# SOIL COMPACTION: IMPACT OF TRACTOR AND EQUIPMENT ON CORN GROWTH, DEVELOPMENT AND YIELD

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## ABSTRACT

Past research indicates that soil compaction affects crop growth and grain yield. As the size and weight of agricultural equipment have increased significantly in the past few decades, the severity and depth of compacted zone may have increased proportionately. Very few studies have been conducted in North Dakota to understand soil compaction under the current machinery, and its effect on crop growth and yield. The research described here was conducted on a no-till corn field at Jamestown in North Dakota in 2013. Five transects were identified on study area representing the five different soil types. The study area was divided into three strips along the row to replicate data collection so as to account for field variability. Field data were collected from the most trafficked and least trafficked rows within each 5 transect× 3 replication combination based on machine traffic pattern. Data collected included soil compaction, soil bulk density, soil moisture content, plant emergence, plant height and grain yield. The early plant emergence data showed significant difference between the trafficked and non- trafficked rows. This might be due to the fact that moderate surface compaction favoured the seed to be in better contact with the soil particles and aided in better germination.The plant height measured didn’t show any significant difference between the transects. The yield data showed significant difference between the transects and no difference was observed between trafficked and non- trafficked rows . It is important to note that the study field was a no-till field for more than 10 years. Collecting subsequent years of data will help to know the effects of soil compaction on crop, and impact of weather cycle on soil compaction. Future plan involves analyzing the effect of winter freeze-thaw cycle on soil compaction as well as studying soil compaction in conventionally tilled and no-till fields.

**Keywords:** Soil compaction, Cone Index, Corn

## INTRODUCTION AND BACKGROUND

Corn production plays an important role to the nation’s economy. Corn acreage has been expanding at a fast rate in North Dakota in the last few years due to higher crop commodity prices, short season varieties available, and the slightly longer crop season in North Dakota. The center for agricultural policy and trade studies at North Dakota State University (Richard and Won, 2013) reported that the corn planted acreage in the state have grown by 148 percent during the past 10 years. According to National Agricultural Statistics Service (USDA, 2013), corn acreage in US is estimated at 39.4 million hectares in 2013 with a slight increase from last year. The US ranks first in corn production with approximately 20 percent of the corn crop exported to other countries (USDA, 2013). The total contribution of corn production to ND State's economy varied between $626 million in 2009 and $ 2.89 billion in 2012 (Richard and Won, 2013). Therefore, knowing the potential problems involved in corn cultivation and finding ways to improve the production would certainly benefit the corn growers.

Soil compaction is considered as an important issue in modern agriculture. The heavier equipment used today for different agricultural practices has the potential to increase the severity of compaction problems. The annual freeze-thaw cycle can alleviate soil compaction up to a depth of 20 cm (Jabro et al., 2012). Preliminary observations indicate that today's equipment has the potential to compact soil down to 4 feet (personal communications with Jody DeJong Hughes, University of Minnesota). Voorhees (1983) reported that soil compaction was not removed at the bottom of the plow furrow in Nicollet silty clay loam soil in Minnesota by the annual freeze-thaw cycle. Soil compaction causes change in soil structure that can vary spatially with respect to the position of tracks and tires on agricultural equipments. Bulk density of the soil and soil strength was higher in the plant row with wheel traffic compared to no wheel traffic (Kaspar et al., 1995).

Soil compaction can reduce corn and soybean yields significantly (Lowery and Schuler, 1994; Ngunjiri and Siemens, 1995; Bicki and Siemens, 1991). The yield reduction were approximately 2.8 Mg/ha in compacted corn fields. These three studies compacted the field artificially using different compacting loads. However, a study by Gelder et al. (2007) analyzing soil compaction by wheel traffic showed that compaction had no effect on grain yield, and plant emergence.

Very little research has been conducted in North Dakota related to soil compaction and its effects on yield. This paper investigates the effects of soil compaction on corn growth and yield in a no-till field. The study also provides information about whether the heavy machinery traffic in the field has an impact on soil properties, plant emergence, plant height and final yield.

