Tarping for the Future: Evaluating Soil Temperature and Soil Greenhouse Gas Fluxes Among Cover Crop Termination Methods for Organic Vegetable Crop Production

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Introduction

Expected warmer and wetter conditions across the upper Midwestern U.S. place farmers in need of applied research identifying sustainable agriculture solutions that are resilient to our changing climate. The method of tarping has emerged as a no-till solution for terminating cover crops, but applied research on this method is lacking. We investigated the influence of cover crop termination methods, including i) mowing & tilling, ii) mowing & tarping, iii) rolling & crimping, and iv) an un-terminated control on weed occurrence, soil health, and greenhouse gas fluxes. Specific objectives of this research include assessing the influence of these cover crop termination methods on soil temperature and greenhouse gas emissions.

Methods

- The soil type in our study area was Ruse-Ensign-Nykanen complex fine sandy loam. Prior to implementation of the treatments, a previously uncultivated field was roto-tilled and a oat and pea cover crop was drilled across the entire study area in May 2023 (Figure 1).
- A fully-randomized block design containing four replicates of the following alternative cover crop termination methods was subsequently established on July 19, 2023: i) Mow-Tarp, ii) Mow-Till, iii) Roll-Crimp, and iv) No-Term. No-term plots were each 12 x 36 (ft) and all other plots were 12 x 52 (ft).
- Soil temperature loggers were used to continuously monitor soil temperature (hourly-intervals) and field-portable trace gas analyzers (LI-7810 and LI-7820; LI-COR Environmental, Lincoln, NE, USA) were used to collect 2 soil carbon dioxide (CO_2) and nitrous oxide (N_2O) gas fluxes observations from each plot on 17 sampling event days (n = 8 per treatment per event) between July – November 2023.

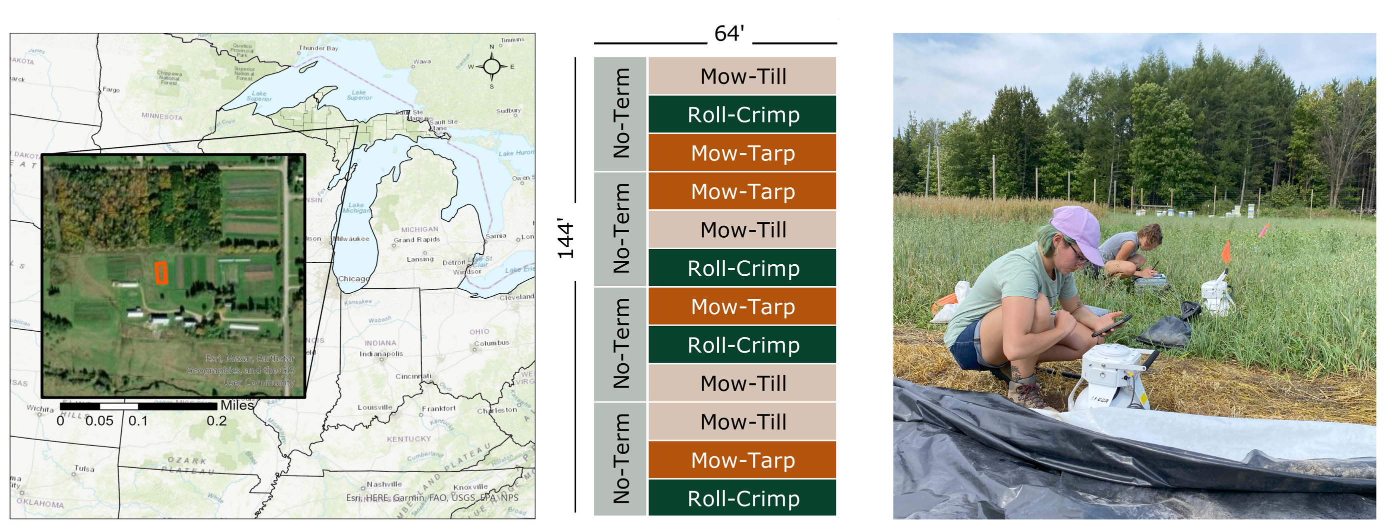

Figure 1. Michigan State University Upper Peninsula Research and Extension Center's MOSA Certified Organic North Farm is located in Chatham, MI (left), where an experimental study design was established (middle), and soil temperature, soil CO_2 flux and soil N_2O flux observations (right) were collected in each replicated treatment.

