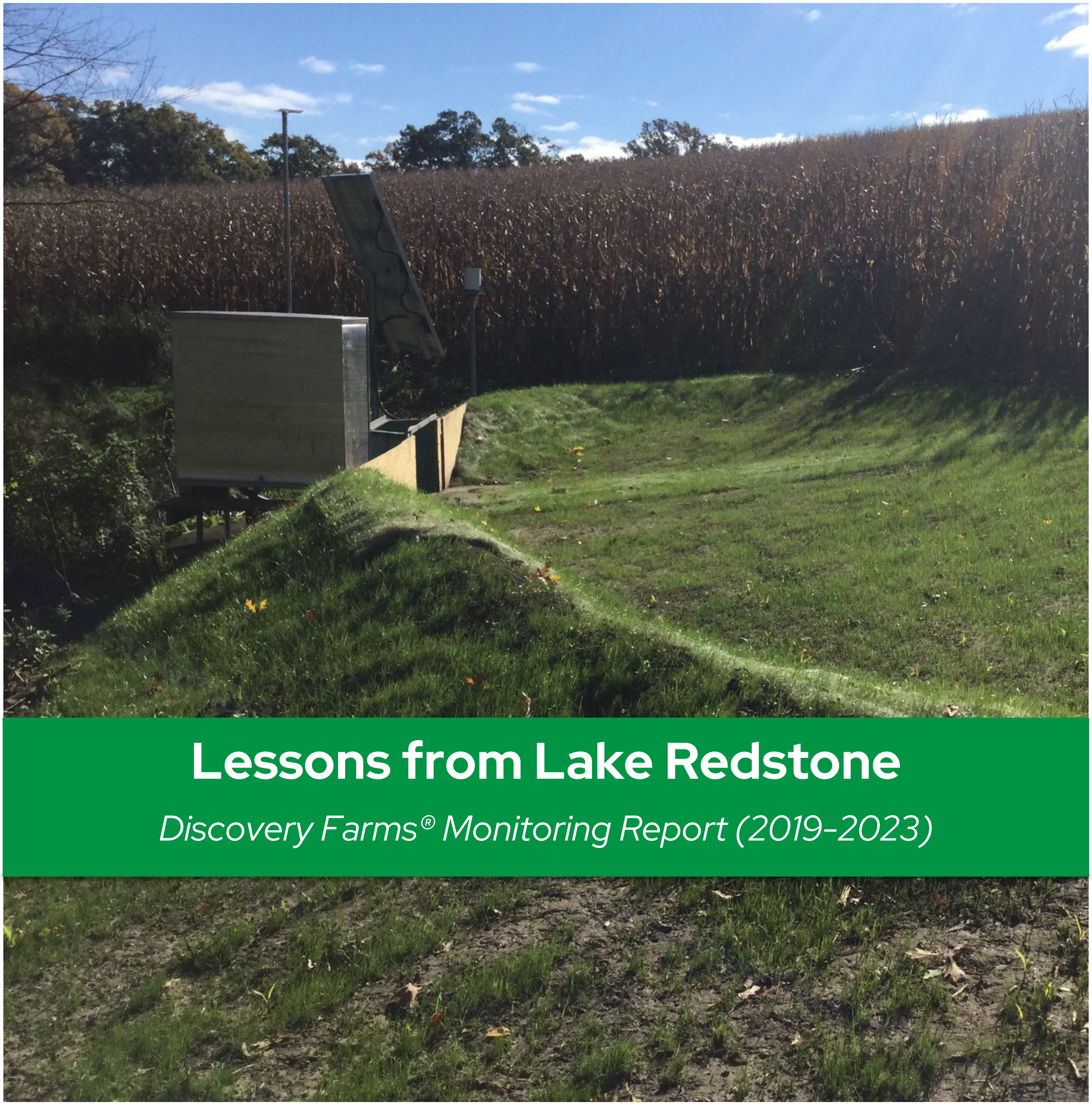

Lessons from Lake Redstone

Discovery Farms® Monitoring Report (2019-2023)

DISCOVERY FARMS WISCONSIN

Lindsey Hartfiel, Ellen Albright, Aaron Wunderlin

agwater.extension.wisc.edu/discovery-farms-program/

Extension
UNIVERSITY OF WISCONSIN-MADISON
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Project Background

Formed in 2001, the Discovery Farms Program is a farmer-led, research and outreach program that conducts water quality studies on privately owned farms throughout Wisconsin. Our program implements research, collects data, analyzes trends, and shares the results with farmers, crop consultants, and policymakers, among others.

In 2018, the Discovery Farms Program, part of the University of Wisconsin Madison's Division of Extension, in partnership with the Juneau County Land and Water Resources Department and the Agricultural Producers of Lake Redstone, began a multi-year water quality monitoring study in the Lake Redstone watershed near the border of Juneau and Sauk Counties. The partnership was established to evaluate cropping and management systems that minimize soil and nutrient losses in surface runoff. Assessing different farming and management practices is important to determine effective soil and nutrient conservation strategies and promote their adoption. In the highly sloped land commonly farmed in this region, soil conservation practices and conservation cropping systems are critical to maintain cropland productivity and minimize soil and nutrient loss to streams and lakes in the valleys.

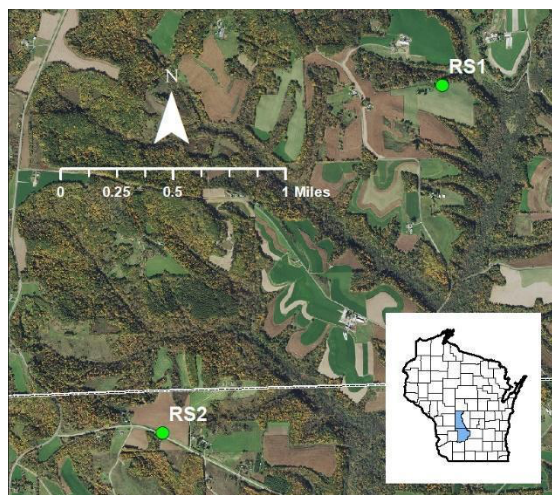

Figure 1. Site locations for the Lake Redstone monitoring project

Two edge-of-field surface runoff monitoring sites, referred to as RS1 and RS2, were identified and installed in fall 2018 to measure and collect runoff from the monitoring basins. The two sites are managed by one farm but are located on two fields approximately 2 miles apart (Figure 1). The farm practices no-till and reduced tillage and uses cover crops. In addition, the farm is part of a community manure sharing program which allows for farmers to trade and apply manure on neighbor's farms and vice versa due to the challenging landscape in this area. With the steep slopes, there are many winding roads that can significantly increase the distance to a field. This program allows the neighboring farmers to share and apply manure where it is more feasible.

Sites were monitored year-round in collaboration with the United States Geological Survey (USGS). All precipitation and runoff event volumes for each year were accounted for. Runoff volume was measured, and sampling was performed using USGS methods. Water samples were analyzed for suspended sediment, phosphorus, and nitrogen. Analyses were performed at the Water and Environmental Analysis

Laboratory (WEAL) in Stevens Point, WI. Total phosphorus and total nitrogen, including their different forms, were measured at the lab or calculated from measured values. Total phosphorus includes particulate phosphorus, which is attached to soil particles, and dissolved phosphorus, which is soluble reactive phosphorus. Total nitrogen includes nitrate (nitrite+nitrate-N), ammonium (ammonium+ammonia-N), and organic nitrogen-N. In some cases, runoff events were too small to collect a water sample, so concentrations were estimated based on the concentrations from the previous and following runoff events.

Agronomic data was collected each year. This farm is a beef operation that grows corn, soybeans, and alfalfa/grass crops. The farmer provided information annually about crops, tillage, and nutrient applications in each field. Crop rotation for each site can be found in Table 1.

Table 1. Crops grown at each site by field year.

	Field Year					
Site	**2018***	**2019**	**2020**	**2021**	**2022**	**2023**
RS1	Corn	Cover mix	Alfalfa/hay	Alfalfa/hay	Alfalfa/hay	Alfalfa/hay
RS2	Corn	Corn	Grass/hay	Grass/hay	Soybean	Corn

*Crop prior to the start of monitoring.

For both sites, the monitoring basins were located within a single field. Site RS1 had a 2.1-acre basin with an average slope of 11%. The dominant soil type was Norden silt loam (Figure 2). Site RS2 had a 1.9-acre basin with an average slope of 7% and a dominant soil type of La Farge silt loam (Figure 3). The sites were monitored from field year (FY) 2019-2023. A field year is defined as October 1 through September 30 and is labeled according to the calendar year in which it ends.