## MATERIALS AND METHODS

### Study area

The study was conducted in a corn field at Jamestown in North Dakota in 2013 crop season. The study area of the field included 12.06 ha, and was divided into three strip plots running the entire length of the field along the direction of the rows. The study area had five different soil types. Five transects were identified, each one representing a specific soil type, running across the strip plots for data collection (Figure 1). The study area had 0-9% slope, and elevations ranging from 461 m to 464 m. The field was planted with corn variety CROPLAN 229VT2PRO at a planting rate of 82,800 seeds per hectare on May11, 2013.

The machine traffic in the field was considered to identify the most trafficked and least trafficked rows within each strip plot. The wheel traffic considered, included tractor dual tires, air cart tires and planter tires as indicated in Figure 2. Based on the vehicle traffic observed, row 6 and 11 were identified as potentially most trafficked, and row 4 and 13 as potentially least trafficked rows.


**Figure 1. Layout of study field overlaid on an aerial image. The strip plots run along the length of the field, along with the five transects identified for data collection.**

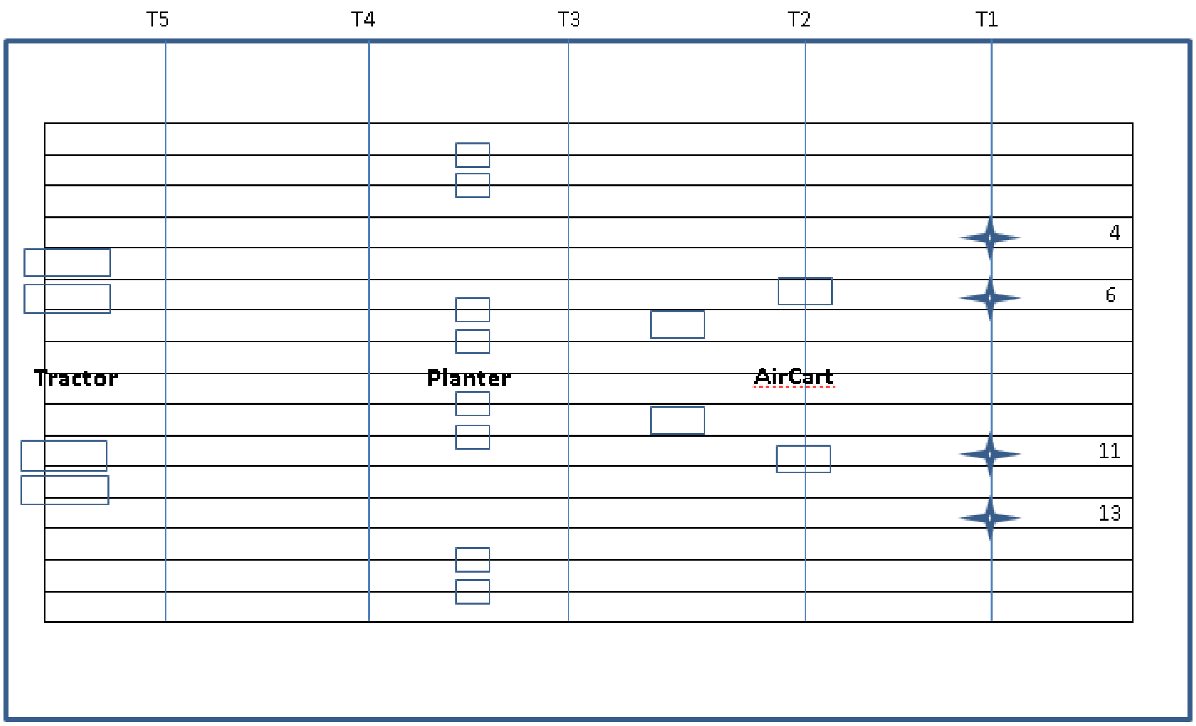


**Figure 2. Layout of field showing vehicle traffic. The polygons indicate wheels, and the horizontal lines indicate rows. The vertical lines are transects, with T1 through T5 indicating different soil types.**

**Data collection**

A hand-held penetrometer was used to measure the soil resistance through cone index (CI). Cone Index is a measure of soil resistance and the degree of compaction. The soil compaction measurement was taken after planting on May 15, 2013 identifying the vehicle traffic in the study area.

