Systems 6 and 7	Spring poultry manure	47.3	75.9	61.8	53.5	4.00	173	62	54
	Systems 8 and 9	Balanced-Spring UAN	-	-	-	-	-	150	-	-

* The application rates reflect assumed plant available nitrogen (PAN), with 5% N loss to volatilization at time of manure application and 60% TKN availability for crop growth. There are no corrections made for P and K availability, and all N applied with UAN is assumed fully available. P and K were applied in the fall of the previous years at MESZ, which includes a small amount of N that is assumed fully lost over winter and not included in the available N.

The balanced treatments (systems 8 and 9) received early winter poultry manure for the 2022 growing season and UAN for the 2024 growing season.

Soil Results and Discussion

Soil samples were collected throughout the study to evaluate nutrient status and various soil health characteristics. Select results are highlighted in Table 2. The initial, or background, soil characteristics are represented by the 2021 fall soil samples, which were collected before the first early winter poultry manure application at the site. Overall, the initial nutrient and organic matter results are similar between all systems at the onset of the study. Early results show improved early available nitrogen with the spring UAN treatments (systems 1 and 2) compared to the poultry manure treatments (systems 4-7). Weather/precipitation patterns complicate evaluation of nitrogen accumulation and transport in the soils, as reflected in the high variability (large stdev) for several of the treatments.

The balanced treatment plots received early winter poultry manure for the 2022 season and spring UAN for the 2024 season (balanced results highlighted in the same color as the applied treatment for ease of comparison). Spring nitrogen availability was variable, but generally higher in the spring UAN treatment plots. Soil phosphorus levels were elevated with the poultry manure treatments in 2022, but remained relatively steady by 2024.

Table 2. Topsoil (0-12") nitrogen and phosphorus analysis average values with standard deviations. 2021 samples were collected in the fall before treatments were applied to the plots to reflect the initial conditions of the soils. 2022 and 2024 samples were collected in late spring. ** The late spring samples were collected before System 3 plots received sidedress nitrogen. Tan/gray shading of systems 8 and 9 (balanced) are highlighted in the same color as the applied treatment for comparison.*

Treatment		Total Available N (lbs/acre)			M3-P (ppm)		
		2021*	2022	2024	2021	2022	2024
UAN	System 1	21 (3)	54 (2)	41 (3)	29 (13)	41 (9)	41 (10)
	System 2	21 (2)	51 (23)	39 (11)	19 (4)	26 (12)	30 (12)
	System 3**	21 (4)	32 (11)	27 (6)	25 (5)	36 (13)	37 (5)
EW Manure	System 4	23 (3)	39 (17)	18 (5)	25 (3)	68 (27)	58 (18)
	System 5	22 (2)	33 (18)	20 (2)	26 (9)	56 (4)	69 (8)
Spring Manure	System 6	25 (3)	33 (5)	22 (8)	40 (8)	63 (18)	48 (29)
	System 7	21 (1)	29 (3)	24 (6)	30 (12)	44 (11)	40 (9)
Balanced	System 8	23 (4)	49 (35)	42 (5)	32 (13)	70 (29)	58 (24)
	System 9	21 (3)	34 (12)	39 (7)	23 (7)	46 (27)	37 (10)

Cover crops impacted water quality and crop yields.

Cover crop time of planting, germination and growth (due to planting and weather conditions), and termination timing have impacted water quality and crop yields during this study, with the most evident impacts in 2024.

Figure 4 illustrates the cover crop management timeline, with photos of the established cereal rye at or near the time of chemical burndown/termination. In 2021, the cover crop was planted/drilled on November 5th after soybean harvest. Dry conditions after planting resulted in low cereal rye germination before overwintering and a poorly established stand in the spring of 2022. The cover crop was chemically terminated over 2-weeks before corn planting as the most conservative management practice to avoid decreased corn yield. Cereal rye was drilled on November 9th, after corn harvest in 2022. The cereal rye termination was delayed until late spring 2023 to evaluate the impact of cover crops on weed suppression, resulting in a robust cover crop stand. The chemical termination was only partially successful due to the growth stage of the cereal rye. We modified the cover crop management in the fall of 2023, and interseeded the cereal rye into standing soybeans on September 22nd. The well-established cover crop was terminated two weeks before corn planting to limit the potential for a corn yield decrease.

