Tillage Effects on Temporal Dynamics of Soil Microbial Community and Physiochemical Properties in North Dakota

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1. Introduction

In the Upper Great Plains region, cold soils impede early germination for corn and soybean systems creating a natural short growing season. Before planting, farmers typically utilize intensive tillage to aerate/warm the soil for earlier planting and germination. Although tillage may extend the growing season, intensive tillage practices can be detrimental to soil health. Currently, new reduced tillage systems are being implemented to both extend growing season while minimizing the adverse effects of intensive tillage on soil health. This on-farm study aims to evaluate the effects of various reduced tillage practices on the temporal dynamics of soil biota and physiochemical properties coupled with soil physical conditions within the growing season of a northern corn-soybean-wheat rotation with particular emphasis on natural soil wetting and drying cycles. Reduced tillage systems in this study include vertical till (VT), and chisel plow (CP). Tillage plots (12 x 550m per plot) were installed near Moorton, ND in 2015 using randomized complete block designs with three replicates on site. Soil of the research area consists of a smectitic silty clay with high shrink-swell capacity.

2. Methods

Sampling Procedure:
Soil samples were collected twice weekly from the quarterly row position to a depth of 15 cm depth. Microbial samples were kept at -15 ^{o}C for a max of two weeks before being freeze dried for PLFA analysis, while enzyme samples were stored at -4 ^{o}C until analyzed. Remaining soil was air dried and ground for physiochemical analyses.

In-Situ Soil Conditions:
Soil temperature and moisture were measured at 5, 10, 15, and 20 cm depths at 30 minute intervals using Decagon 5TM sensors deployed with EM50G data loggers in each treatment replication.

Microbial Analysis:
Soil microbial community structure and variation were assessed using a PLFA completed by Microbial ID in Delaware, USA.

Enzyme Analysis:
Soil enzymes activities including β-Glucosidase, Ammonium Oxidation, and Nitrate Reductase will be measured. Due to lab time constraints, selected sampling dates based on environmental shifts will be analyzed for enzyme activity variations first.

Soil samples will undergo a set of chemical and physical analyses.
Chemical Properties:
- pH and EC (1:1 suspension)
- Total Nitrogen (Vario Macro Cube CHNOS analyzer)
- Nitrate – NO_3^- (Trans-nitration of salicylic acid)
- Ammonium – NH_4^+ (Berthelot Reaction/ Indophenol Reaction)
- Total Organic Carbon (Primacs^{SLC} TOC analyzer)
- Extractable Manganese (DPTA .033 M H_3PO_4 extraction)
- Extractable Sulfur (Monocalcium phosphate extraction)
- Phosphorus (Olsen method)

Physical Properties:
- Particle Size Distribution, Bulk and Particle Densities
- Water Retention Curves with van Genuchten parameters
- Modeled Thermal Conductivities, Diffusivities, Heat Phase Shifts and Ground Heat Fluxes over time
- Modeled Gas permeabilities and diffusivites over time

Statistical Analyses will include temporal autocorrelations, spectral and cospectral analysis for repeated cycling and temporal lags, and a mixed model ANOVA with Turkey's HSD at 0.05 level. Static physical properties will be used as spatial covariates. All statistics will be performed in SAS 9.4.

3.1. Results

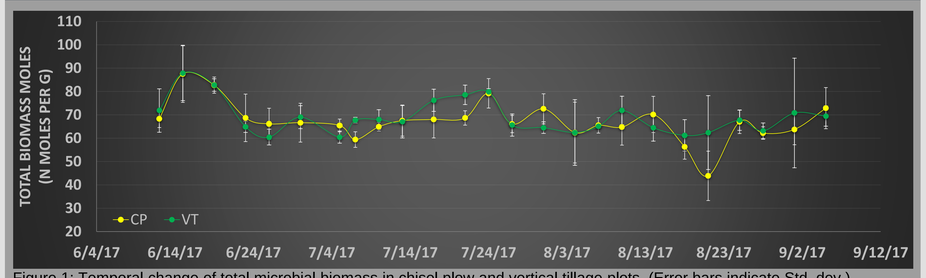


Figure 1: Temporal change of total microbial biomass in chisel plow and vertical tillage plots. (Error bars indicate Std. dev.)