The soil sample cores from 0-18 cm were collected using a soil auger to measure moisture content and bulk density. Moisture content was measured using gravimetric method. Plant emergence count data were collected along each transect from each strip plot on 12 and 16 days after planting (DAP). A 7.5 m section was chosen along the rows of each transect and plant emergence was counted. The plant height was measured at tasselling stage (92 DAP) along the rows of 7.5m section in each transect to evaluate the impact of compaction. The height of the corn plant was measured from the soil surface to the arch of uppermost leaf that was partially emerged from the whorl of the plant.

The yield data were collected using a hand-harvesting method along each transects. A 3m section was selected along the rows of each transect to collect the cobs. Two rows in trafficked and non-trafficked zone was chosen in each replicate along each transect. Therefore, a total of 6 trafficked and 6 non-traffciked rows were chosen for the data collection in each transect. The cobs collected in each row was weighed using a digital scale and labeled. The 5 cobs representative of trafficked and non- trafficked rows in each replicate along each transect were selected to determine the mositure content based on ASABE standard for moisture determination. Then, the cobs weight were optimized for 15 percent moisture content and the finalweight was calculated, and converted to yield.

Statistical analysis was performed on the collected data using a statistical software SAS, version 9.3. Analysis of variance (ANOVA) was performed to analyze plant emergence, plant height and grain yield response to compaction by wheel traffic. The Duncan's test was used to compare treatment means.

## RESULTS AND DISCUSSION

### Soil compaction

The soil penetrometer reading indicate that the CI values follow a similar pattern for different trasnsects up to 37.5 cm depth, and followed by a sharp increase (Figure 3). In general, the average CI readings for the fiver soil types varied from 1.31 to 1.82 MPa in the study area with an average of 1.51 MPa. Due to the limitation of the cone penetrometer, soil compaction was measured only up to 48 cm depth. These limited data still show that soil compaction increases sharply after 40 cm depth in all soil types. The cone index profile of this study area agrees well with the findings reported by Varsa et al. (1997) in which the CI profile was greater in subsoils (40 to 100 cm depth) with an average of 2.5 MPa for silt loam soils. A comparison of compaction levels at the trafficked (T) and non- trafficked (NT) rows indicated significant differences in some of the transects at the top soil (0-10 cm) and as well as subsoils (40 – 45 cm) (Figure 3). The average CI for the most trafficked areas varied from 1.06 MPa at 5 cm depth to 2.28 MPa at 45 cm depth, while the average CI reading for the least trafficked rows varied from 1.00 MPa at 5 cm depth to 2.09 MPa at 45 cm depth.

### Plant emergence

Plant emergence at 12 DAP varied from 1 to 6 plants/area, with the average being 5 plants/area for Trafficked rows and 2 plants/area for Non-Trafficked rows. Plant emergence at 16 DAP varied from 16 to 26 plants/area with an average of 22 plants/area for Trafficked rows and 21 plants/area for Non-Trafficked rows. A comparison of plant emergence data at 12 DAP showed significant difference between trafficked and non-Trafficked rows (Figure 4a). It is clear from the figure that the plant emergence count on trafficked rows were on average 150% higher than the non- trafficked rows in all soil types. This might be due to the fact that moderate compaction favoured better seed contact with the soil particles and aided in better germination. The plant counts from 16 DAP showed no significant difference between trafficked and non- trafficked rows and also between the transects (Figure 4b). The lack of difference in plant emergence between trafficked and non- trafficked rows at 16 DAP indicate that some compaction on the top layers (5 cm) help the seeds to emerge earlier in the loamy and sandy loam soils covered in this study.