Analysis of the cover crop (Table 3) indicates a low C:N ratio of 10:1 on average between treatments in 2022, which may result in nitrogen release for the growing corn plant and potential leaching of nitrogen into the tile water. However, the 2022 drainage nutrient results did not show a difference in water quality with cover crops (Fig.5), likely due to the poor cover crop establishment that year (Fig.4). The overall average C:N ratio among the cover crop systems was 63:1 in 2023 and 25:1 in 2024, likely indicating N tie up, which contributed to crop yield reduction and slightly improved water quality observed with the cover crop plots compared to the no cover crop plots. The uptake and storage of nitrogen with the cover crops in 2024 is especially notable, with significantly improved water quality for all N-source treatments with cover crops compared to the equivalent no-cover crop treatments (Fig. 5).

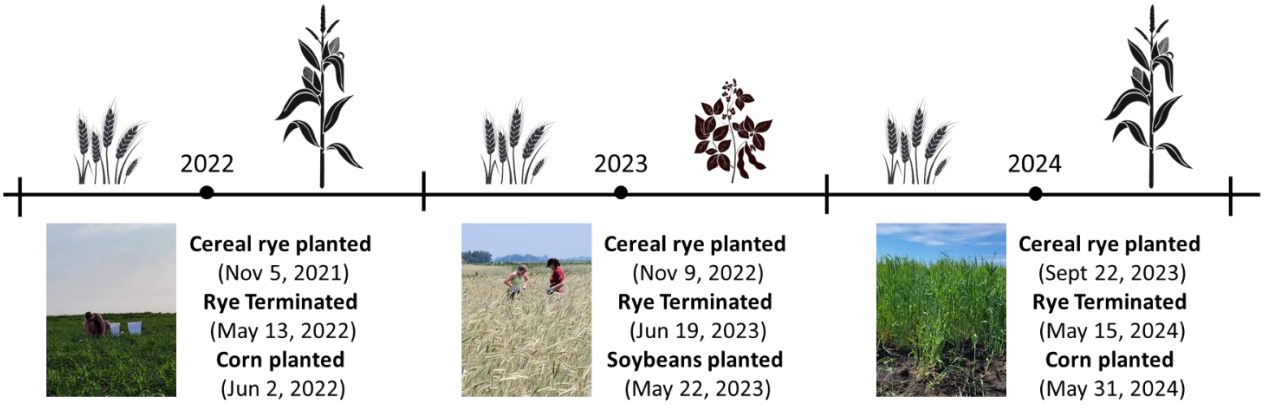

Figure 4. Cover crop management timeline with photos of cereal rye growth at time of biomass sampling (2022 and 2024) or after chemical burndown (2023). The cover crop was terminated (chemical burndown) at least two weeks before corn planting in 2022 and 2024. In 2023, soybeans were planted green into the standing cover crop and the cover crop was terminated over 3 weeks into the growing season.

Table 3. Winter cereal rye cover crop C:N ratio.

		C:N Ratio		
Treatment	**N Source**	**2022**	**2023**	**2024**
System 1	Spring UAN	11:1	59:1	24:1
System 3	Split UAN	11:1	51:1	26:1
System 4	EW PM	10:1	70:1	18:1
System 6	Spring PM	10:1	67:1	29:1
System 8	EW PM (2022)/ Spring UAN (2024)	9:1	62:1	27:1

The impacts of treatment on water quality have been measured throughout the study. Figure 5 shows the average drainage water concentrations each year. In 2022, the first year with UAN or manure application to the plots and the first year of tile flow, there were small but insignificant

differences with treatment. The combination of spring manure with cover crops may have resulted in slightly lower overall NOx-N concentrations in 2022. Manure and UAN were not applied in 2023 for the soybean year, but there were still differences measured in water quality between the treatment plots. Lower NOx-N concentrations were observed with cover crops for most N-source treatments, with the exception of spring manure. Spring manure treatment with and without cover crops had the lowest NOx-N concentrations in 2023. During the second year of manure or UAN application for the corn season, large differences in NOx-N concentrations with treatment were observed. Spring manure with cover crops again had the lowest NOx-N concentrations, and all cover crop treatments improved water quality.