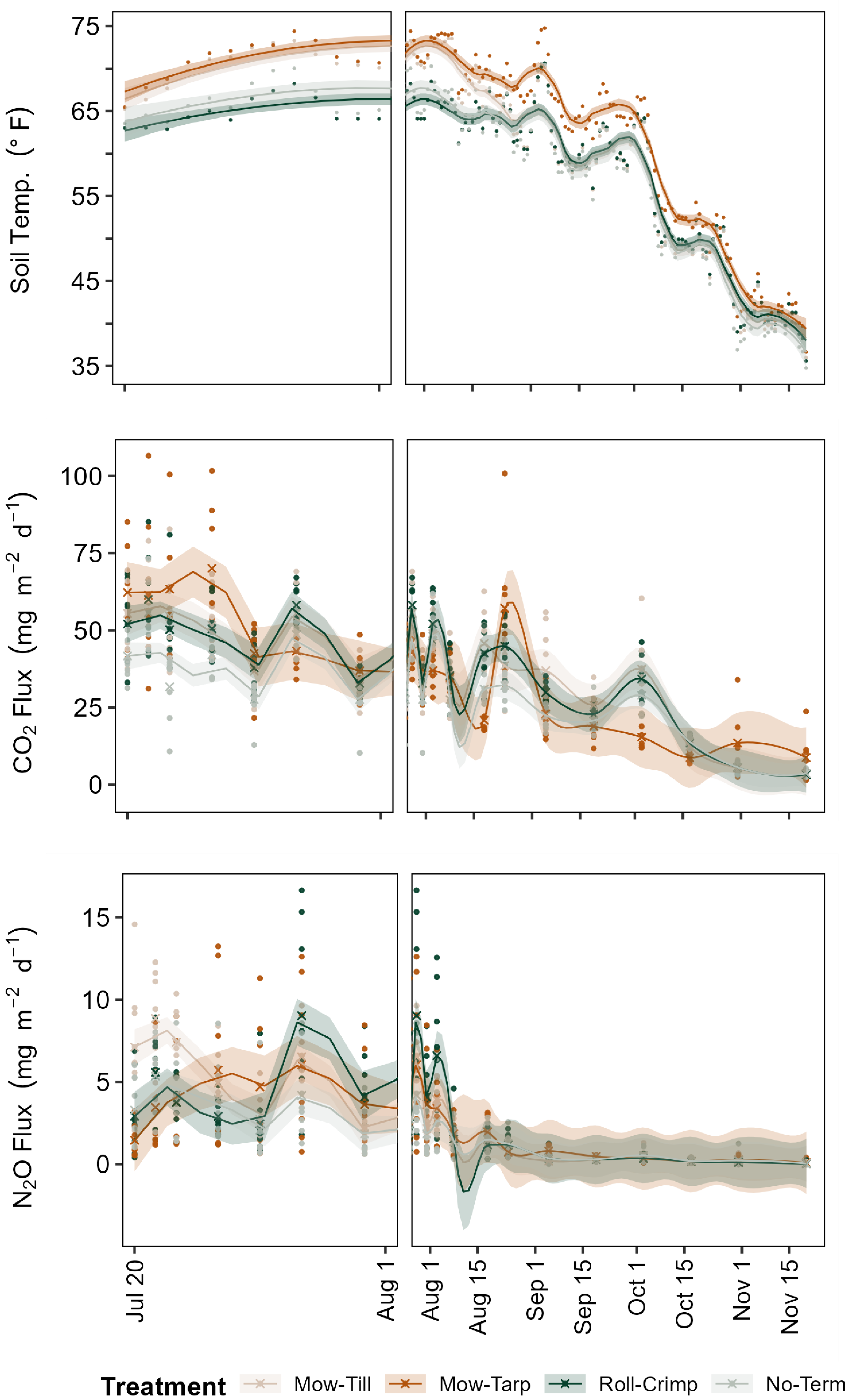

Figure 2. Daily mean soil temperature (top; °F), soil CO_2 flux (middle) and soil N_2O flux (bottom; mg m^{-2} d^{-1}) observations (points) collected in each treatment where lines and shaded ribbons were generated using local regression smoothing in R. The x-axis was expanded between Jul. 20 and Aug. 1 to improve interpretation during the first 12 days of the treatment period.

Table 1. Summary statistics including number of observations (n), mean (± standard error) for soil CO_2 fluxes (mg m^{-2} d^{-1}), soil N_2O fluxes (mg m^{-2} d^{-1}), and soil temperature (°F), and Kruskal-Wallis rank mean comparisons (Mean Test) for each treatment.