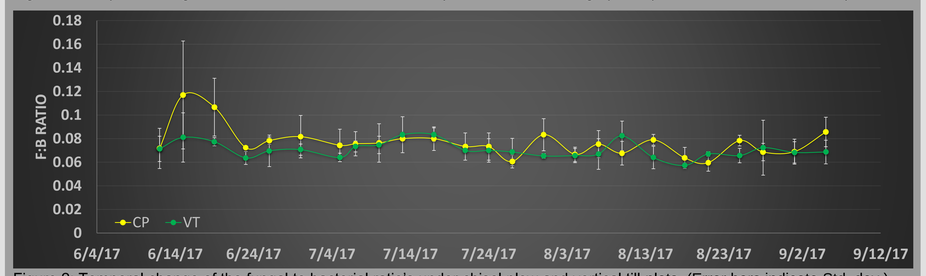


Figure 2: Temporal change of the fungal to bacterial ratio's under chisel plow and vertical till plots. (Error bars indicate Std. dev.)

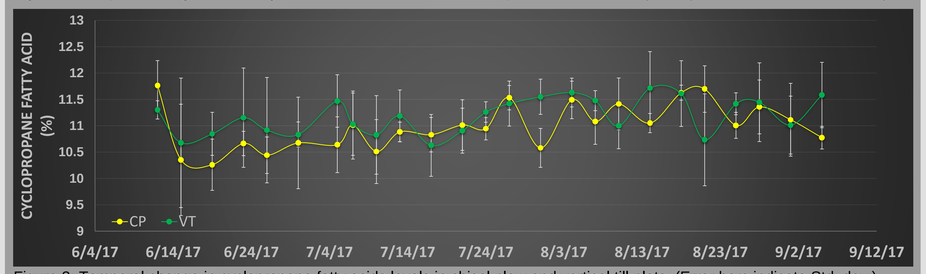


Figure 3: Temporal change in cyclopropane fatty acids levels in chisel plow and vertical till plots. (Error bars indicate Std. dev.)

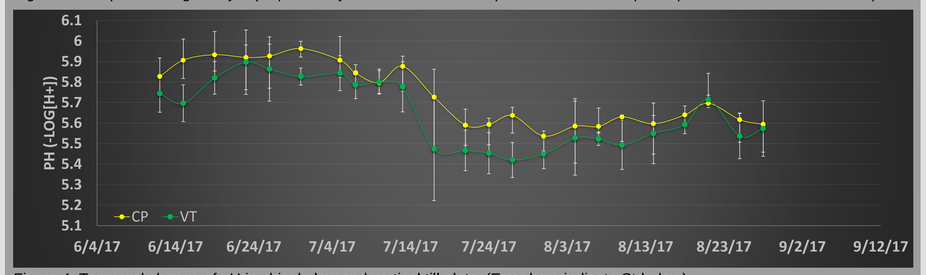


Figure 4: Temporal change of pH in chisel plow and vertical till plots. (Error bars indicate Std. dev.)

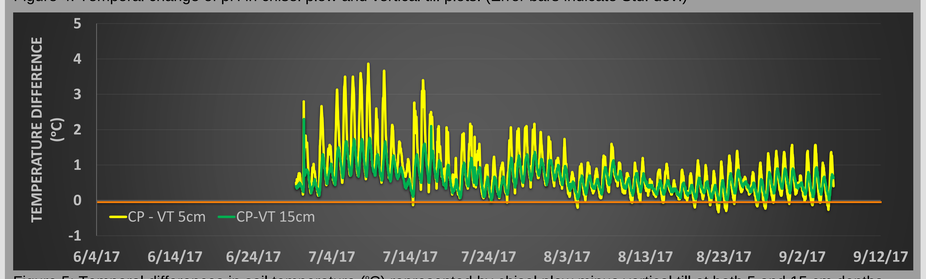


Figure 5: Temporal differences in soil temperature (°C) represented by chisel plow minus vertical till at both 5 and 15 cm depths.