Figure 2. RS1 monitoring basin and soil types

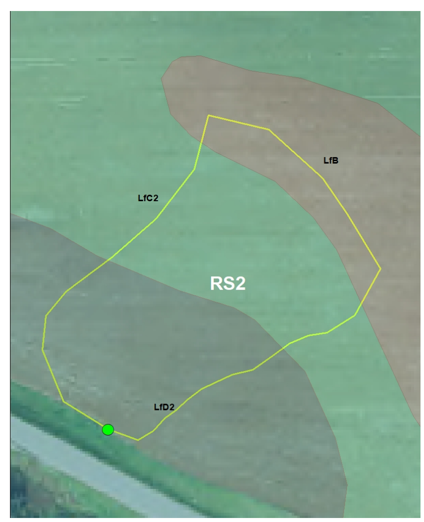

Figure 3. RS2 monitoring basin and soil types

Precipitation

Both sites had a rain gauge to collect rainfall data. Frozen precipitation (primarily snowfall) was estimated using the nearby Mauston weather station data. The frozen precipitation was converted to its liquid equivalent so it could be compared equally to rainfall. In the first year of monitoring (FY19), the rain gauge at RS1 was determined to be unreliable. Therefore, for FY19, the RS2 rain gauge was used for both sites until its repair early the following year. After which, each site independently measured rainfall. Rain gauges were calibrated annually. The 30-yr normal (1991-2020) annual precipitation for Mauston is 36.33 inches.

At site RS1, annual precipitation ranged from 30.01 inches to 37.11 inches during the monitoring period. Snow (frozen precipitation) contributed 5.5% to 13.9% of the annual precipitation. Total annual precipitation was below average every year except for FY20 at RS1 (Figure 4). At RS2, the annual precipitation was typically lower than at RS1, ranging from 26.87 inches to 32.33 inches during the monitoring period. This showcases that rainfall is not uniform within an event even at small distances. Snowfall contributed to 6.4% to 13.9% of the annual precipitation at RS2. Every year during the monitoring period had below average precipitation at RS2.

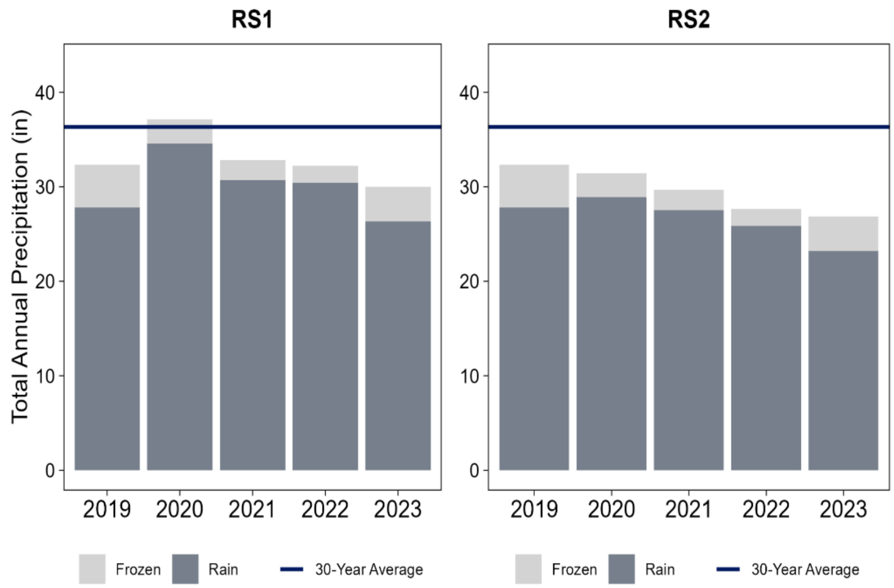

Figure 4. Total annual precipitation at sites RS1 and RS2. The darker gray portion represents rainfall while the lighter gray represents the liquid equivalent of snow and other frozen precipitation. The 30-yr average is represented by the solid line.

While the annual precipitation was below average for most of the monitoring period, there were months with above average precipitation at each site (Figure 5). Above average precipitation is typically associated with greater risk for runoff and soil and nutrient losses, especially in early spring through early summer. During this time period, soils can still be frozen or saturated, preventing infiltration of snowmelt or rainfall. During later spring to early summer, the soil is still vulnerable, especially if there is no overwintering cover, as the new crop is being established. All this allows for runoff to occur and the transport of soil and nutrients. Above average precipitation during the heart of the growing season (e.g., July 2019) is often less of a concern for water quality. During this time period, the year's crop is typically well-established with a high-water need and a protective canopy for the soil. These factors reduce the risk for runoff and the transport of soil and nutrients.

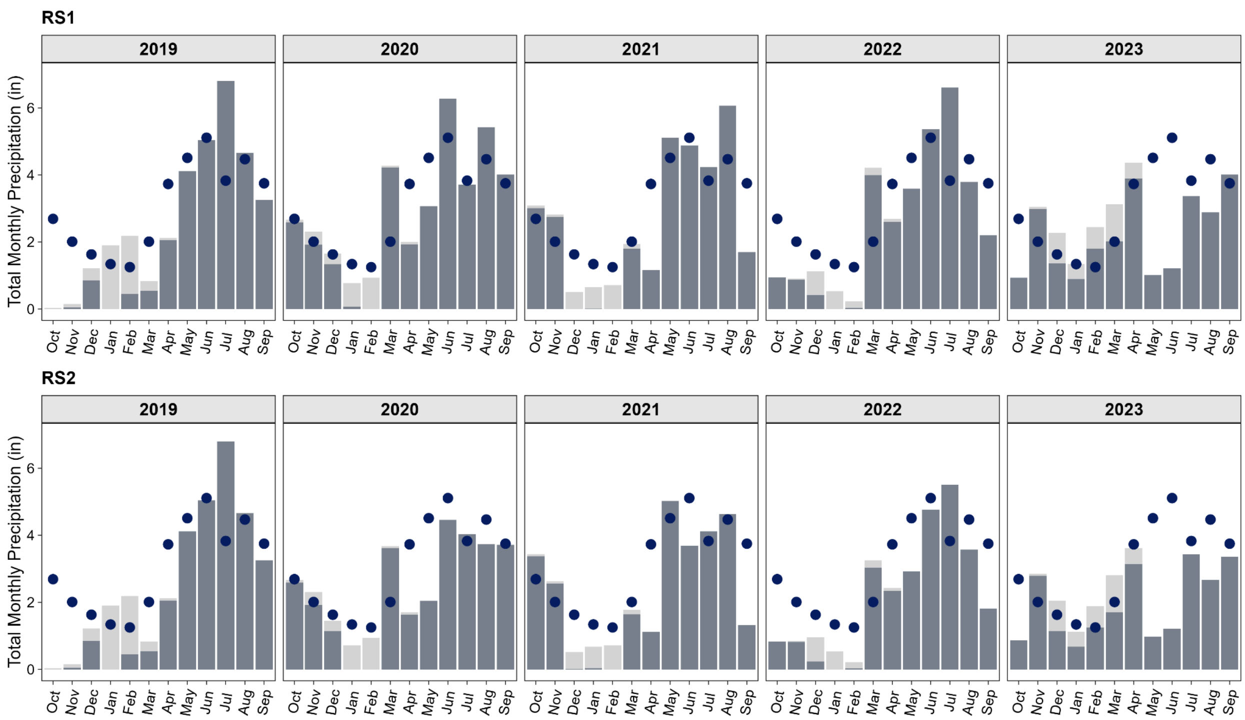

Figure 5. Monthly precipitation for RS1 (top) and RS2 (bottom) by year. The darker gray potion of the bars represents rainfall while the lighter gray portion represents the liquid equivalent of frozen precipitation. The 30-year monthly averages are represented by the dark circles.

There were 722 (RS1) and 659 (RS2) rain events over the course of the project. Thirty-five (RS1) and 27 (RS2) of those events were greater than 1". Of those, there were six events at both sites that were greater than 2". Not all of these larger events caused runoff. The largest rainfall event occurred on July 6, 2019, and was 3.58". This event was equivalent to about a 5-yr, 24-hr storm event and produced runoff at both sites.

Runoff

Total runoff for this project was 11.26" (RS1) and 15.34" (RS2) accounting for 6.8% (RS1) and 10.4% (RS2) of the total precipitation during the monitoring period. Annually, total runoff ranged from 0.02" to 4.06" (RS1) and 0.33" to 7.20" (RS2). Across other cropland sites in the long-term (2004-2023) Discovery Farms dataset, median annual runoff is 3.44" (average of 3.96"). The majority of runoff occurred during frozen soil conditions (Figure 6). The soils were frozen for 15-25% of each year, but on average, contributed to 60% of the annual runoff events. Runoff on frozen soils accounted for 73-100% of the annual runoff water volume at the sites. The majority of this runoff occurred in the month of March (Figure 7). Runoff is common during the month of March due to the frozen soil conditions restricting infiltration of snowmelt and rainfall.