Treatment	n	CO_2	Mean Test	n	N_2O	Mean Test	n	Soil Temp.	Mean Test
Mow-Till	136	37.5 (± 1.7)	a	136	2.9 (± 0.3)	a	496	57.9 (± 0.5)	a
Mow-Tarp	136	42.2 (± 2.2)	a	136	4.3 (± 0.3)	a	496	60.7 (± 0.5)	b
Roll-Crimp	136	36.8 (± 1.6)	a	136	2.5 (± 0.3)	a	496	56.7 (± 0.4)	c
No-Term	136	30.0 (± 1.3)	b	136	2.0 (± 0.2)	a	372	56.3 (± 0.5)	c

Significant between-treatment mean differences are indicated by (a), (b) and (c) at p<0.05

Results

- Preliminary results show that the highest mean daily soil temperatures (60.7 °F) occurred in the Mow-Tarp treatment and were 2.7 and 3.9 (°F) warmer when compared to Mow-Till and Roll-Crimp mean daily soil temperatures, respectively (Table 1).
- The cover crop termination practices had no significant impact on mean N_2O fluxes (mg m^{-2} d^{-1}) when comparing among all treatments, however the 4.3 (mg m^{-2} d^{-1}) mean N_2O flux in Mow-Tarp was the largest mean detected among treatments, and was 148% and 172% larger than the Mow-Till and Roll-Crimp mean fluxes, respectively (Table 1).
- The 30.0 (mg m^{-2} d^{-1}) mean CO_2 flux occurrence detected in the No-Term treatment was significantly lower ($p<0.05$) when compared to all other treatments, and the 42.2 (mg m^{-2} d^{-1}) mean CO_2 flux in Mow-Tarp was the largest observed among treatments. However, mean CO_2 fluxes detected in the Mow-Till, and Mow-Tarp and Roll-Crimp were not significantly different when compared to each other.

Discussion

The mean daily Mow-Tarp soil temperatures were statistically warmest among all treatments, at least 5 °F warmer than all other treatments for 55 of the 124 (44%) days. However, soil temperatures in the Mow-Till and Mow-Tarp treatments were statistically similar during the first 3 weeks of the study period (Figure 2).

When only the effective Mow-Till, Mow-Tarp and Roll-Crimp termination treatments were considered, there were no significant differences detected among treatments for soil CO_2 nor soil N_2O fluxes, indicating that reduction of soil GHG emissions may not be a justifiable reason for selecting among these cover crop termination methods. However, our study did not consider lifecycle emissions from fuel, plastic, or other cover crop management materials.

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What the Tarp? Assessing Influence of Cover Crop Termination Practices on Soil Health and Fertility in Organic Vegetable Crop Production

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Introduction

Establishing and terminating cover crops is a common practice used by organic farmers to improve soil health and fertility, prevent soil erosion, and sustain the soil microbiome. A limited amount of research has focused on assessing the influence of a novel no-till cover crop termination method known as soil tarping on soil health and fertility. Our ongoing research project was directly informed by regional farmers' use of tarping as a tool for terminating cash or cover crops and controlling weeds without tillage. We investigated the effects of three different cover crop termination methods in a spring seeded oat-field pea mix including i) mowing & tilling, ii) mowing & tarping and iii) rolling & crimping on soil fertility and soil health parameters.

Methods

The soil type in our study area was Ruse-Ensign-Nykanen complex fine sandy loam. Prior to implementation of the treatments, a previously uncultivated field was roto-tilled and an oat and pea cover crop was drilled across the entire area in May 2023.

A fully-randomized block design containing four replicates of the following alternative cover crop termination methods was subsequently established on July 19, 2023 i) Mow-Till, ii) Mow-Tarp, and iii) Roll-Crimp. Plots were each 12 x 52 ft (Figure 1).

Aggregate soil samples were collected from each plot on 7/19/2023 and 8/7/2023 and sent to The Cornell Soil Health Laboratory where active carbon, Autoclave-Citrate Extractable Protein, total carbon, total nitrogen, and soil organic carbon parameters were tested.

The soil samples from each plot and treatment type were compared between pre- and post-treatment study periods. Linear mixed-effects models were used to estimate means for all soil health response variables where timing (as pre or post) and treatment were fixed-effects and plot was a random-effect. The Tukey method was used to for all pair-wise mean comparisons in R (Table 1).