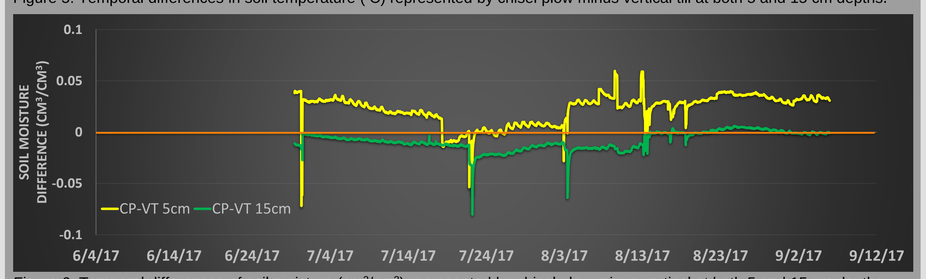
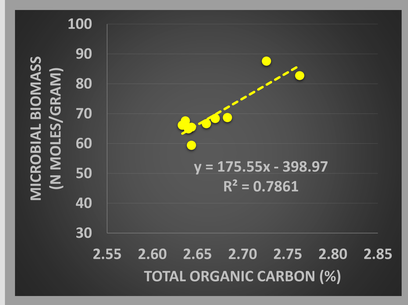


Figure 6: Temporal differences of soil moisture (cm^3/cm^3) represented by chisel plow minus vertical at both 5 and 15 cm depths.

3.2. Results



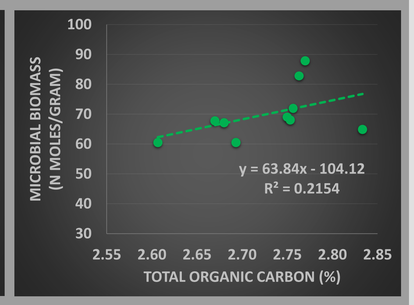


Figure 7 & 8: Regression analysis of total microbial biomass vs. total organic carbon in chisel plow (left) and vertical till (right).

Table 1: Regression analysis preformed on a range of microbial and physiochemical properties to estimate relationships among compared variables at a 95% confidence interval.

Tillage	Source of Analysis	r^2	P-Value
Chisel Plow	Total Biomass vs. pH	0.05	0.33
Vertical Till		0.01	0.59
Chisel Plow	F:B Ratio vs. pH	***0.21***	***0.03***
Vertical Till		0.00	0.79
Chisel Plow	Total Biomass vs. Total Organic Carbon	***0.79***	***<0.01***
Vertical Till		0.22	0.18
Chisel Plow	F:B Ratio vs. Total Organic Carbon	***0.66***	***<0.01***
Vertical Till		0.01	0.80
Chisel Plow	Total Biomass vs. Manganese	0.19	0.07
Vertical Till		***0.27***	***0.02***
Chisel Plow	F:B Ratio vs. Manganese	***0.39***	***<0.01***
Vertical Till		0.13	0.13
Chisel Plow	Total Biomass vs. Ammonium	0.15	0.10
Vertical Till		0.00	0.98
Chisel Plow	F:B Ratio vs. Ammonium	***0.25***	***0.03***
Vertical Till		0.01	0.63
Chisel Plow	Total Biomass vs. Cyclopropanes	***0.23***	***0.04***
Vertical Till		***0.37***	***0.01***
Chisel Plow	F:B Ratio vs. Cyclopropanes	***0.49***	***<0.01***
Vertical Till		***0.49***	***<0.01***

4. Discussion

- Microbial communities and their ratios do not appear to vary substantially over time or among the two tillage systems (Fig.1-2).
- Some indications in the raw data appear to suggest periods of stationary composition followed by periods of fluctuating composition with or without time lags between tillage treatment.
- In-situ soil sensors revealed chisel plow created warmer seed beds to a 15 cm depth than vertical tillage (Fig. 5). However, chisel plow tended to be wetter near the soil surface and vertical tillage wetter at the 15 cm depth (Fig.6).
- Microbial composition had a range of weak to strong relationships with physiochemical properties. Chisel plowed plots had a higher tendency for strong relationships with variables as compared to vertical tillage (Table 1).
- Plausible causes for weak relationships observed in vertical tillage plots may be due to more soil stratification within the undisturbed seed bed, as compared to the more homogenously mixed seed bed in the chisel plow plots.
- A noted change in pH was observed around the beginning of the R1 stage of the soybeans (Fig.4).
- Future analyzes will include temporal autocorrelations, spectral and cospectral analysis for repeated cycling and temporal lags of microbial compositions and enzyme activities with environmental and soil physiochemical variables.

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