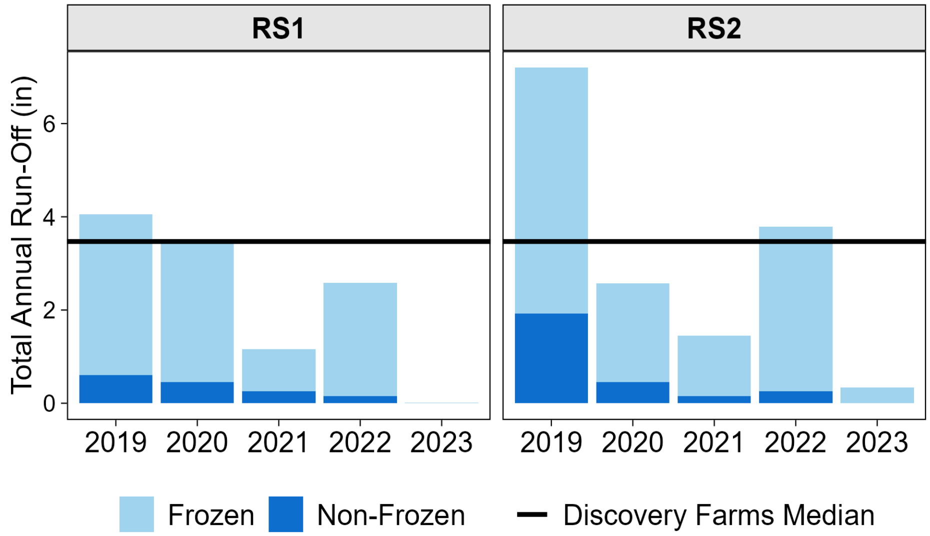

Figure 6. Annual runoff for RS1 (left) and RS2 (right). The light blue portion of the bar represents the runoff that occurred on frozen soils while the dark blue portion represents the runoff during non-frozen conditions. The black line is the Discovery Farms median annual runoff at other crop sites (2004-2023).

There were 41 (RS1) and 43 (RS2) runoff events over the course of the project. The largest runoff event at RS1 (1.95") was a continuous event that occurred from March 3 through March 9, 2020. The largest runoff event at RS2 (2.72") was a continuous event that occurred from March 14 through March 18, 2019. Both were caused by snowmelt (RS1) or snowmelt with rain (RS2) on frozen soils.

Formed in 2001, the **Discovery Farms Program** is a farmer-led, research and outreach program that conducts water quality studies on privately owned farms throughout the state of Wisconsin. The historical dataset is used to look for trends related to runoff and management practices. Median losses are calculated and used as a comparison with farm specific data. This allows the farmer and others to see how a farm compares to other farms in the state. It is not used to determine "good" or "bad" results, as many variables including landscape and precipitation trends influence regional differences throughout the state.

Medians in this report represent Discovery Farms edge-of-field surface runoff monitoring from 2004-2023 for cropland sites. There are 21 sites, 112 site years of data, and over 2100 runoff events used to calculate the medians throughout this report. The Lake Redstone sites are not included in the medians for this report.

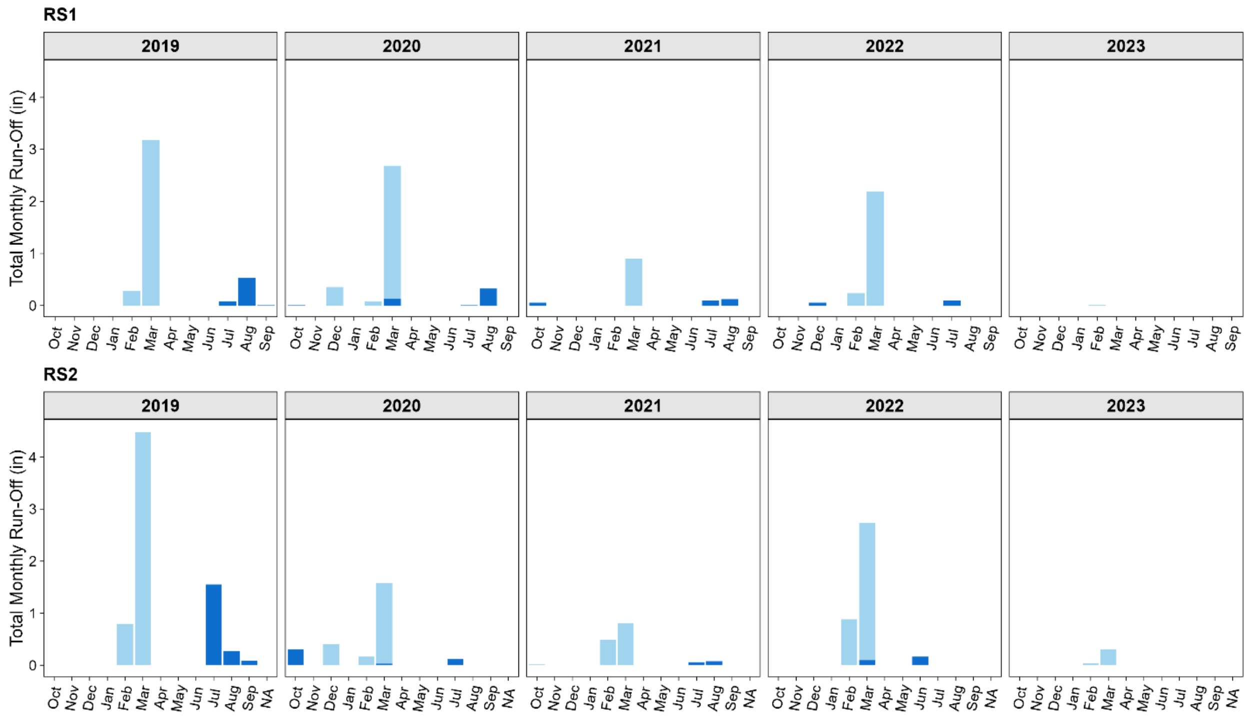

Figure 7. Total monthly runoff for RS1 (top) and RS2 (bottom). The light blue portion of the bar represents the runoff that occurred while the soils were frozen while the dark blue portion represents the runoff during non-frozen soil conditions.

Runoff on Frozen Soils

Runoff generation on frozen soils can be classified into three general categories. First, **rain on frozen ground** occurs when rain arrives on frozen soils with no snowpack present and prompts runoff. This type of event was observed once at both RS1 and RS2 in late December of 2019. Next, **snowmelt** runoff is driven solely by water from melting snowpack with no rainfall. This type of event can occur during mid-winter thaws, as seen at both sites in February 2020 and 2022, and during the spring thaw, which occurred in March for both sites and all years of the study. Finally, a combination of **snowmelt and rain** can also prompt runoff on frozen soils. This event type was observed occasionally at both sites throughout the frozen soil periods, but was most common in late winter.

Snowmelt runoff constituted the majority of runoff generation on frozen soils at RS1 and RS2 (Table 2). The largest runoff volumes observed under frozen soil conditions at these sites were associated with either snowmelt or snowmelt and rain (Figure 8).

Table 2. Distribution of frozen soil runoff events at RS1 and RS2.

Site	Frozen-Soil Runoff Type	Total Number of Events (2019-2023)	Proportion of Total Frozen-Soil Runoff Events
RS1 North-Facing Slope	Rain on Frozen Ground	1	5%
	Snowmelt	13	59%
	Snowmelt and Rain	8	36%
RS2 South-Facing Slope	Rain on Frozen Ground	1	4%
	Snowmelt	18	69%
	Snowmelt and Rain	7	27%

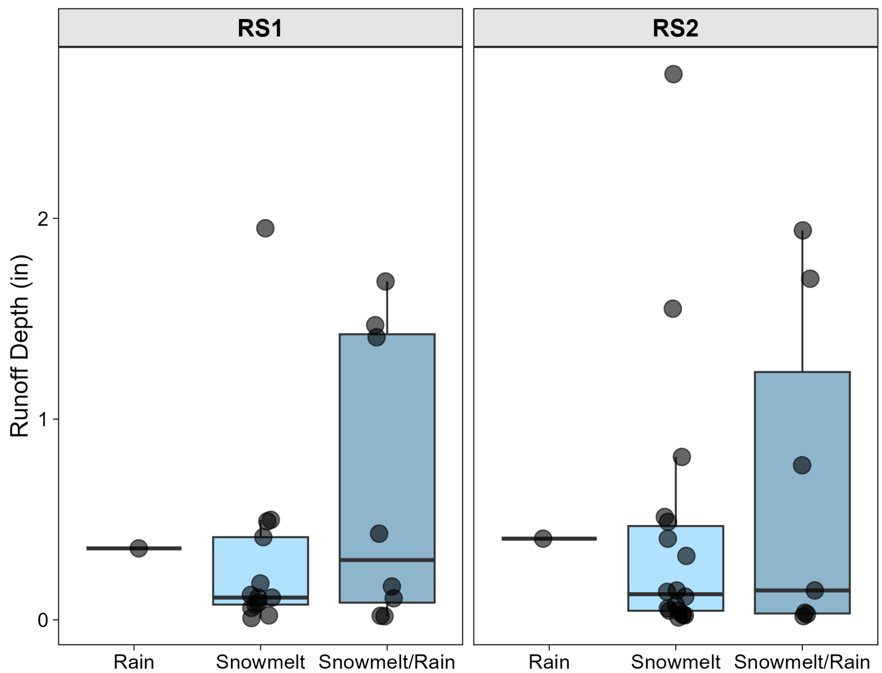

Figure 8. Runoff Depth by Event Type (2019-2023). Dots represent individual runoff events that occurred on frozen soils. Box plots illustrate the distribution of values within each group.