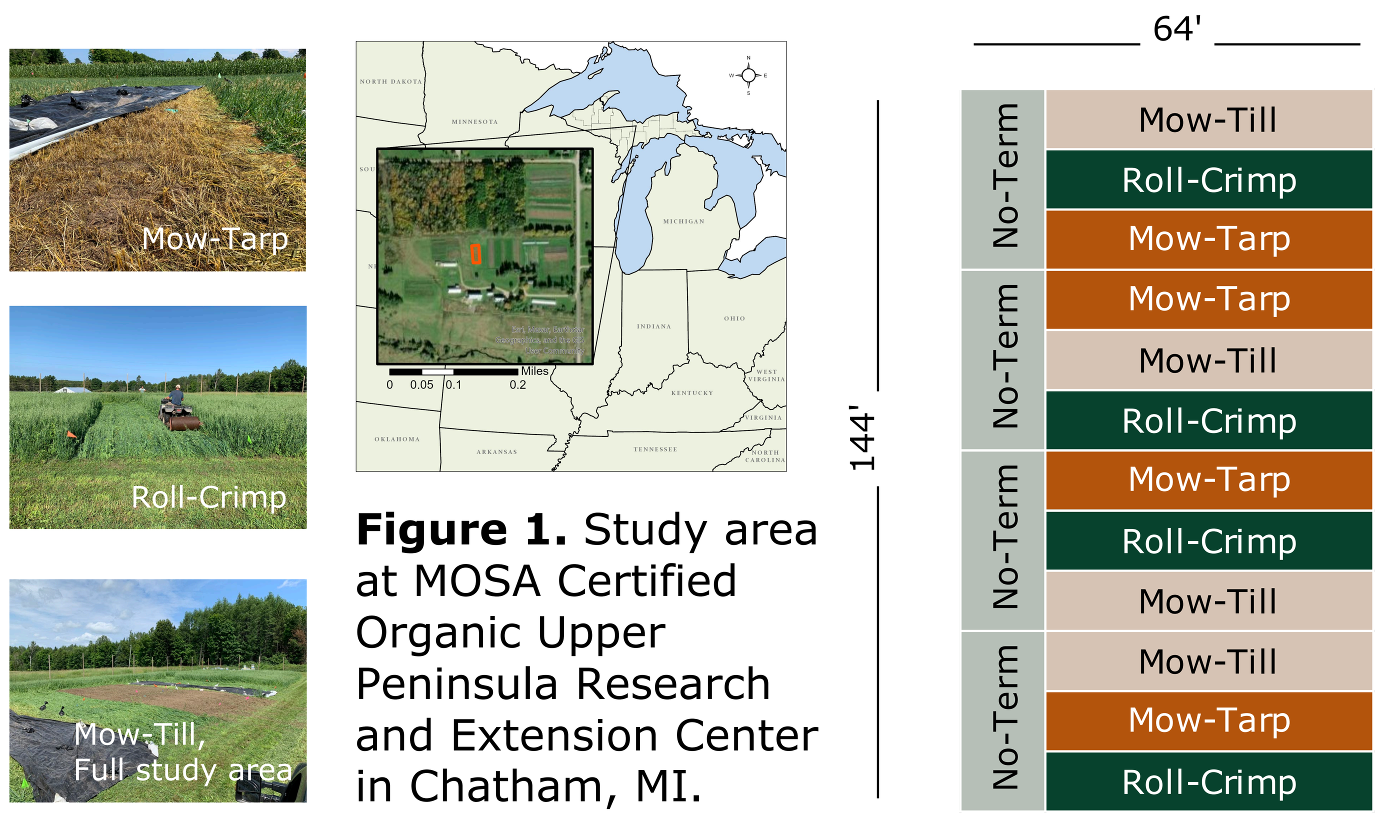

Figure 1. Study area at MOSA Certified Organic Upper Peninsula Research and Extension Center in Chatham, MI.

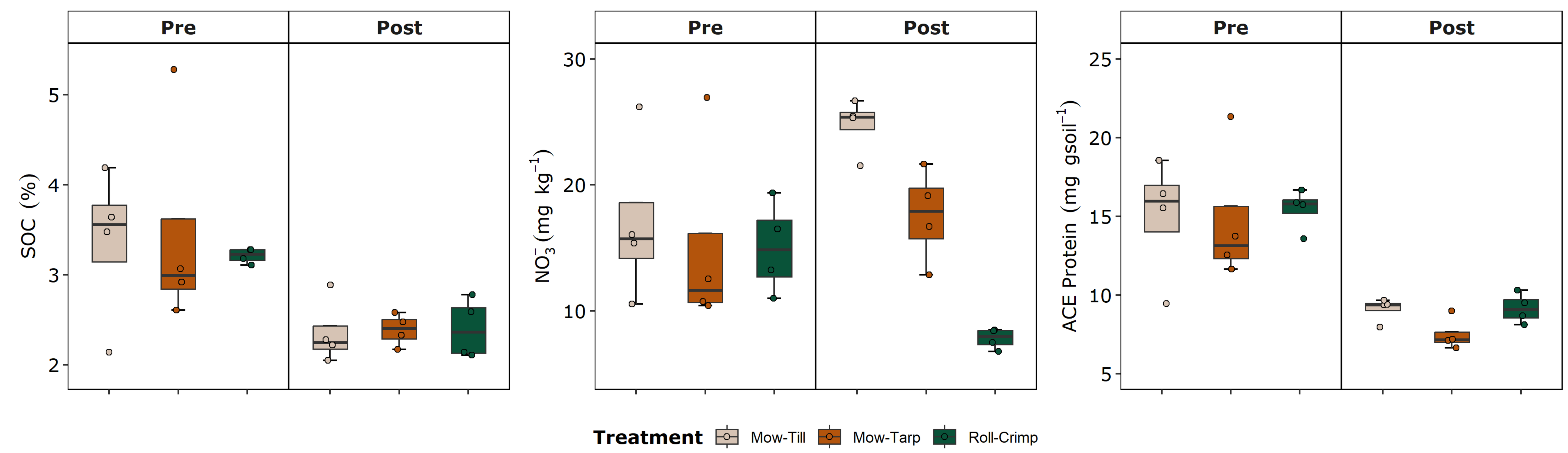

Figure 2. Soil organic carbon (SOC; left) , soil nitrate (NO_3^-; middle), and Autoclave-Citrate Extractable Protein (ACE Protein; right) observations (points) for each treatment during pre- and post-treatment study period. Boxplot lines represent median, 25%, and 75% quartiles, while whiskers represent quartiles ± 1.5 · interquartile range.