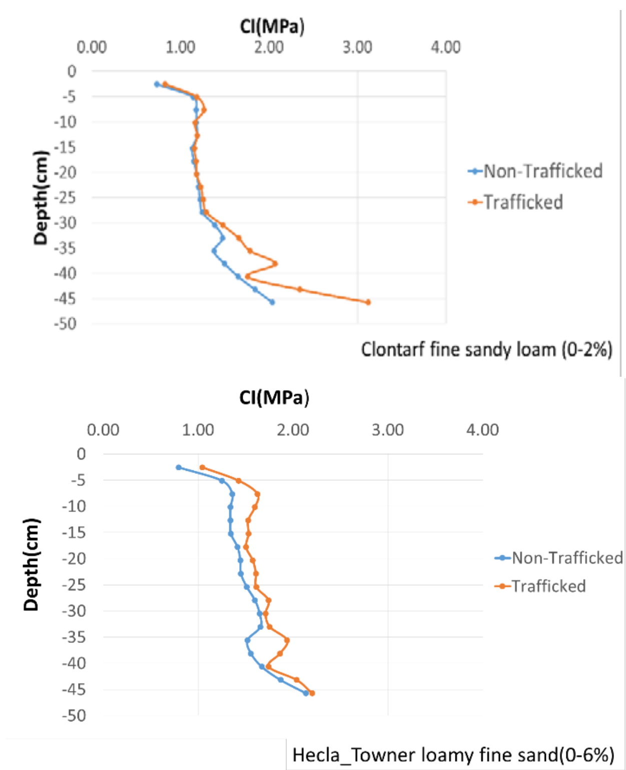


**Figure 3. Comparison of CI profile for trafficked and non-trafficked rows with different soil types**

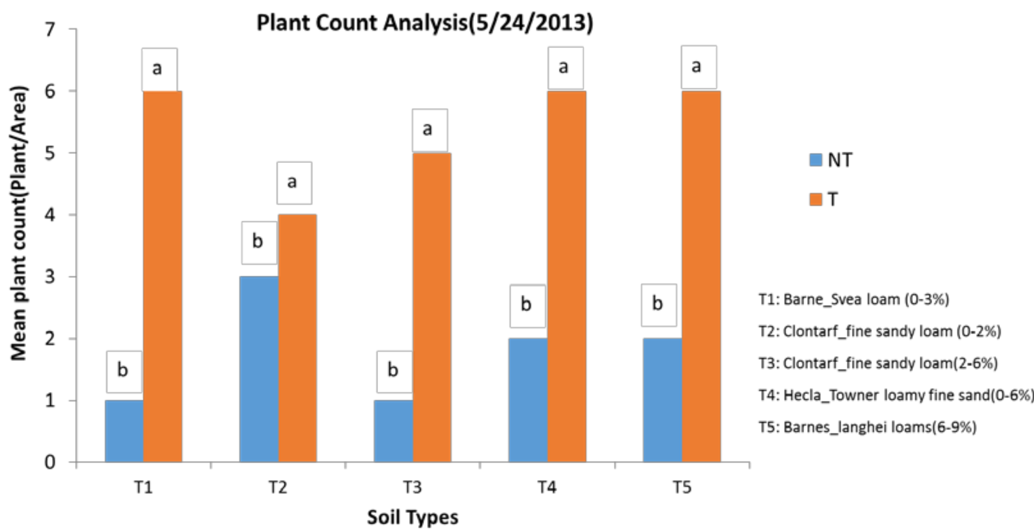


**Figure 4a. Plant emergence count at 12 DAP for the five soil types in the study area. Means with the same letter are not significantly different (α= 0.05) between trafficked (T) and non-trafficked (NT) rows.**