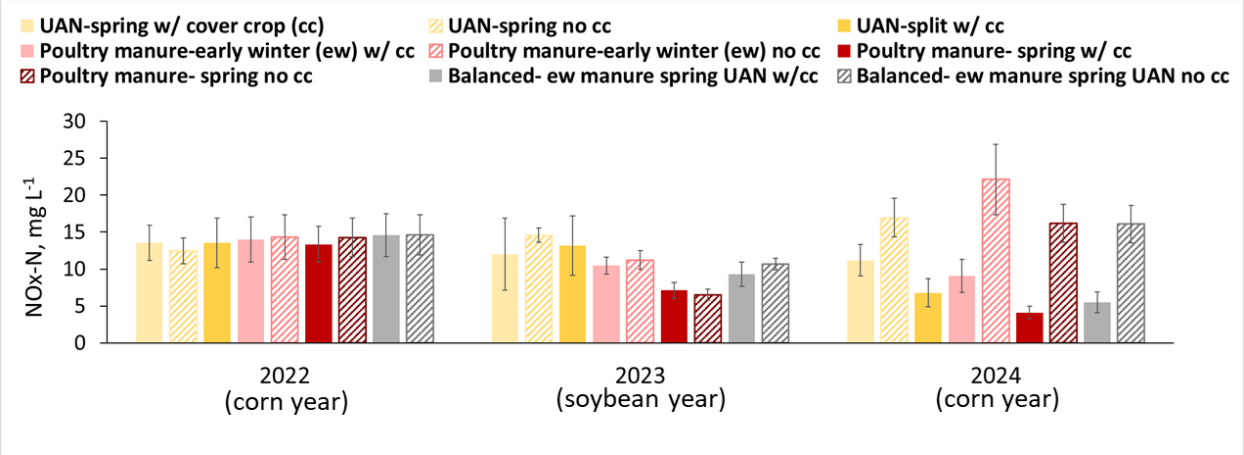

Figure 5. Average weekly tile drainage water NOx-N concentrations by treatment with standard deviation error bars. The solid bars are the cover crop treated plots, and the thatched are the no cover crop plots.

Water quality analysis found similar average NOx-N concentrations for most N-source treatments, with N concentration reductions observed with cover crops (comparing cover crop vs no cover crop). Early winter poultry manure without cover crop (system 5) had the highest average NOx-N concentration in 2024. Spring poultry manure with cover crop resulted in the lowest 2024 average NOx-N concentration.

More detailed tile drainage water data, with the treatment average NOx-N concentrations (Fig 6) and dissolved phosphorus (DRP)(Fig.7) show drainage season patterns. The first sampling date (3/27) data may reflect movement of N and P under saturated conditions in the plots before the dewatering pumps were installed in the sumps for the season.

Consistent differences in NOx-N concentrations were measured throughout the drainage season with treatment, while DRP results are less definitive. All of the cover crop treatments reduced NOx-N concentrations. In addition to weekly sample collection, three sets of daily event samples were collected to capture potential flushing of NOx-N with rainfall events (outlined in blue).