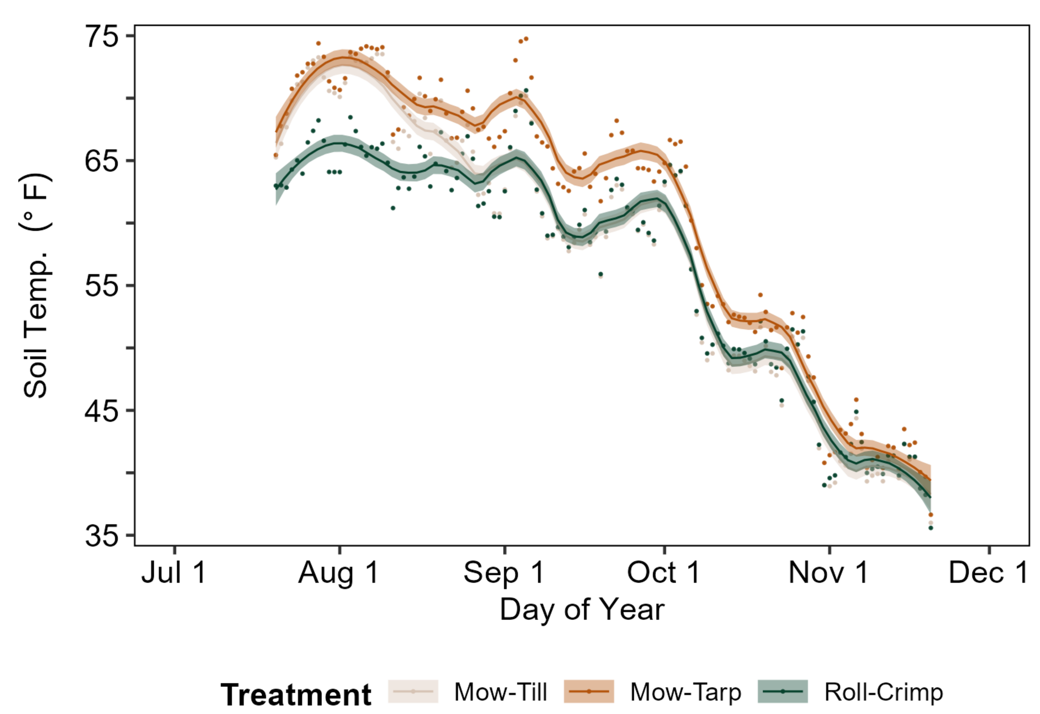

Figure 3. Mean daily soil temperature (°F) observations for each treatment throughout the study period.

Table 1. Soil sample summary, including number of observation (n), mean (± standard error) for nitrate (NO_3^-; mg kg^{-1}), inorganic nitrogen (IN; $NO_3^- + NH_4^+$; mg kg^{-1}), soil organic carbon (SOC; %), and ACE Protein (mg g^{-1}) during the pre- and post-treatment study period.

Timing	Treatment	n	NO_3^-	MCT NO_3^-	IN	MCT IN	SOC	MCT SOC	Protein	MCT Protein
Pre	Mow-Till	4	17.0 (±3.29)	a	23.3 (±3.47)	a	3.36 (±0.43)	a	14.99 (±1.95)	a
	Mow-Tarp	4	15.2 (±3.95)	a	21.6 (±4.44)	a	3.47 (±0.61)	a	14.81 (±2.21)	a
	Roll-Crimp	4	15.0 (±1.83)	a	21.1 (±2.07)	a	3.21 (±0.04)	a	15.46 (±0.66)	a
Post	Mow-Till	4	24.7 (±1.12)	b	30.3 (±1.26)	b	2.36 (±0.18)	a^w	9.11 (±0.38)	a^w
	Mow-Tarp	4	17.6 (±1.88)	b	23.1 (±2.03)	b	2.39 (±0.09)	a^w	7.50 (±0.51)	a^w
	Roll-Crimp	4	7.80 (±0.41)	a^w	13.4 (±0.34)	a^w	2.40 (±0.17)	a	9.16 (±0.48)	a^w

Significant between-treatment mean differences are indicated by (a) and (b), where within-treatment mean differences indicated by (^{w}) at p<0.1.