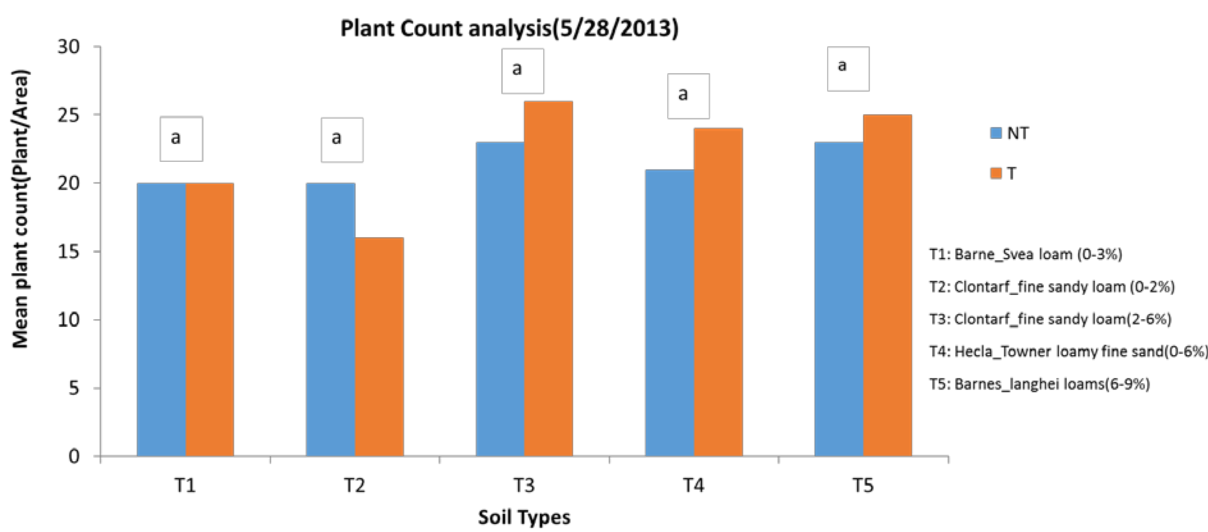


**Figure 4b. Plant emergence count at 16 DAP for the five different soil types. Means with the same letter are not significantly different (α= 0.05) between transects, T and NT rows.**

## Soil moisture content

Mositure content in the field has an impact on soil compaction and its effect varies depending up on soil types. The volumetric water content, calculated using the bulk density and weight of the soil samples, varied from 15 to 32% in the study area with an average of 20% and standard deviation of 3.82%. As expected, CI readings were significantly correlated to soil moisture content (Figure 5). A power model between CI and soil moisture content was able to explain 59 % of the variability in CI. For developing the correlation, the CI from the top 18 cm was averaged. Further investigation needs to be done using soil sample cores collected at a higher depth.

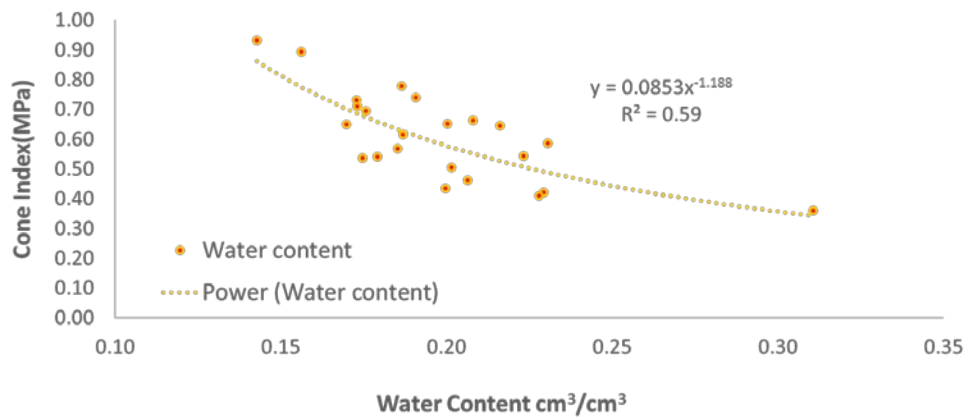


**Figure 5. Correlation between soil resistance (CI) and volumetric water content**

## Plant response to compaction

The plant height showed no significant difference between the trafficked and non-trafficked areas within each transect (Figure 6). It can be noted from the cone index profile for the study area, the CI values for all the transects varied from 1.2 MPa to 1.6 MPa at depths  between 10 cm and 35 cm. There was less difference in the CI values between trafficked and non-trafficked rows and transects. This less variation in CI values can explain the plant height similarity for the study area.

The grain to cob mass ratio didn't vary much between trafficked and non-trafficked rows (Figure 7). It becomes essential to determine this ratio as it has an influence over the yield and biomass production.

The yield data also showed that there was no significant difference between the trafficked and non-trafficked rows along each transects but significant difference can be observed between some of the transects (Figure 8). Similar finding was reported by Murdock and James (2008) in which there was no significant yield difference between compacted and non-compacted treatments. The highest average yield (Transect T2 ) indicated 18.9 % yield increase compared to transect T1 which contributed to the lowest yield. The average CI values versus the grain yield for the study area is shown in Figure 9. The graph shows an optimum cone index value for a higher yield in all the transects except transect T2. The lower CI values reflected in higher yield for transect T2 which might be less susceptible to compaction due to machine traffic.

