UNDERSTANDING COVER CROP EFFECTS ON WATER QUALITY UNDER INTENSE PRECIPITATION

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ABSTRACT

Climate change is expected to increase the frequency of extreme precipitation events, which could also increase runoff, erosion nutrient loss, and flooding. Cover crops are a best management practice for cropping systems that are vulnerable to soil erosion. The objective of this research was to analyze the effects of cover crops and precipitation intensity on surface runoff and water quality under natural precipitation events. Edge-of-field runoff and water quality data were collected from 2015 -2022 in a corn (*Zea mays*) - soybean (*Glycine max)* cropping rotation with two levels of cover crop use (with cover crops and without cover crops) and two levels of phosphorus fertilizer (no phosphorus and with phosphorus). Water samples were analyzed for total phosphorus, dissolved reactive phosphorus, and total suspended solids. Runoff hydrographs were used to compute runoff volume, peak flowrate, time to peak flowrate, and time to runoff initiation. Runoff events were placed into five categories based on maximum 30-minute precipitation intensity. Cover crops increased the time to peak flowrate under the highest intensity precipitation events by an average of 12 minutes. Increasing precipitation intensity increased erosion for the no-cover crop treatment over 3 times more than for the with cover crop treatment. Total phosphorus loss increased with increasing precipitation intensity for all treatments except the combination of cover crops and no P fertilizer application. These results indicate that cover crops may be a promising best management practice to reduce runoff intensity and sediment loss under high intensity precipitation events.

INTRODUCTION

With precipitation events predicted to increase in intensity due to climate change (USGCRP, 2023), farmers will need to know if their current management practices will change in effectiveness. These extreme events are predicted to exacerbate issues already linked to surface runoff such as sedimentation of lakes and reservoirs and eutrophication due to nutrient concentrations in the runoff and sediment (Sondergaard et al, 2001; EPA, 2024). Precipitation amount and intensity are drivers of the production of surface runoff. Surface runoff carries sediment and nutrients that can have detrimental effects on the environment in which they are deposited, leading to sedimentation and eutrophication (Correll, 1998; Dodds et al., 1992). Sedimentation of reservoirs reduces storage capacity for freshwater and impacts flood management ability. Solutions to this problem involve costly operations to remove the sediment, which can then end up farther downstream creating new problems. Eutrophication of waterbodies leads to deadly algal blooms that can impact humans as well as the fresh and saltwater species living in them. These additional nutrients increase algal production, blocking sunlight from reaching benthic plant species, thereby interrupting photosynthesis and reducing oxygen in the environment (hypoxia). Cover crops are a conservation practice option for fields at high risk of soil erosion and runoff. Studies have shown that cover crops can increase infiltration rate and reduce soil erosion (Folorunso et al., 1992; Siller et al., 2016; Steele et al., 2012). Reducing runoff, soil erosion, and nutrient loss also benefits the farmer. The loss of topsoil can impact several different aspects of crop growth and development including soil moisture capacity, root penetration, and emergence. The objective of this research was to determine if increasing precipitation intensity would influence the effects of cover crop use on surface runoff and water quality.

MATERIALS AND METHODS

Site Description

This study was conducted at the Kansas Agricultural Watershed (KAW) field laboratory in Ashland Bottoms, KS. The KAW field lab consists of 18 small watersheds (about 0.5 ha each) separated by terraces, each with equipment for monitoring edge-of-field runoff. Soils are mapped as Smolan silty clay loam with 3-7% slopes. The cropping system was a no-till corn (*Zea mays*) - soybean (*Glycine max)* rotation. The experimental design is a 2x3 factorial, with two levels of cover crop (with cover crop [CC] and without cover crop [NC]) and three levels of phosphorus fertilizer management. However, for this study we only used two levels of P fertilizer management (0 P fertilizer addition and spring injected P fertilizer placement) because those treatments remained relatively unchanged for the duration of the study (Oct. 2015 through Sept. 2022).

Data Collection

Each plot outlet had a 0.45 m H-flume paired with a 730 Bubbler Module and a 6712/6700 ISCO Auto Sampler. Water depth was recorded each minute with the bubbler module. Runoff event sampling occurred once the depth in the flume exceeded the 0.015 m enable level. After the enable level was reached, a 200 ml sample was collected for each 1 mm of runoff and composited in a 10 L bottle. Once the event was complete, samples were collected within 24 hours and stored at 4 C until analysis for total suspended solids (TSS) and total phosphorus (TP). One-minute runoff data was downloaded from the ISCO sampler. Precipitation was measured on one-minute intervals with 4 tipping bucket rain gauges distributed across the experimental site.