Results

NO_3^- moderately significantly ($p<0.1$) increased by 8.66 (mg kg^{-1}) in Mow-Till plots, whereas NO_3^- significantly ($p<0.05$) decreased by 6.96 (mg kg^{-1}) in Roll-Crimp plots in post- compared to the pre-treatment timing (Figure 2; Table 1).

Soil organic carbon (SOC) moderately significantly decreased ($p<0.1$) by 0.333 (%) and 0.335 (%) in the mow-till and Mow-Tarp treatments when the post- was compared to the pre-treatment timing, respectively. However no significant SOC difference was detected between the post- and pre-treatment periods within the Roll-Crimp plots (Table 1).

The 7.31 (mg g^{-1}) mean ACE Protein level decrease detected in Mow-Tarp was the greatest within treatment comparison among all termination methods, however ACE Protein levels were significantly lower in all treatments during the post-treatment period when compare to pre-treatment (Table 1).

Discussion

Soil NO_3^- levels were moderately significantly greater ($p<0.1$) in the Mow-Till and significantly lower ($p<0.05$) in the Roll-Crimp when the post-treatment study period was compared to pre-treatment indicating that additions of cover crop nitrogen residues were rapidly converted to inorganic nitrogen within the first three weeks following termination. Whereas inorganic forms of nitrogen were likely scavenged by microbes and/or taken up by vegetative regrowth during the first three weeks following the Roll-Crimp termination.

Mow-Till and Mow-Tarp SOC levels were moderately significantly lower ($p<0.1$) during the post-treatment study period when compared to pre-treatment indicating more soil carbon was mineralized or decomposed during the first three weeks following termination when compared to the Roll-Crimp. These findings are consistent with the mean daily soil temperatures which were 5.6 (°F) and 6.4 (°F) warmer in the Mow-Till and Mow-Tarp when compared to the Roll-Crimp during the first three weeks following termination (Figure 3).

To Tarp or Not to Tarp? Evaluating Effectiveness of Cover Crop Termination Methods and Weed Management Outcomes for Organic Vegetable Crop Production in the U.S. Midwest

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Introduction

This study was initiated in response to regional farmers' use of soil tarping as a termination tool for cash or cover crops without tillage. This research focuses on four termination treatments i) mowing & tilling, ii) mowing & tarping, iii) rolling & crimping, and iv) an un-terminated control in a spring-seeded oat-pea field mix. The aim is to assess the influence of these treatments on weed suppression, aboveground plant biomass, soil health, and ultimately on climate change resilience.