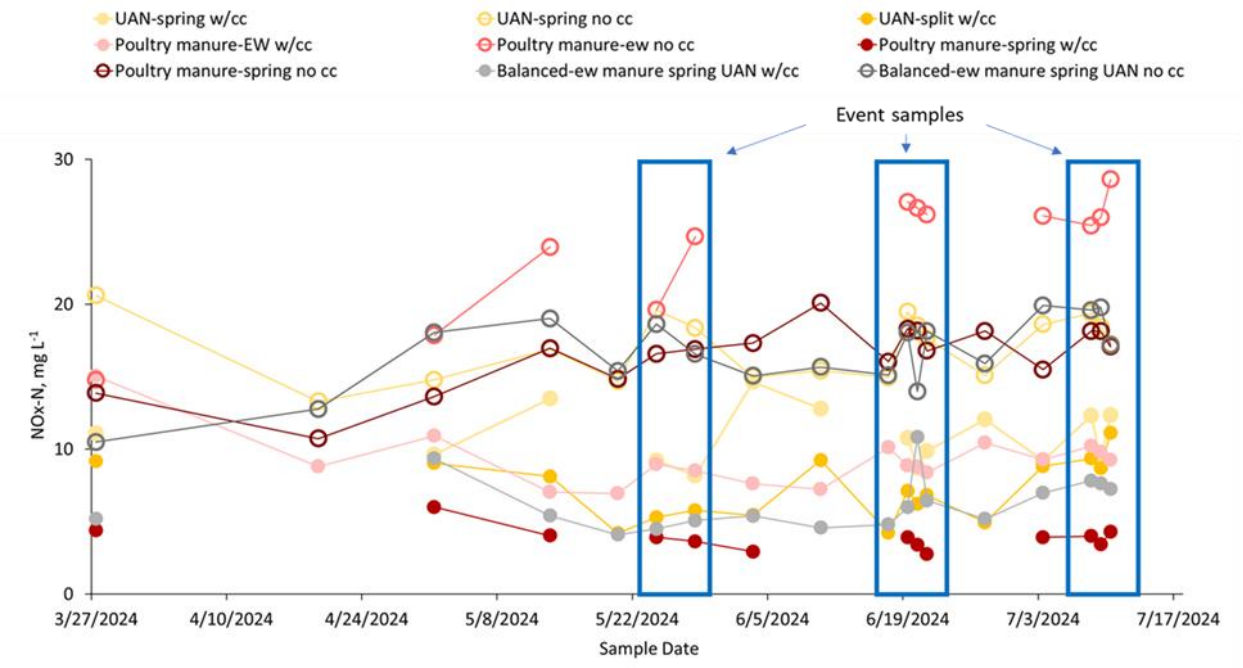

Figure 6. 2024 drainage NOx-N sample results. Differences in NOx-N concentrations between treatments are consistent throughout the drainage season, with the highest concentrations measured with early winter applied poultry manure without cover crops (system 5) and the lowest concentrations with spring applied poultry manure with cover crops (system 6). All cover crop treatments improved water quality.

Soybean and corn yields were negatively impacted by cover crops in 2023 and 2024.

The plots were planted to soybeans in 2023, with a notable reduction in yields at the cover crop plots (Fig 8a). Late termination and incomplete burndown of the cover crop shaded the growing soybean plants in 2023. Field observations confirmed soybean plant growth and development were delayed in the cover crop plots, resulting in lower yields compared to the no cover crop plots.

A yield decrease was also observed in 2024 with the corn crops within all N-source treatments. Again, the cover crop was terminated later in the season due to wet conditions in the spring, however the chemical termination (burndown) of the cover crop appeared effective and early corn growth was observationally similar between plots.