Declines in local snowpack were often associated with snowmelt runoff events at the Lake Redstone sites (Figure 9). However, there were instances in which snowpack declined without triggering runoff, which could be the result of sublimation (when snow is lost directly to the atmosphere as water vapor without melting first), storage of meltwater within the snowpack or depressional storage, or differences in snowpack between Mauston and the edge of field sites. This last consideration is likely in March of 2022 when several snowmelt runoff events were observed at the sites (especially north-facing RS1), but no snowpack was left in Mauston.

For the most part, rain on snow triggered runoff at RS1 and RS2. However, there were a few instances in the winters of 2019 and 2023 when a rain on snow event did not prompt runoff at either site. The rainwater could have been held in the snowpack present at these times and/or depressional storage in the field. Previous analysis of a Discovery Farms site in southern Wisconsin suggests that snowpack can hold water from small rain events. Specifically, several rain events up to about 0.5 inches were observed falling on 1-5 inches of snowpack, and these events did not trigger runoff.

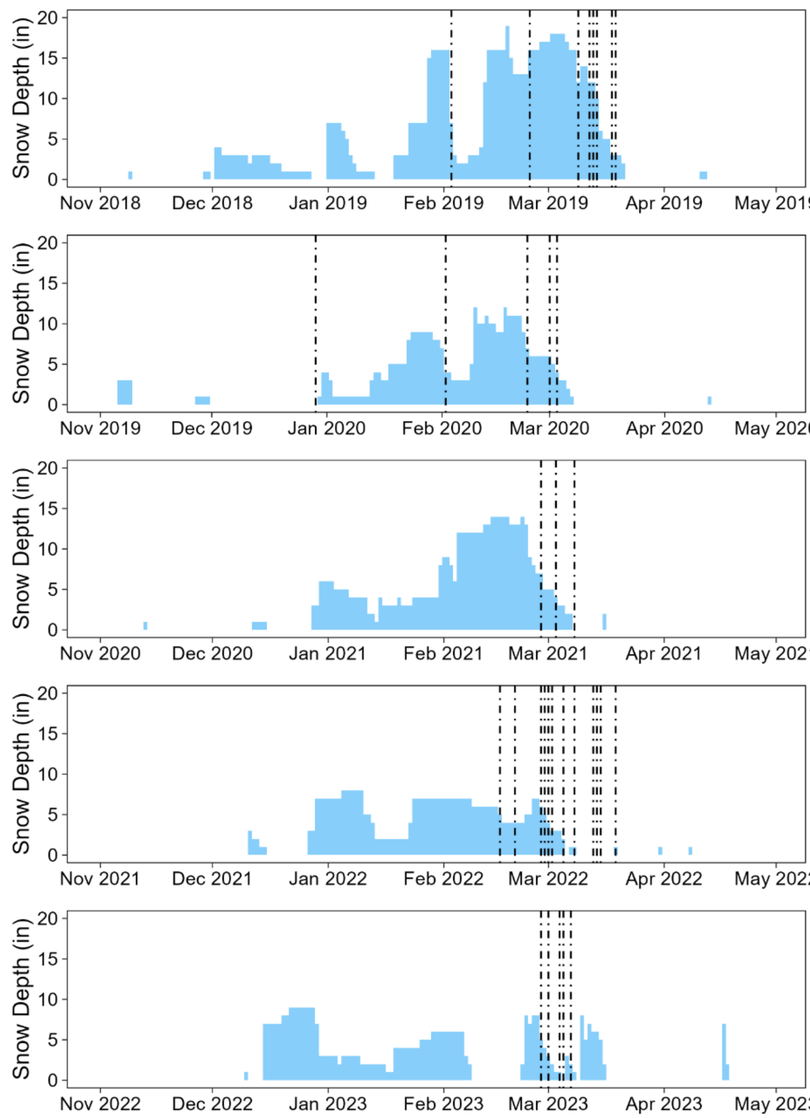

Figure 9. Local Snowpack Depth and Runoff Events (2019-2023). The blue bars represent the depth of the snowpack recorded at the Mauston NOAA weather station. Dashed vertical lines indicate a runoff event on frozen soils at either RS1 or RS2.

Non-Frozen Soils Runoff

There were 19 (RS1) and 17 (RS2) runoff events when the soil was not frozen. The largest non-frozen soil runoff event at RS1 (0.45”) was on August 6, 2019, resulting from a 1.44” rain event. The largest non-frozen soil runoff event at RS2 (1.54”) was on July 6, 2019, from a 3.58” rain event. Looking more into these non-frozen soil runoff events, we were able to identify specific soil conditions for runoff to occur. These are related to both soil moisture and rainfall.

At the RS2 site, there were soil moisture and temperature probes. Previous work has demonstrated sites nearby to each other have relatively low variability in both soil temperature and soil moisture (Radatz et al., 2013). Therefore, the soil moisture and temperature probes were deployed at only one location. Soil moisture, measured as volumetric water content, was recorded at 15-minute intervals. Over the 5-year monitoring period, the soil moisture ranged from 19-49% (Figure 10) with 29% soil moisture being the most commonly observed soil moisture throughout the study period. Looking only at the soil moistures associated with a runoff event, the soil moisture ranged from 32-49% (median of 39%). Therefore, runoff on non-frozen soils only happened when the soil moisture was greater than 32%, with runoff being more likely as the soil moisture increased beyond 32%.

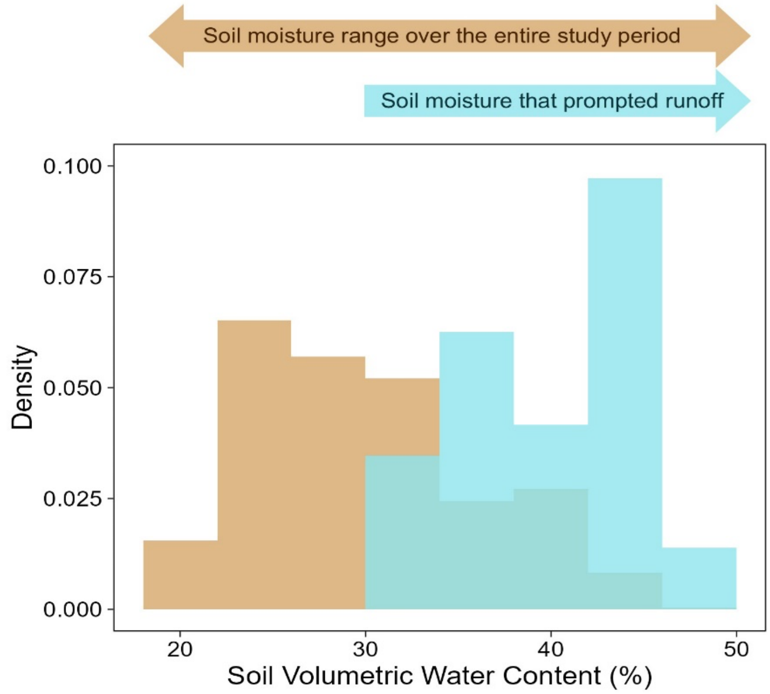

Figure 10. Comparing probability density distributions of observed soil moisture across the entire study period (brown) versus soil moisture immediately preceding runoff events (blue). Density was used to compare the distributions on the same scale. Runoff only occurred when the soil moisture exceeded 32%. Soil moisture is an average of the top 0-30 cm of the soil profile at RS2 and is assumed to represent both sites. Only the non-frozen period is plotted.

Similarly, we can look at total rainfall within three-day windows as a predictor of whether runoff will occur on non-frozen soils. Over the whole study period, the distribution of 3-day antecedent rainfall ranged from 0" to 4", but was most commonly 0.13" (Figure 11). Looking more closely at the rainfall that triggered runoff on non-frozen soils, this only occurred when there was 0.5" to 4" of rain in the previous three days (includes the rainfall event that triggered runoff). The most typical previous three days of rainfall to trigger runoff was 1.76."