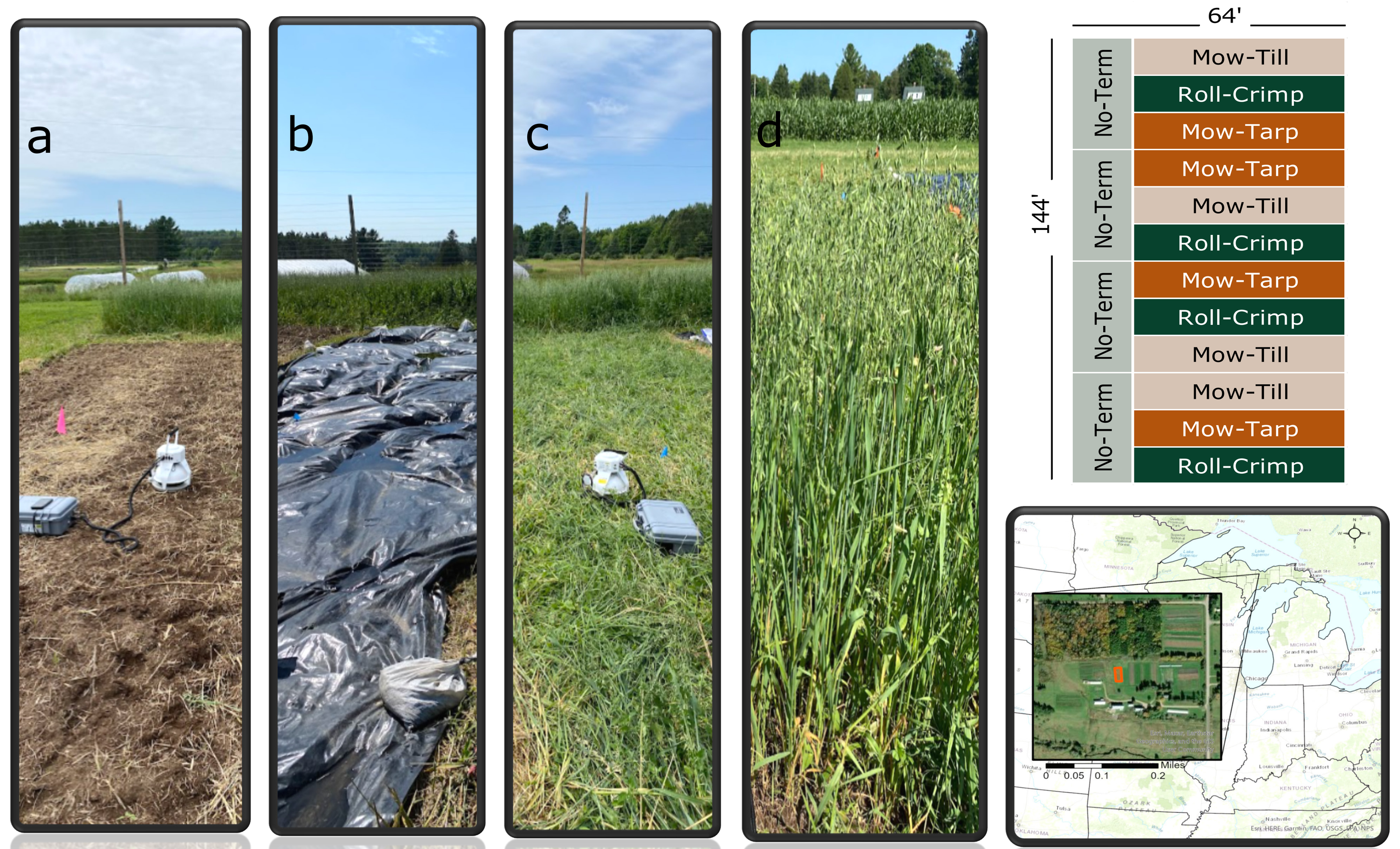

Figure 1. Four treatments were compared at the MOSA certified organic Michigan State University Upper Peninsula Research and Extension Center North Farm in Chatham, MI, including Mow-Till (a), Mow-Tarp (b), Roll-Crimp (c), and no-termination (d).

Methods

Prior to implementation of the treatments, a previously uncultivated field was roto-tilled and a oat-pea cover crop was drilled across the entire area consisting of a Ruse-Ensign-Nykanen fine sandy loam complex in May 2023.

- A total of sixteen plots were established on July 19, 2023 using a fully randomized block design containing four replicates of each treatment including methods i) Mow-Till, ii) Mow-Tarp, iii) Roll-Crimp, and iv) No-Term where the No-termination plots 12′(W) x 36′ (L) were perpendicular to the other 12′(W) x 52′(L) plots (Figure 1).
- Biomass sampling consisted of 3 random 1 ft^2 quadrants samples (see Figure 2.) per treatment plot collected 10 weeks post-termination to determine cover crop and weed biomass. Biomass included all above ground plant material, both living and dead (Figure 3).

