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Quantifying the Effect of Tillage and Cover Crops on Soil Moisture and Temperature in Central Ohio

Abstract

A cover crop is planted to a field to provide a variety of environmental and economic benefits such as slowing soil erosion and improving soil health (Clark, 2019). One of the biggest concerns farmers face when adopting cover crops is the fear of fields not drying out as quickly in the spring for planting. To explore this concern, sensors monitoring soil moisture and temperature were placed in seven Ohio fields in 2022 and 2023 at depths of 3- and 6-inches under one of three management conditions: conventional tillage, no-till, and no-till with a cover crop. Quantification of differences in soil moisture and temperature between conventional tillage, no-till, and cover crop management using soil sensors revealed no statistical difference in moisture and temperature in the spring. The results of this study provide evidence that cover crops can be incorporated as a soil management strategy with little measurable impact to the soil moisture and temperature at planting and throughout the season.

Keywords. cover crops, no-till, soil management

Introduction

A cover crop is planted to provide a variety of environmental and economic benefits such as slowing soil erosion and improving soil health (Clark, 2019). Cover crops have been adopted to mitigate climate change impacts in a variety of ways. However, cover crops can affect planting windows (Kaye et al. 2017). This spring management issue is often what prevents farmers from implementing cover crops as a practice on-farm.

Future success of cover crop adoption will depend on demonstrating the economic value and agronomic feasibility to farmers. One of the biggest concerns farmers face when adopting cover crops is the fear of fields not drying out as quickly in the spring for planting. This has been exacerbated by recent weather patterns in Ohio resulting in exceptionally wet spring weather. In fact, Ohio farmers are now experiencing ten fewer days available for field work in April and May since 1995 due to wet spring weather (Griffin, 2024). The potential risk of delayed planting deters farmers from trying to add cover crops into their management practices.

Additionally, USDA incentive payments to boost cover crop adoption through the Environmental Quality Incentives Program (EQIP) increased from approximately $5 million in 2005 to over $90 million in 2016 (Bowman et al., 2018). Other financial incentives for cover crops are also available to farmers. Despite the benefits and incentives, adoption of cover crops remains low at 4.7% of harvested cropland acres according to the 2022 Census of Agriculture (Bowman et al., 2024).

To investigate this concern, soil moisture and temperature sensors were placed in fields with different management practices to measure differences in how the soil dries and warms in the spring.

Methods

In 2022, TEROS 11 sensors (METER Group, Pullman, WA) were installed in fields in the fall after field work was completed. Two sensors were paired with one ZL6 data logger to measure soil moisture and temperature, hourly. For each data logger, the sensors were inserted into an undisturbed soil profile at 3-inches and 6-inches below the soil surface (Figure 1). These depths were selected to provide representative measures near planting depth and the root zone. While 3-inches is deeper than typical planting depth, shallower installation could lead to inadequate soil contact especially in the conventionally tilled fields.

Figure 1. TEROS 11 sensors installed in the soil profile at 3- and 6-inch depth.

Treatments represented were:

1. No-till with a cover crop (NT-CC).
2. No-till without a cover crop (NT).
3. Tillage.

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Sensors were placed in neighboring fields with similar soil types and drainage. All locations consisted of silt loam and silty clay loam soils. Data collection was replicated across three paired sites with each treatment in West Central Ohio in 2022 and 2023. Sensors were placed in the same soil types in different fields with two sensors per treatment. Each sensor tracked both moisture and temperature.

In 2022, this region of Ohio experienced average temperatures and slightly above average precipitation (100-125% of the long-term normal (1991-2020)) during the growing season (Wilson, 2022). The 2023 growing season experienced average temperatures and slightly below average precipitation (75-100% of the long-term normal [1991-2020]; Wilson, 2023).

Sensors were removed at the time of planting and nitrogen sidedress (for fields with corn crops) and then re-installed during the growing season to continuously monitor soil moisture and temperature. Sensors were reinstalled for the 2023 growing season in early January, removed briefly on most sites for planting and nitrogen sidedress, and taken out for the final time prior to harvest at the end of the season. Table 1 provides details by field for cover crop termination date, plant date and the crop planted for that growing season.

Data were averaged by year and location and the weekly and monthly means for each treatment were calculated. Paired treatments were compared for each time scale for differences in soil temperature and moisture with an analysis of variance (ANOVA) using PROC GLM in SAS 9.4 (SAS, 2023).

Results

The weekly average soil moistures and temperatures through April and May are shown in Table 2. The ANOVA showed no statistical differences for any week during that time period. No differences were observed when years were analyzed independently.