There is also an interaction between the soil moisture right before runoff began and total rainfall (within the previous 3-day period) that triggered a runoff event. Greater rainfall (>1.2") was needed to generate runoff when the soil moisture was lower (<40%) (Figure 12). If the soil moisture was higher to begin with (>40%), only 0.5" of rain was needed to trigger runoff.

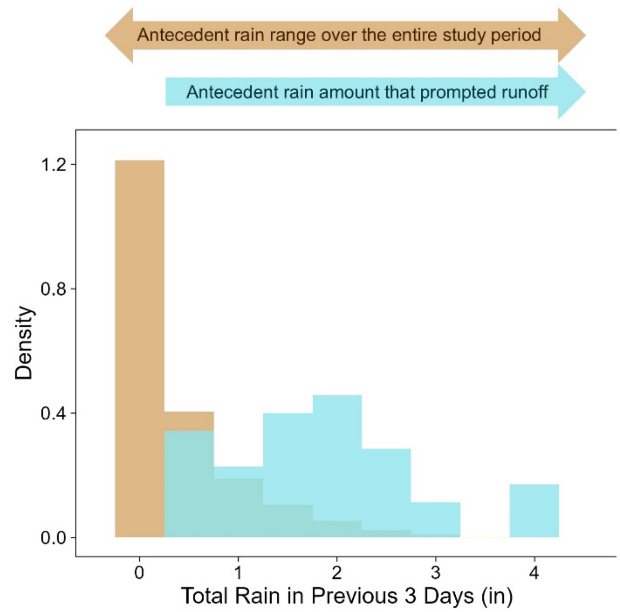

Figure 11. Comparing probability density distributions of antecedent rainfall (event plus any rain in the preceding three days) across the entire study period (brown) versus rainfall that prompted runoff (blue). Density was used to compare the distributions on the same scale. Runoff only occurred when the event plus antecedent rainfall exceeded 0.5 inches. Rainfall is measured separately at each site. Only the non-frozen period is plotted.

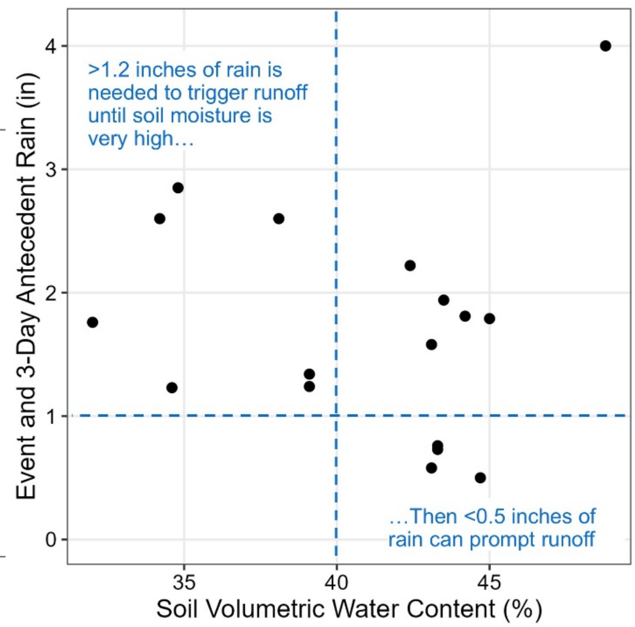

Figure 12. Biplot of antecedent rainfall and soil moisture associated with runoff events on non-frozen soils at RS2 over the study period. When soil moisture was less than 40%, at least 1.2 inches of rain were needed to prompt runoff. At higher soil moisture, as little as 0.5 inches of rain could cause runoff.

Overall, during the non-frozen period at both sites, runoff generation only occurred when soil moisture exceeded 32% and total rainfall within the previous 3 days was at least 0.5 inches. There wasn't a clear pattern with rainfall intensity and runoff generation. Several instances of high rainfall intensity (>1.5 inches per hour) did not produce runoff, and almost all of the observed runoff events were associated with rainfall intensities less than 1 inch per hour. Antecedent soil moisture and the total amount of rain that fell are more important factors in determining runoff generation.

Soil

Total soil loss during this project was 388 lb/ac (RS1) and 491 lb/ac (RS2). At RS1, the majority of the soil loss (90%) occurred on frozen soils. Note, the soil is defined as being frozen if there is frost left in the soil at any depth. During the snowmelt time period, the top layer of the soil can thaw while there is still frost left deeper in the soil. This prevents infiltration and can leave the top layer of soil vulnerable to transport via runoff. In contrast, at RS2, the majority of the soil loss (79%) occurred on non-frozen soils. One reason for the marked difference between the sites may be due to differences in their slope aspects. The RS1 site was located on a north facing slope while the RS2 site was on a south facing slope. Due to the north facing slope at RS1, we suspect that the soil took longer to warm up than at the RS2 site. Note, soil temperature probes were only located at the RS2 monitoring site (for reasons stated in the "Non-frozen Soils Runoff" section above).

The annual soil loss ranged from 0.03-253 lb/ac (RS1) and 1.82-388 lb/ac (RS2) (Figure 13). At RS1, the majority of the soil loss (78%) occurred in the month of March. This is when the majority of runoff also occurred. At RS2, the majority of the soil loss (68%) resulted from a single event on July 6, 2019, during a 3.58" rain event. The site was in a corn crop during that time frame. During that same event at RS1, less than 1 lb/ac of soil loss occurred. However, that site was in a

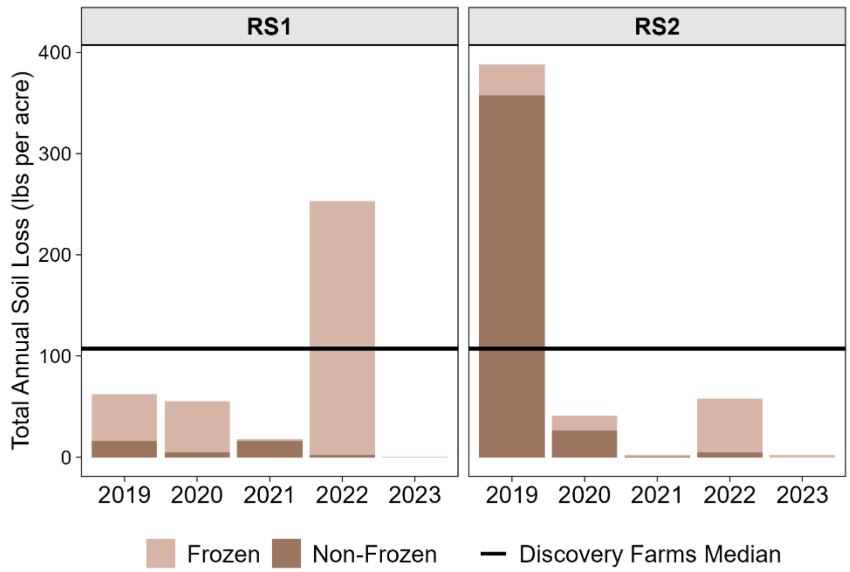

Figure 13. Total annual soil loss by site and year. The light brown portion of the bars represents soil loss during frozen soil conditions while the darker brown portion represents soil loss during non-frozen conditions. The Discovery Farms median soil loss at cropland sites is represented by the solid black line.

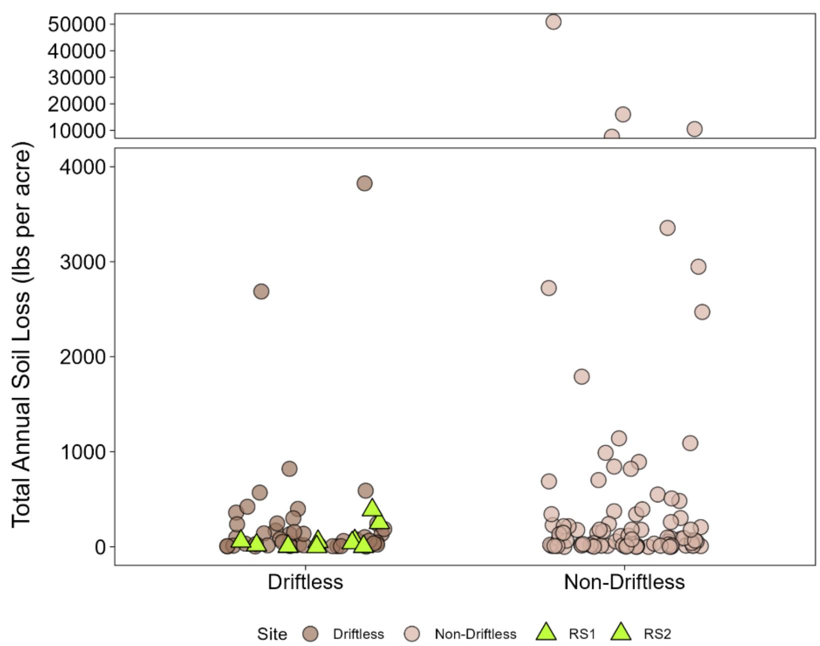

Figure 14. Total annual soil losses at the Lake Redstone sites compared to other Discovery Farms cropland sites (2004-2023) within the Driftless Region (Vernon, Lafayette, and Iowa Counties) and the rest of Wisconsin. Each point represents total soil loss during one year of monitoring at one site. Each site is typically monitored for 5-7 years.

year-round cover crop mix at that time which allowed for greater soil protection during that large rain event.