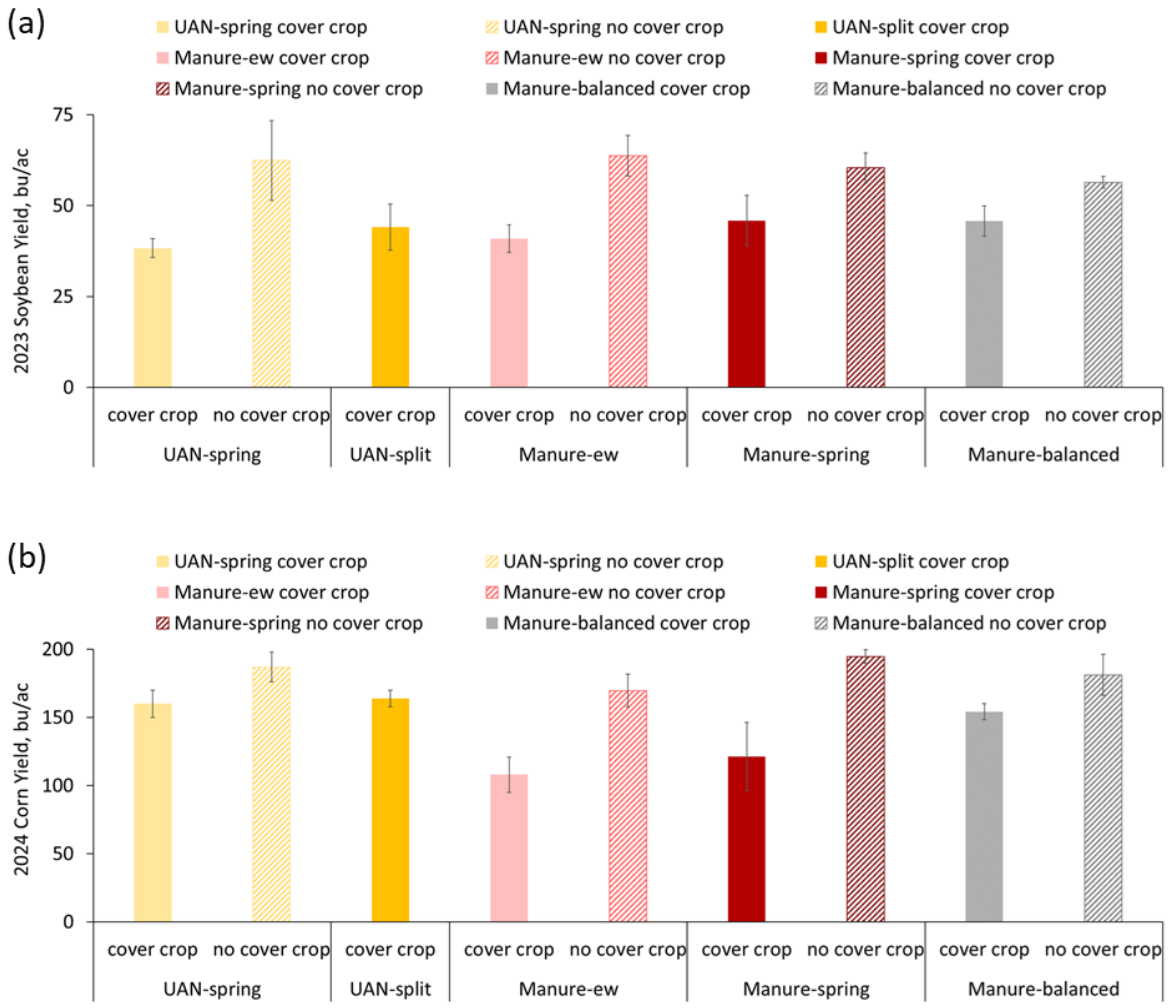

Figure 7. Soybean (a) and corn (b) yields for 2023 and 2024, with standard deviations.

While the results are limited in the number of years of study, varying climatic conditions in each year, and years since implementation of drainage, some specific findings are of note:

1. Manure application timing: spring manure versus early winter
    a. Spring manure improved yields (soybean and corn) compared to EW manure
    b. Improved water quality was measured with spring manure when compared to EW manure application
2. Cover crop timeline based on growth stage instead of time prior to corn planting
    a. It is generally recommended to terminate cover crops 2-weeks prior to planting corn to reduce the potential for allelopathic impacts on corn plant growth and yields
    b. Cover crops were terminated two weeks before corn planting in 2022 and 2024, but 2024 cover crops were planted 6 weeks earlier in the season than the 2022 cover crop.

    c. Corn yields were minimally impacted by the 2022 cover crops, but were severely impacted by the 2024 cover crops.
3. Split UAN with a cover crop did not improve yields, but did have result in a modest improvement in water quality in 2024
4. Treatments combining cover crops and manure are promising for water quality but show a negative impact on crop yields This finding highlights the complicated interactions of N tie-up from cover crops and only partially available N from poultry manure early in the growing season.
    a. A single plot accidently received a double poultry manure application in 2024. While not intended, this provided an interesting case study as the double application corrected for the corn yield deficit (186 bu/acre corn compared to the treatment average of 109 bu/acre from the other two plots). The water quality impact is uncertain as less flow was observed from this plot, but the average NOx-N concentration was lower than the UAN with cover crop treatment.
5. P levels in soils are not appreciably increasing with poultry manure compared to UAN with supplemental P application.

Progress Toward Project Metric

KPI #1: Data on yield, soil and water quality. Measured annually by collection of environmental datasets.

Data on crop yields, cover crop biomass and nutrient uptake, soil nutrients and health parameters, and water quality have been collected throughout the study. This year (2024) was the second year of manure and synthetic fertilizer application at the site, and results reflect the early impact of the prescribed treatments. Additionally, this year was the first year UAN was applied to the balanced manure treatment plots (systems 8 and 9) to differentiate the treatment from the early winter manure treatment plots (systems 4 and 5) and reflect potential residual nutrients available from the 2022 year's treatment.