Table 1. Treatments, cover crop seeding method, rate and termination, crop and plant date for each field in 2022 and 2023.

Treatment[1]	Cover Crop Seeding Method	Cover Crop Seeding Rate (lb/ac)	Cover Crop Termination Date	Tillage Type and Depth	Crop Planted	Plant date
Year 2023						
Madison Co: NT, NT-CC (cereal rye)	drill	41	21-Apr	n/a	soybean	20-Apr
Madison Co: Tilled	n/a	n/a	n/a	Disk 2-4”	soybean	19-May
Fayette Co: NT, NT-CC (triticale)	broadcast	35	26-Apr	n/a	soybean	20-Apr
Fayette Co: Tilled	n/a	n/a	n/a	Vertical 2”	soybean	14-Apr
Champaign Co: NT	n/a	n/a	n/a	n/a	soybean	17-May
Champaign Co: NT-CC (cereal rye/wheat mix)	broadcast	30	19-Apr, 26-Apr	n/a	corn	25-Apr
Champaign Co: Tilled	n/a	n/a	n/a	Rip>10”	corn	10-May
Year 2022						
Madison Co: NT, NT-CC (cereal rye)	drill	41	6-May	n/a	soybean	29-Apr
Madison Co: Tilled	n/a	n/a	n/a	Chisel 6”	corn	13-May
Fayette Co: NT-CC (triticale)	broadcast	35	25-Apr	n/a	corn	29-Apr
Fayette Co: NT, Tilled	n/a	n/a	n/a	Rip>10”	corn	1-May
Champaign Co: NT	n/a	n/a	n/a	n/a	corn	14-May
Champaign Co: NT-CC (cereal rye/wheat mix)	broadcast	30	2-May, 24-May	n/a	soybean	25-May
Champaign Co: Tilled	n/a	n/a	n/a	Chisel 6”	soybean	1-May

Table 2. Weekly average soil moisture and temperature at 3- and 6-inch depths through April and May.

	Soil Moisture, 3" (%)				**Soil Moisture, 6" (%)**				**Soil Temperature, 3" (ºF)**				**Soil Temperature, 6" (ºF)**			
Week	CC	NT	Till	p-value	CC	NT	Till	p-value	CC	NT	Till	p-value	CC	NT	Till	p-value
1	32.6	32.6	31.4	0.6224	34.5	33.7	33.8	0.6645	46.0	46.2	46.2	0.7437	45.5	45.6	45.7	0.8864
2	33.3	33.6	32.0	0.2508	35.1	34.3	34.5	0.6529	49.2	49.2	49.3	0.9480	48.5	48.5	48.6	0.9822
3	30.8	31.8	29.3	0.4126	33.4	33.5	33.7	0.9454	51.7	51.3	51.7	0.8849	51.6	51.2	51.3	0.8729
4	29.7	30.1	29.2	0.9435	30.7	30.8	32.9	0.7151	55.2	53.9	53.5	0.7794	54.4	53.0	52.7	0.7441
5	33.9	33.6	31.8	0.5167	34.0	32.8	33.9	0.6733	52.2	51.7	52.1	0.9801	52.0	51.5	52.4	0.8948
6	34.6	33.9	31.3	0.3389	34.1	33.5	34.5	0.8241	57.3	57.5	58.6	0.2623	56.1	55.7	57.2	0.1736
7	33.4	34.4	29.7	0.2060	33.3	34.9	34.2	0.4441	63.4	63.1	65.3	0.5836	62.7	62.1	64.3	0.7532
8	32.2	32.2	29.4	0.5314	32.6	34.2	33.4	0.8121	64.7	64.2	61.0	0.7697	63.7	63.2	61.8	0.9082
9	29.8	29.2	25.9	0.6122	31.6	32.5	9.3	0.7680	70.8	71.0	70.6	0.9962	69.1	70.6	69.1	0.9298

No statistical differences were observed in temperature at either depth throughout the season among treatments (Figure 2). After planting, tilled ground ran 0 to 4 ºF warmer from mid-April to June until the crop canopied. The tilled ground was about 1 ºF warmer than NT-CC and NT through the rest of the season.