There was low soil loss at both sites throughout the monitoring period despite the steep slopes. The sites were maintained with continuous cover through alfalfa/hay/grass mixtures throughout most of the monitoring period. At RS2, there were also corn and soybeans grown in the rotation with cover crops. The sites were only tilled once (RS1) or twice (RS2) during the monitoring period, and both used reduced (vertical) tillage methods. Likely due to minimal tillage and the continuous cover, the magnitude of the soil loss at these sites was low compared to other Discovery Farms cropland monitoring sites in the Driftless region and across the rest of the state (Figure 14).

Phosphorus

Total phosphorus (TP) loss during this project was 3.43 lb/ac (RS1) and 1.55 lb/ac (RS2). The majority of the TP loss occurred during frozen soil conditions at RS1 (86%) and RS2 (62%). Annual TP loss ranged from 0.002-1.51 lb/ac (RS1) and 0.01-0.72 lb/ac (RS2; Figure 15). The majority of the TP loss occurred in the month of March at RS1 (53%). At RS2, most of the TP loss also occurred in the month of March (48%), but a single event on July 6, 2019, contributed to 25% of the TP loss during the monitoring period.

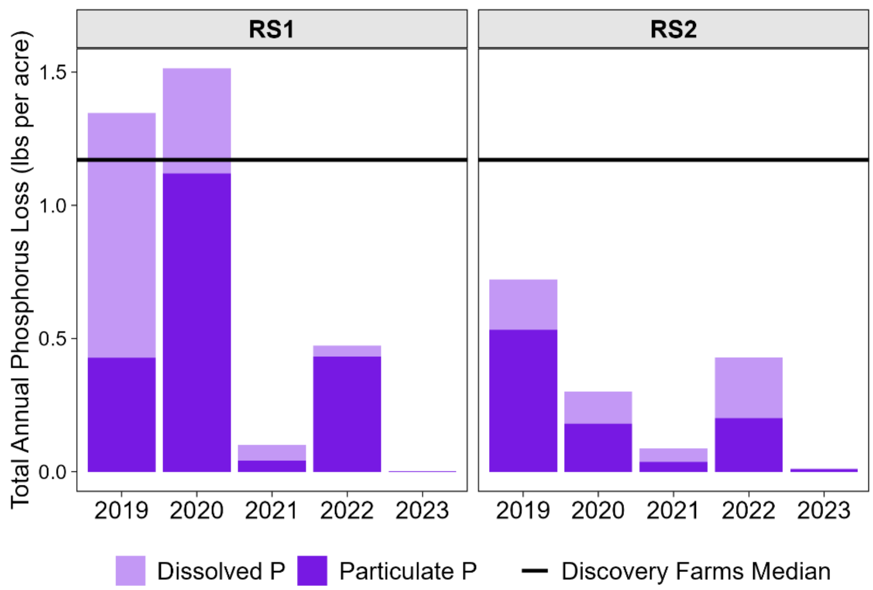

Figure 15. Total annual phosphorus loss by site and year. The darker purple portion of the bar represents particulate phosphorus loss while the lighter purple represents dissolved phosphorus loss. The Discovery Farms median total phosphorus loss at cropland sites is represented by the solid black line.

Total phosphorus loss is the sum of two forms of phosphorus: particulate phosphorus (PP) and dissolved phosphorus (DP). Particulate phosphorus is primarily found bound to soil particles. As such, particulate phosphorus and soil losses are usually correlated. Dissolved phosphorus is held in solution in the runoff water, and these losses may occur even if soil erosion does not. Dissolved phosphorus losses are more commonly seen during frozen soil conditions, following a surface manure application, or in a high soil test phosphorus environment.

On average, across the monitoring period, the majority of TP losses were in the PP form at RS1 (59%) and RS2 (62%). However, there were some years where the majority of losses were in the DP form (Figure 16). The majority of DP losses occurred during frozen soil conditions at RS1 (74%) and RS2 (82%). The majority of PP losses also occurred during frozen soil conditions at RS1 (95%) but only about half (51%) the losses at RS2 occurred during frozen soil conditions.

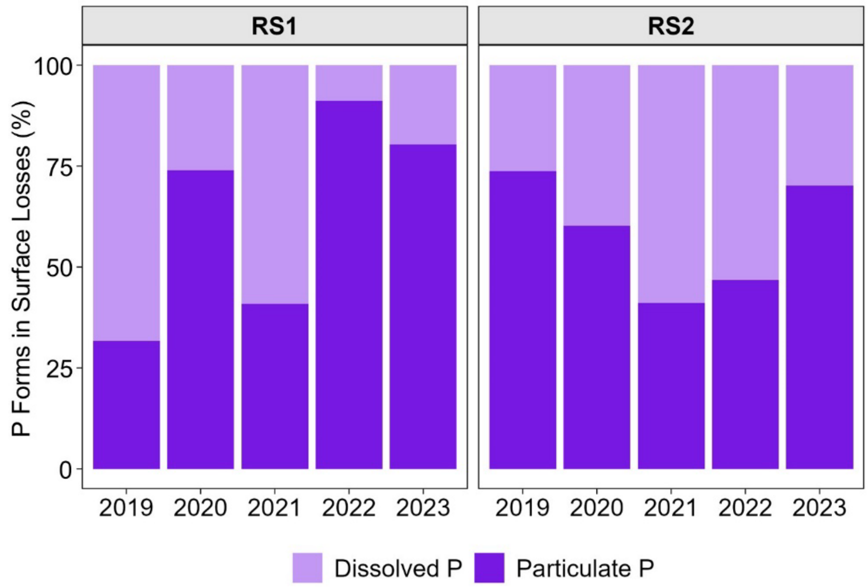

Figure 16. Percentages of phosphorus forms (particulate and dissolved) in total annual phosphorus losses by site and year.

The magnitude of the annual TP losses at RS1 and RS2 were consistently low in comparison to other cropland Discovery Farms sites in the Driftless region as well as other Discovery Farms sites across the state (Figure 17). While the losses were low at these sites, there are strategies that can be used to reduce the risk of TP loss on any farm. These include managing the farm

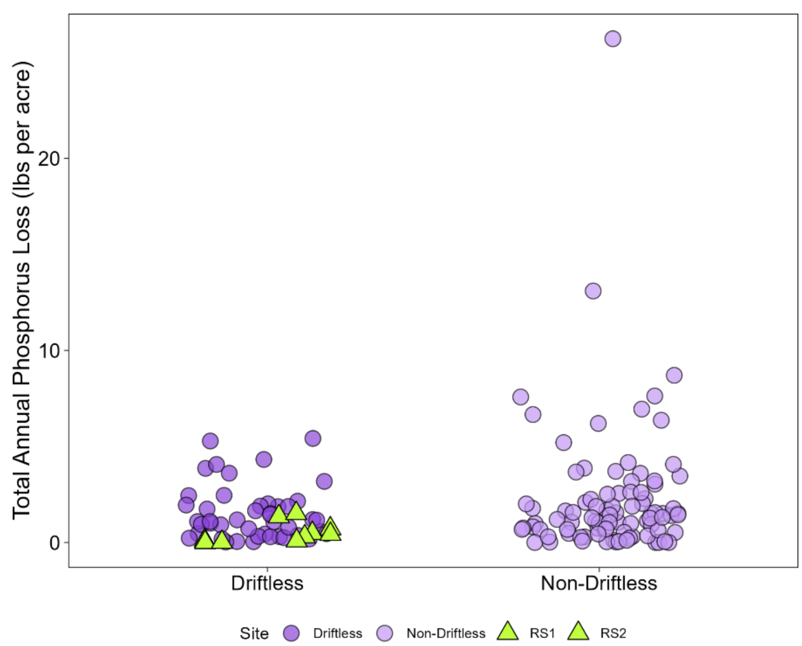

Figure 17. Total annual phosphorus losses at the Lake Redstone sites compared to other Discovery Farms cropland sites (2004-2023) within the Driftless Region (Vernon, Lafayette, and Iowa Counties) and the rest of Wisconsin. Each point represents total soil loss during one year of monitoring at one site. Each site is typically monitored for 5-7 years.

system for timing by avoiding high-risk time periods for runoff (e.g., March snowmelt) and managing nutrients within the field to match crop needs.