Data Analysis

One-minute flume depth measurements (h_a) were used to calculate runoff volume (m^3/s) using the equation from Bos (1989), where A, B, and C equal 0.0238, 2.5473, and 0.2540 respectively for a 0.45-m H-flume.

$$\text{Log } Q = A + B \log h_a + C [\log h_a]^2$$

Runoff characteristic variables such as runoff volume, peak flow, time to initiation of runoff, time to peak runoff were computed from runoff event hydrographs. There were 96 runoff events during the 7-year monitoring period. Runoff events without sufficient water quality data for analysis were removed from the dataset (primarily events with less than 2 mm of average runoff), leaving 71 events used for statistical analysis. Precipitation events were categorized based on maximum 30-minute precipitation intensity with category “a” being the least intense and category “e” being the most intense (Table 1). Runoff, sediment losses, and phosphorus losses were summed within each category and divided by the total precipitation that occurred for that category to normalized the data based on precipitation depth. Three-way ANOVA with fixed effects of cover crop, P fertilization, precipitation category, and all interactions was used to determine treatment effects on water quality variables and hydrograph characteristics.

Table 1. Precipitation intensity categories used to separate runoff events for statistical analysis.

Category	Range for 30-min maximum precipitation intensity (mm/hr)
a	0 to 13.2
b	13.21 to 26.4
c	26.41 to 39.6
d	39.61 to 52.8
e	>52.8

RESULTS AND DISCUSSION

Runoff Characteristics

Peak flow rate increased with increasing precipitation intensity. The increase tended to be greater for the no-cover crop management compared to the with cover management (Figure 1). Categories c and d maintained the same peak flowrate despite the increased precipitation intensity. The time to peak flowrate (TTP) was affected by cover crop treatment and intensity category. Cover crop use increased the TTP by an average of 14 min for the most intense precipitation events (category e; Figure 2).

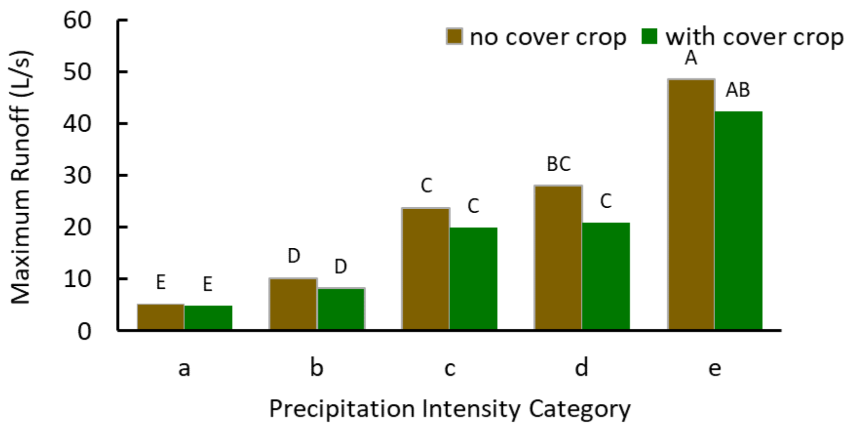

Figure 1. Peak flow rate from a no-till corn-soybean rotation without a cover crop (NC) and with a cover crop (CC) for different precipitation intensities (Table 1).

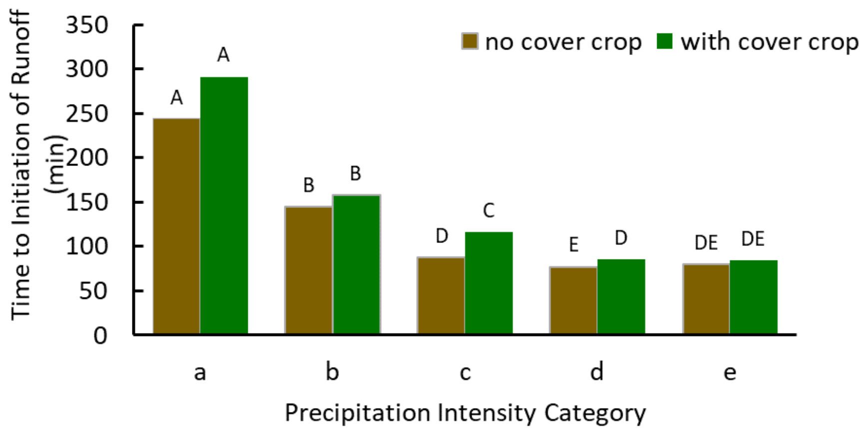

Figure 2. Average time from the beginning of a precipitation event to the peak flowrate of surface runoff from a no-till corn-soybean rotation without a cover crop (NC) and with a cover crop (CC) for different precipitation intensities (Table 1).