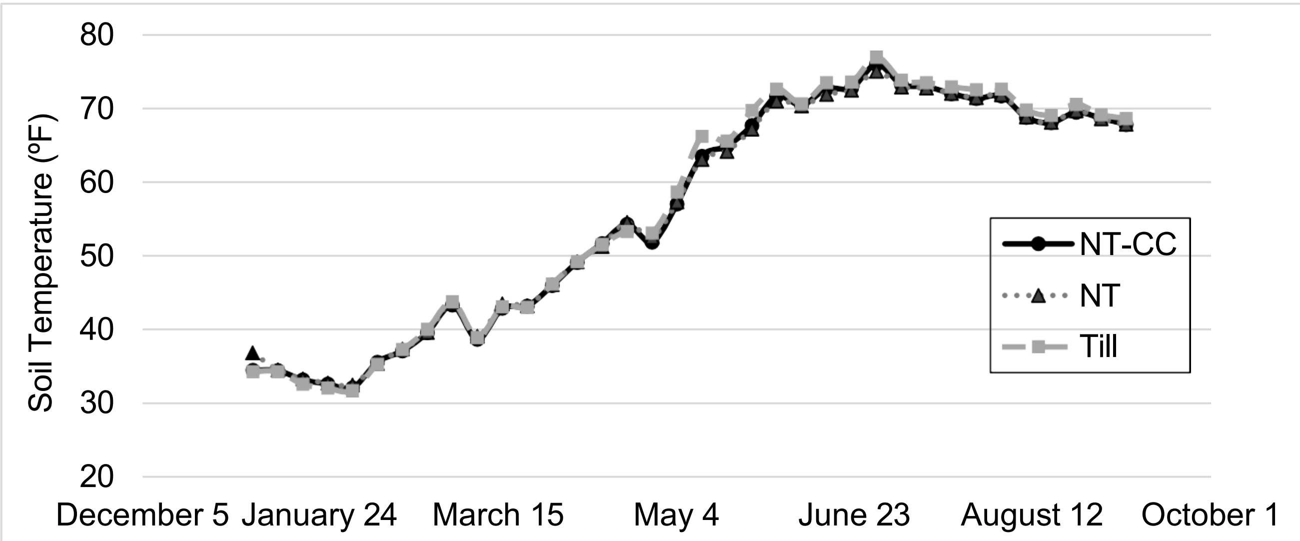

Figure 2. January through April soil temperature at 3-inch depth averaged across all sites and years by soil management type.

Tilled and NT-CC soil moisture at the 3-inch depth were similar from January through March and then in April, NT-CC started to have a higher moisture content (Figure 3). NT was generally wetter in February through April, then again in July and August. NT-CC had the highest soil moisture in June, on average, then aligned closely again with tilled until the end of August, where tilled soil moisture dropped off more quickly. Soil moisture at the 6-inch depth showed similar trends as the 3-inch depth, although changes were buffered by the soil profile (Figure 4).

During the summer months, NT-CC and NT on average retained more moisture than tilled fields, but there were some deviations, possibly due to weather differences across the sites. Overall, percent moisture across the treatments never differed more than 5 percentage points and no statistical differences were observed. The largest numerical spreads occurred in February, March, and September.