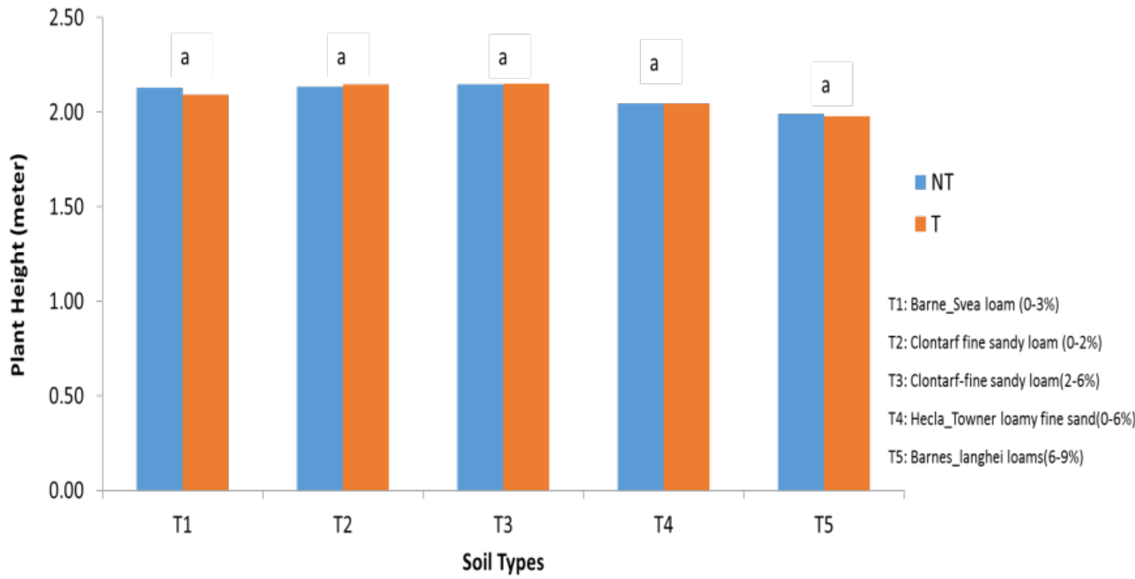


**Figure 6. Plant height measurement at taselling stage(92 DAP) for Trafficked and non-trafficked areas plotted against soil types. Means with the same letter are not significantly different (α= 0.05) between soil types, T and NT rows.**