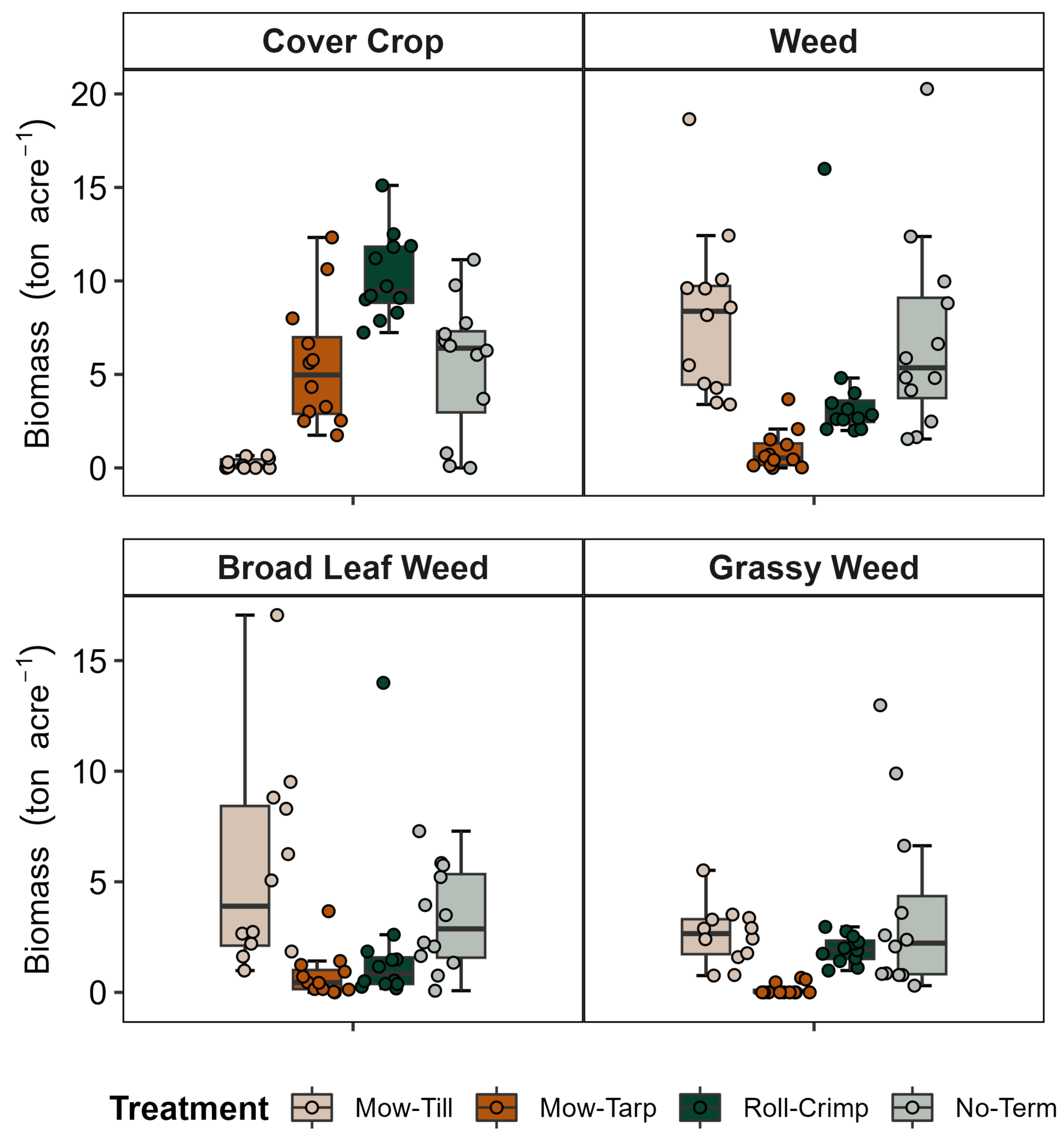

Figure 2. Aboveground dry matter biomass observations (points; tons acre^{-1}) for all treatments plots where plant type was separated into Cover Crop (top-left) and Weed (top-right), and where weed type was further separated to compare Broad Leaf Weed (Bottom left) with Grassy Weed (bottom right) biomass. . Boxplot lines represent median, 25%, and 75% quartiles, while whiskers represent quartiles ± 1.5 · interquartile range.

Table 1. Summary statistics, including number of observations (n), mean biomass (± standard error), and Tukey honest significant difference comparisons (Mean Test) for each plant type (cover crop and weed), and treatment. Linear mixed-effects models were used to estimate mean biomass where plant type (as Cover Crop or Weed) and treatment were fixed-effects and plot was a random-effect. The Tukey method was used to for all pair-wise mean comparisons in R.

Plant Type	Treatment	n	Biomass (tons acre^{-1})	Mean Test
Cover Crop	Mow-Till	10	0.2 (± 0.1)	a
	Mow-Tarp	12	5.5 (± 1.0)	b
	Roll-Crimp	12	10.2 (± 0.7)	c
	No-Term	12	5.5 (± 1.1)	b
Weed	Mow-Till	12	8.2 (± 1.3)	a
	Mow-Tarp	12	0.9 (± 0.3)	b
	Roll-Crimp	12	4.0 (± 1.1)	c
	No-Term	12	7.0 (± 1.5)	ac

Significant between-treatment mean differences are indicated by (a), (b) and (c) at $p < 0.05$.

Results

Preliminary results showed numerous significant differences among treatments for both weed and cover crop biomass (Table 1 and Figure 2).

- The 8.2 (tons acre^{-1}) mean weed biomass detected in Mow-Till was significantly higher when compared to the 4.0 and 0.9 (tons acre^{-1}) means detected in Roll-Crimp and Mow-Tarp, respectively.
- The 0.2 (tons acre^{-1}) mean cover-crop biomass in the Mow-Till was significantly lower when compared to the 5.5, 10.2, and (tons acre^{-1}) means detected in Mow-Tarp, Roll-Crimp and No-Term, respectively.
- The 7.0 (tons acre^{-1}) mean weed biomass detected in No-Term was not significantly different than the 8.2 and 4.0 (tons acre^{-1}) means detected in the Mow-Till and Roll-Crimp treatments, respectively
- Cover crop biomass in the Roll-crimp and Mow-tarp treatments consisted of primarily dead or non-viable plants

Figure 3. Methods used for biomass sampling included 1 ft^2 metal quadrants, where hand cut and sorted samples were collected in paper bags, and subsequently placed in a drying oven prior to mass determination using a digital balance.

Discussion

Preliminary results show a variety of responses to cover crop termination treatments in terms of cover crop persistence, regrowth and/or weed growth.

The Mow-Till method, was effective in terminating cover crops, but resulted in higher weed biomass compared to other termination treatments. The Mow-till treatment showed significantly lower cover crop biomass, suggesting potential challenges in cover crop regeneration.

This research highlights the need for further research to refine cover crop termination methods for sustainably control weeds and regrowth of cover crops. This ongoing study aims to provide actionable practices for regional farmers, contributing to adaptive solutions in organic vegetable production amid climate change- induced challenges.