Timing of nutrient applications is an important tool to reduce the risk of TP losses from fields. A late winter manure application at RS1 in 2019 contributed to 77% of that year's TP losses. That same year, five additional manure applications were made during lower risk time periods, and there were not any large increases in TP losses following those subsequent manure applications (Figure 18). There was a small increase in TP loss on August 6th, which was related to high runoff volume rather than a high TP concentration. Both concentration of losses and runoff volume contribute to the total losses (lb/ac).

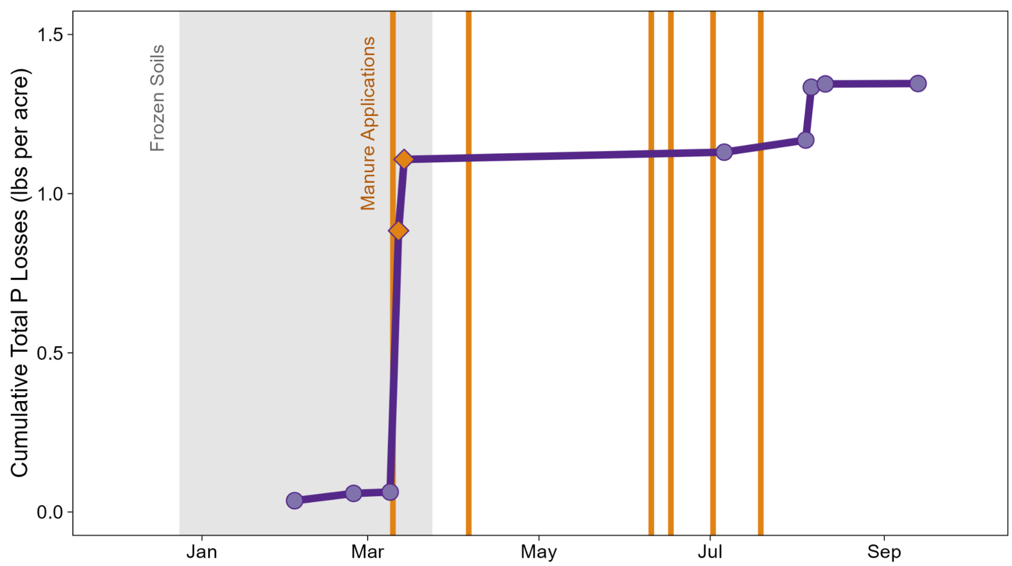

Figure 18. Cumulative total phosphorus losses at RS1 over the 2019 field year. Each point represents a runoff event. Manure was applied to the field six times over the course of the year. One application occurred on frozen soils immediately before two runoff events (orange diamond points). These two events were responsible for 77% of total annual phosphorus losses at this site for 2019. Later manure applications made in season were not associated with elevated phosphorus losses in runoff.

Soil test phosphorus (STP) is an estimate of plant available phosphorus and is one more tool to help reduce the risk of TP losses, especially in the form of DP. Elevated STP levels have been shown to increase the concentrations of DP leaving the field in both surface runoff and tile drainage across Discovery Farms monitoring sites (Figure 19). When STP becomes higher than the crop need, there is an increased risk for the excess phosphorus to be lost via runoff. To reduce this risk, farmers can draw down their STP over time by limiting phosphorus applications to get the STP levels in closer alignment with the crop needs. At both the Lake Redstone sites, they were able to draw down their STP levels (Table 3) by having no phosphorus applications at either site after 2019.

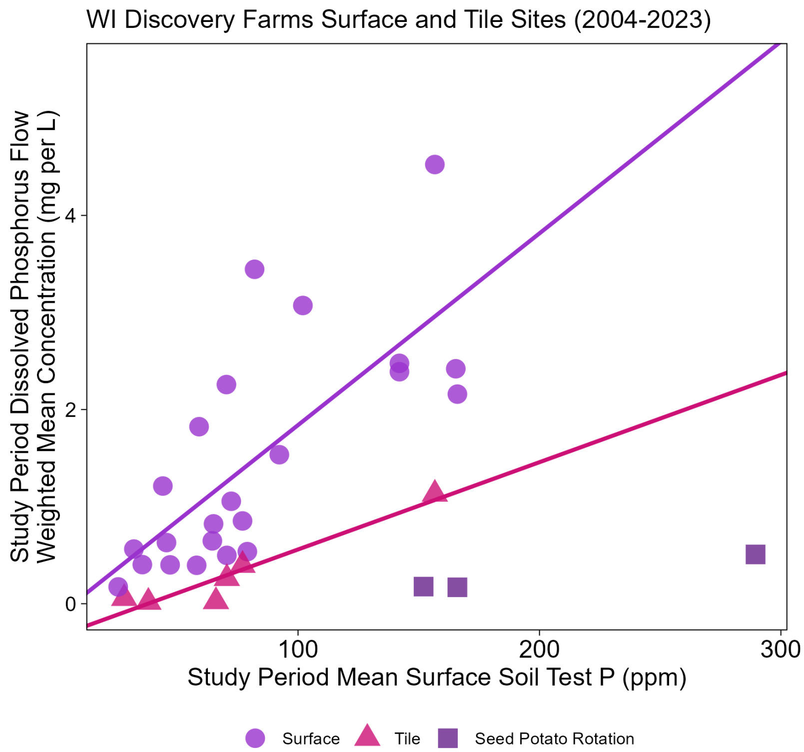

Figure 19. There is a direct relationship between average soil test phosphorus and study period flow-weighted mean dissolved phosphorus concentrations at Discovery Farms surface (purple circles) and tile (pink triangle) edge-of-field sites. One exception to this relationship are three sites in a seed potato rotation where soils are maintained in acidic conditions, which is expected to alter soil phosphorus mineralogy such that the soils can have high STP without having high levels of phosphorus forms that are vulnerable to transport in surface runoff.

Table 3. Soil test phosphorus levels at each site across the monitoring period.

	Depth	RS1	RS2
Fall 2019	0-1"	48	32
	0-6"	29	25
Fall 2021	0-1"	43	19
	0-6"	28	13
Fall 2023	0-1"	22	22
	0-6"	17	16

Nitrogen

Total nitrogen (TN) loss during this project was 15.8 lb/ac (RS1) and 7.6 lb/ac (RS2). The majority of the TN losses occurred when the soil was frozen at RS1 (93%) and RS2 (67%). Annual TN loss ranged from 0.03-7.44 lb/ac (RS1) and 0.16-3.74 lb/ac (RS2) (Figure 20). The majority of the TN loss occurred in the month of March at RS1 (85%). At RS2, most of the TN loss also occurred in the month of March (53%), but a single event on July 6, 2019, contributed 21% of the TN loss during the monitoring period.

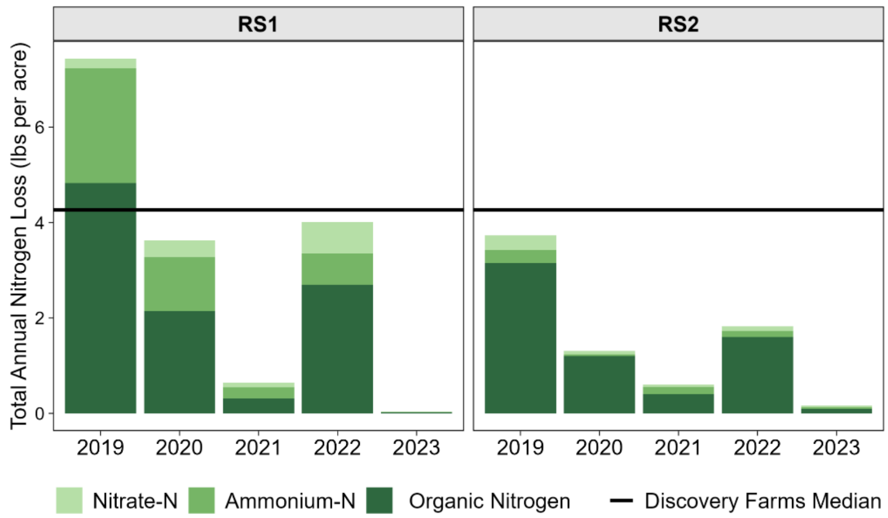

Figure 20. Total annual nitrogen loss by site and year. The color of the bar represents the form of nitrogen. The black solid line represents the Discovery Farms median at other cropland sites.