Cover crop management decisions are needed to mitigate yield losses with later termination of the cover crops and interseeding the cash crop in the spring. Water quality benefits have been realized with cover crops, but at the cost of yield decreases with all N-source treatments. Soil nutrient and health indicators have been measured, but it is too early to identify treatment effects.

KPI #2: Improved understanding of manure integrated cropping systems and their impact on soybean yield and soil and water quality. As more livestock are integrated into the Iowa landscape, we need to improve understanding of the beneficial potential of this manure resource.

Early results indicate a consistently positive impact of cover crops on water quality, but at a negative consequence on crop yields with the current cover crop management plan.

Final Project Results (layman's terms for all audiences)

Iowa State University has partnered with Iowa Soybean and Iowa Egg Council to explore integrated agricultural systems to promote soil health and environmental resilience. Additional projects have been funded by the Egg Industry Center and National Science Foundation (Soil Tech) to explore and document the dynamics involved in nutrient mineralization and the potential greenhouse gas potential. This is a unique, long-term study that included the

establishment of new field plots in 2021, that are now established and producing useful data. Sample collection and data analysis continued through 2024.

The field site includes 27 plots with the following treatments:
1. Cover crop with spring UAN
2. No cover crop with spring UAN
3. Cover crop with split UAN with 75 lbs N/acre spring applied and 75 lbs N/acre as sidedress
4. Cover crop with early winter manure
5. No cover crop with early winter manure
6. Cover crop with spring manure
7. No cover crop with spring manure
8. Cover crop with balanced early winter manure and spring UAN
9. No cover crop with balanced early winter manure and spring UAN

All plots are managed using strip till. The first manure and UAN treatments were applied for the 2022 corn year, with the first three years of treatment effects monitored in 2022-2024. Our cover crops were terminated well before corn planting, however the cover crop had reached maturity with C:N ratios above 20:1, reducing N availability to the growing cash crop. While there were measurable improvements in water quality, a better balance in termination timing, N availability to the plant, and cash crop planting is needed to achieve optimal soybean and corn plant growth and yields.

A concern with poultry manure application is soil phosphorus accumulation and potential losses in surface water. The first years' results from this study do not indicate high rates of P accumulation in the topsoil (0-12") with poultry manure compared to UAN treatments (with P application). Moving forward, this study will provide practical guidance to farmers interested in maximizing yield, resiliency to varying climatic conditions, and protecting downstream water quality.

Additional Funded Projects

Manure management for sustainable egg production and environmental resilience. Iowa Egg Industry Center. S. McMillan, M. Soupir, D. Andersen, S. Hall. $84,990. 7/1/23 – 6/30/25.

Sensor integration to demonstrate benefits of regenerative agriculture on soil health. Soil Tech. S. McMillan, D. Andersen, M. Soupir, C. Gomes, N. Hoover. $50,000. 1/1/24 – 12/31/24.

Poultry manure management to promote soil health and environmental resilience. Iowa Egg Council. M. Soupir, D Anderson, N. Hoover. $69,540. 1/1/24-12/31/24.

Proposed and Pending Projects

Managing Soil Health and Microbes for Climate-Resilient Agriculture. USDA-NIFA. M. Soupir, D. Andersen, N. Hoover, A. Howe, M. McDaniel, S. McMillan.

Advancing In Situ Nitrogen Monitoring in Soils to Inform Farm Management. SoilTech. S. McMillan, M. Soupir, C.Gomes.

Presentations

Soupir, M., N. Hoover, D. Andersen, M. McDaniel, R. Kanwar. Integrated agricultural systems to promote soil health and environmental resilience. Presented to the Iowa Soybean Association Productivity Committee on June 20, 2024.

Hoover, N., M. Soupir, D.Andersen, R. Kanwar. Quantifying the Co-Benefits of Combined Regenerative Agriculture Practices with Poultry Manure Management in a Corn-Soybean System. SWCS, July 23rd, 2024.

Manure Applicator Certification Program- Spring vs. Fall applied poultry manure video segment (recorded Sept.7th for 2024 training season)

Posters

Hoover, N. Optimizing regenerative agricultural practices for environmental resilience and sustainability. Poster presented at the Iowa Soybean Research Center Research Day, Ames, IA, Sept. 5, 2024.