Water Quality

Total suspended solids loss was reduced by cover crop use, with larger reductions observed for the highest precipitation intensities (categories d and e) (Figure 3). The TSS loss for NC plots increased by 1.1 kg/ha/mm from category c to d, whereas there was no difference in TSS loss for precipitation categories c, d, and e for the CC plots.

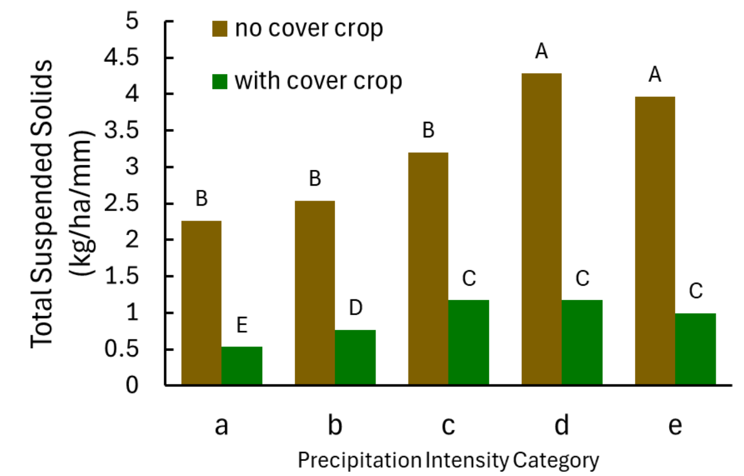

Figure 3. Average total suspended solids loss (kg/ha/mm) in surface runoff from no-till corn-soybean rotation without a cover crop (NC) and with a cover crop (CC) for different precipitation intensities (Table 1).

Total phosphorus loss was impacted by the interaction of cover crops and P fertilizer (Figure 4). The CC plots with no P fertilizer applied did not show a significant difference in TP loss as precipitation intensity increased and had the least TP loss overall. For plots without CC, the TP loss increased with increasing precipitation intensity. The TP loss also increased with increasing precipitation intensity for CC plots that received P fertilizer. Although cover crops decreased sediment loss, this same effect was not observed for total P loss because cover crops increased dissolved P reactive P loss (data not shown).

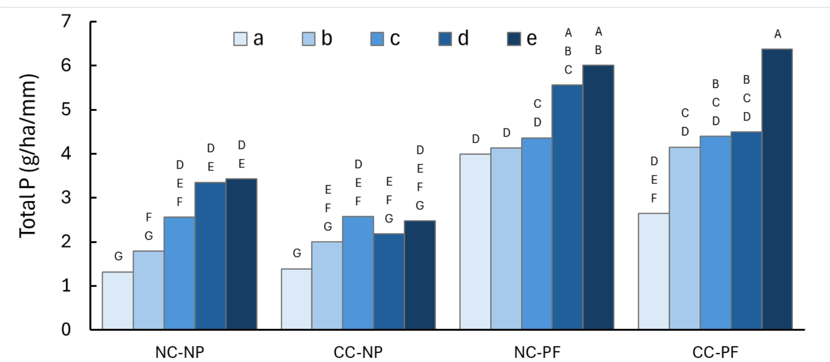

Figure 4. Effect of precipitation intensity category (Table 1), cover crop, and P fertilizer addition on average total phosphorus loss from a no-till corn-soybean rotation (NC-NP=no cover crop and no P fertilizer; CC-NP= with cover crop and no P fertilizer; NC-PF= no cover crop and with P fertilizer; CC-PF= with cover crop and with P fertilizer).

Under intense precipitation events cover crops maintain a reduction in sediment loss compared to no cover treatments. Cover crops also tended to maintain a peak flow reduction as precipitation intensity increased. However, cover crops paired with phosphorus fertilizer did have the most phosphorus loss out of the treatments. With these results it is promising that cover crops will continue to reduce soil erosion and runoff intensity under intense precipitation events, but without other BMPs may not improve water quality.

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