Total nitrogen loss is the sum of three forms of nitrogen: organic nitrogen, nitrate, and ammonium. Organic nitrogen is associated with soil loss whereas nitrate and ammonium are dissolved in the runoff water and more often associated with manure applications. Nitrate moves easily with soil water through the soil profile and is a common water quality concern in tile drainage systems or in coarse-textured soils where water can infiltrate rapidly to groundwater.

On average, the majority of TN losses were in the organic nitrogen form at RS1 (63%) and RS2 (85%). However, the ratio of losses in each form varied from year to year (Figure 21). The RS1 site had a higher

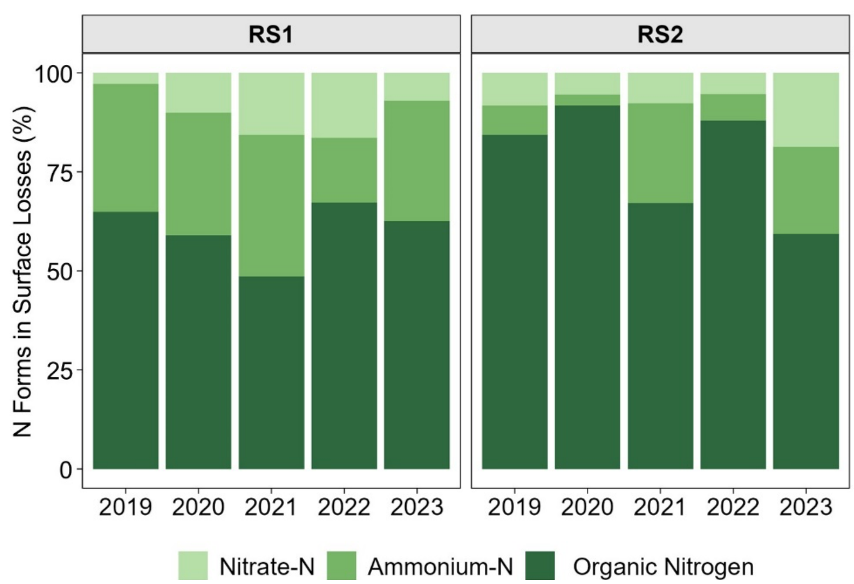

Figure 21. Percentage of various nitrogen forms to total losses by site and year.

proportion of TN losses in the ammonium form (58%) than RS2 (8%). Over half (54%) of the ammonium losses at RS1 occurred in the first year of monitoring (2019). A single runoff event following a recent manure application in March 2019 resulted in 48% of the ammonium losses at RS1 throughout the entire monitoring period. Nitrate made up the smallest proportion of the TN loss at both RS1 (9%) and RS2 (7%).

A summary of all the losses at the monitoring sites can be seen in Table 4 (RS1) and Table 5 (RS2).

Table 4. Summary of RS1 annual values.

Field Year	Total Precipitation (in)	Runoff (in)	Soil (lb/ac)	Total P (lb/ac)	Total N (lb/ac)
2019	32.3	4.06	62.1	1.35	7.44
2020	37.1	3.44	55.1	1.51	3.63
2021	32.9	1.16	17.5	0.10	0.65
2022	32.2	2.58	253	0.47	4.02
2023	30.0	0.02	0.03	0.002	0.03

Table 5. Summary of RS2 annual values.

Field Year	Total Precipitation (in)	Runoff (in)	Soil (lb/ac)	Total P (lb/ac)	Total N (lb/ac)
2019	32.3	7.20	388	0.72	3.74
2020	31.4	2.57	41.0	0.30	1.31
2021	29.7	1.45	2.52	0.09	0.60
2022	27.7	3.79	57.8	0.43	1.82
2023	26.9	0.33	1.82	0.01	0.16

KEY LESSONS LEARNED

There are steps you can take on your farm to reduce the risk of losing soil and nutrients to downstream water bodies. Ultimately, this boils down to managing your system for timing by avoiding field work (e.g., tillage and nutrient applications) during high-risk times for runoff when you have the flexibility to do so, layering practices to best protect your soil and nutrients, and managing your soil system to reduce the risk of nutrient transport.

1) Timing Plays a Big Role in Preventing Soil and Nutrient Losses

At the Lake Redstone monitoring sites, the majority of runoff occurred on frozen soils as a result of snowmelt and early spring rains on frozen and/or saturated soils. On non-frozen soils, the soil moisture needed to be 32% or greater for runoff to be generated. On soils with moisture in the range of 32-40% moisture, >1.2″ of rainfall (from the event that starts runoff + any rainfall that occurred in the previous 3 days) was needed to generate runoff. On saturated soils (>40% soil moisture), it can take as little as 0.5″ of rainfall to cause runoff. Making management decisions that account for the soil conditions and the highest risk time period for runoff (early spring through early summer) can reduce the risk of soil and nutrient losses.

March Manure Application Case Study

At the RS1 site, a March manure application on frozen soils was made. Soon after this application was made, there were two runoff events. This resulted in 77% of the annual total phosphorus losses for the year (1.05 lb/ac in FY2019) (Figure 18). There were five additional manure applications later in the year when the risk for runoff was lower, and these did not result in any large increase in total phosphorus losses.

Manure applications can also result in elevated ammonium or nitrate concentrations in surface runoff. A single runoff event following the manure application in March 2019 resulted in 48% of the ammonium losses at RS1 (2.12 lb/ac) throughout the entire monitoring period.

Overall, the losses at the Lake Redstone monitoring sites were low, but this demonstrates the risk that one management decision can have on soil and nutrient losses. It is best practice to avoid late winter nutrient applications on frozen soils when snowmelt is likely. It is also important to avoid field work on vulnerable, saturated soils, especially if there is more precipitation in the forecast. This is another time period where the risk of runoff would be elevated. Visit the Wisconsin Runoff Risk Advisory

Forecast from the Wisconsin Manure Management Advisory System to explore the risk of runoff in your area.

2) Layering Practices Can Reduce the Risk of Soil and Nutrient Losses

Despite the steep slopes at the two Lake Redstone monitoring sites, they were able to achieve consistently low soil and nutrient losses in comparison to other Driftless Region sites that Discovery Farms has monitored. The farm prioritizes protecting their soil and nutrients on their farm through practices like reduced tillage, cover crops, and using perennial crops in their rotations.

Identifying the problem areas of your fields where erosion occurs is a great first conservation step. Once identified, you can build a network of practices that work to protect your soil and nutrients, keeping them in place. It's important to assess your fields annually, including protected areas like a grassed waterway, as things can change over time. Another strategy is to think of your farm across its entire crop rotation, identifying if there are opportunities to reduce soil disturbance and/or increase soil cover across all your managed acres. For example, if you could keep erosion prone areas in a perennial cover or year-round cover via cover crops or interseeding. Check out the Discovery Farms Field Walkover Guide to explore how to identify areas of your fields that might need additional attention and soil protection.

3) Soil Testing is a Strategy to Manage Your Soils and Reduce the Risk of Nutrient Losses

Soil tests are a great method to assess the nutrients available within your soils but also the risk for nutrient losses from runoff. For example, elevated soil test phosphorus (STP) has been shown to increase concentrations of dissolved phosphorus in both surface runoff and tile drainage in the Discovery Farms dataset (Figure 19). If STP is higher than the crop need, there is an increased risk for the excess phosphorus to be lost via runoff. To reduce this risk, farmers can draw down their STP over time by limiting phosphorus applications to get the STP levels in closer alignment with the crop needs. At both the Lake Redstone sites, they were able to draw down their STP levels (Table 3) by having no phosphorus applications at either site after 2019. If you are interested in assessing your STP levels on your farm, check out the Agriculture Water Quality Program's STP project.

References

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Participating farmers and project partners make this research possible

Thank you to our participating farmer and project partner, Juneau County Land and Water Resources Department, who participated in this research. This project provided lessons learned and added to the robust Discovery Farms dataset. Farmer leadership is a pillar of the Discovery Farms foundation. We commend our participating farmer and others involved in this research including the Agricultural Producers of Lake Redstone farmer-led watershed group for their leadership and support of conservation beyond edge-of-field monitoring. Having access to on-farm research results can paint a clearer picture of agricultural impact water quality.

Lessons Learned from Lake Redstone

Discovery Farms Monitoring (2019-2023)

Authors: Lindsey Hartfiel, Ellen Albright, Aaron Wunderlin

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For over two decades, UW Discovery Farms has worked with Wisconsin farmers to identify water quality impacts of different farming systems around the state. The program, which is part of the Agricultural Water Quality Program in UW-Madison's Division of Extension, is under the direction of a farmer-led steering committee. If you are interested in learning more about UW Discovery Farms or this research, visit agwater.extension.wisc.edu/discovery-farms-program/ or email Lindsey Hartfiel at lindsey.hartfiel@wisc.edu.

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