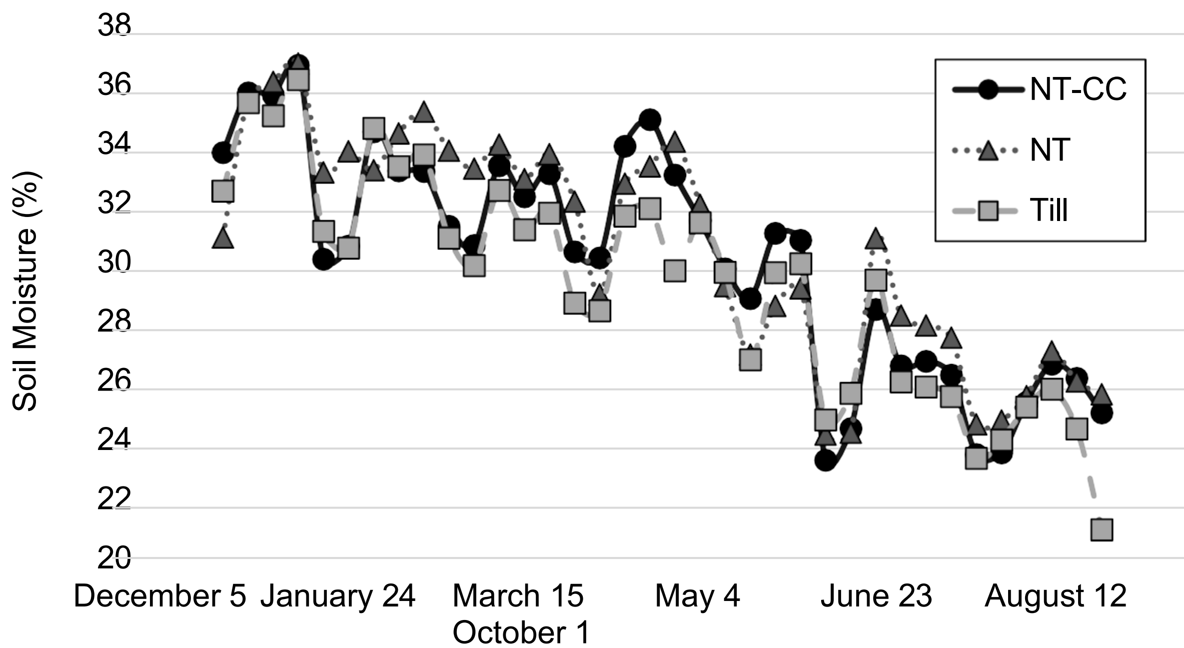

Figure 3. December through September soil moisture at 3-inch depth averaged across all sites and years by soil management type.

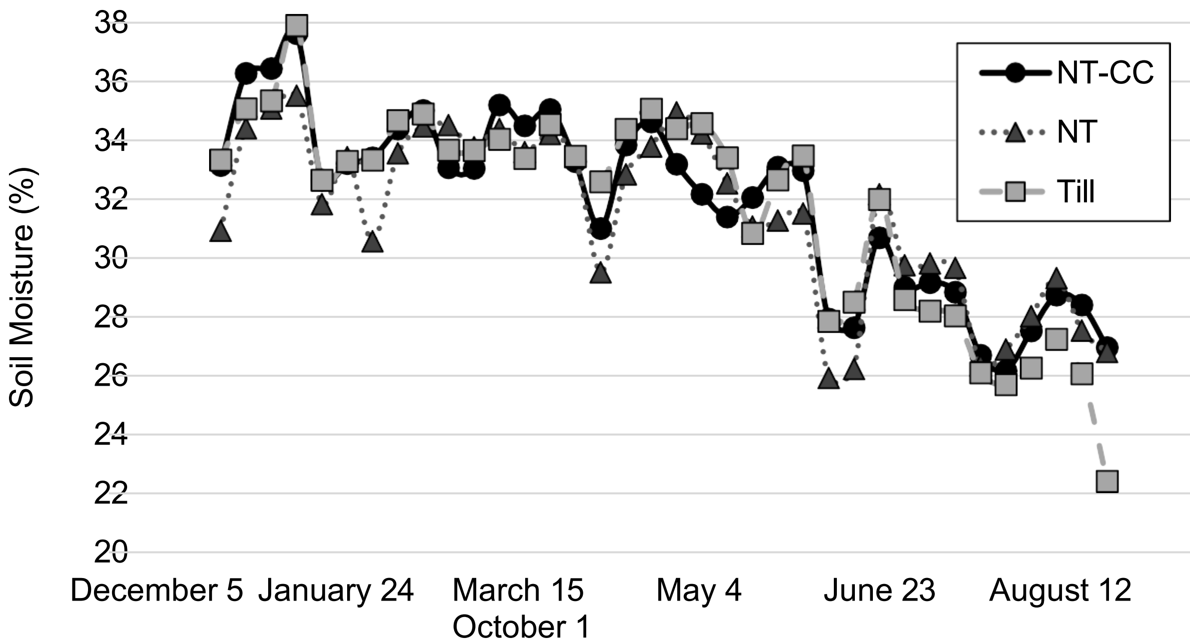

Figure 4. December through September soil moisture at 6-inch depth averaged across all sites and years by soil management type.

Conclusion

The results of this study did not provide evidence that there is a difference in soil moisture and temperature between no-till, no-till with cover crops and tilled. Although these results were not significant at 3- and 6-inch depths, there may be situations where surface conditions are different than measured levels. Farmers in this study did not experience any practical impact to their planned planting timeline because of their chosen soil management strategy. Annual variability in rainfall and temperatures will have a larger effect on planting suitability during spring than field-level soil management. It should be noted that this experiment is limited by the environmental conditions experienced during the study period. While we did observe minor numerical differences in soil moisture, they varied less than 5 percentage points during the planting window and no statistically significant differences were detected. Currently, little scientific data is available to accurately understand the practical implications of soil moisture differences. Whether a field is fit to plant at a specific moisture content depends on many factors including equipment size and the farmer’s willingness to take on risk. Differences in cover crop species and biomass accumulation at the time of termination could affect farmers’ experiences and present complications not observed during this study.

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