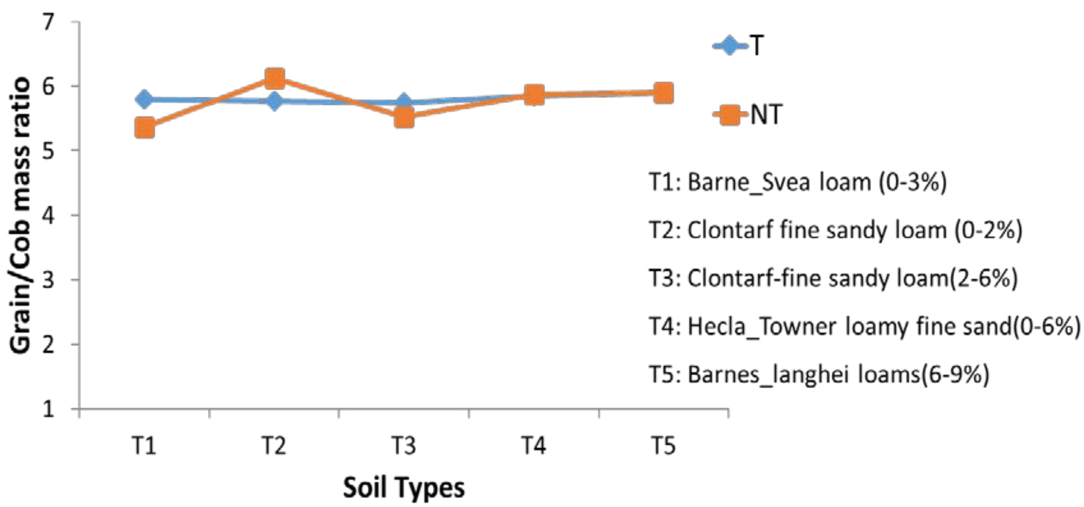


**Figure 7. Average grain/husk mass ratio for Trafficked and non-trafficked rows under different soil types**

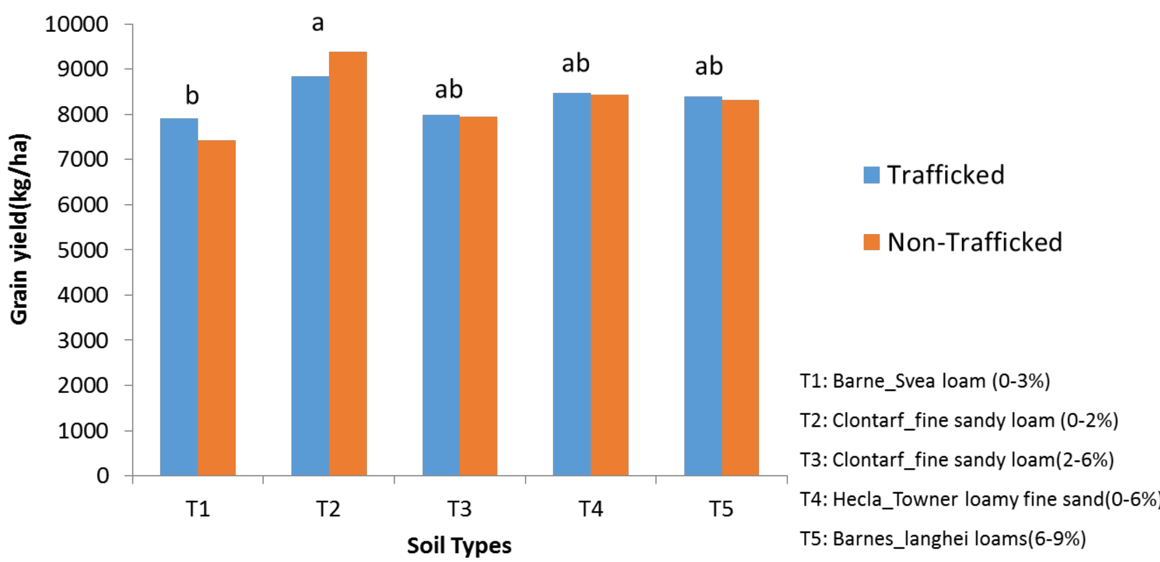


**Figure 8. Average grain yield optimized at 15% moisture content for compacted and non-compacted rows plotted against soil types.Means with the same letter are not significantly different (α= 0.05) between transects.**

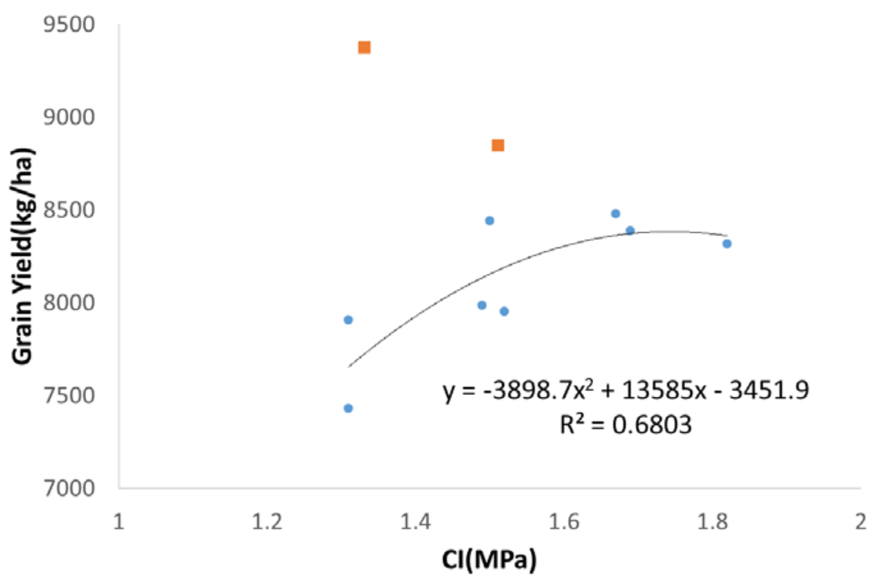


**Figure 9. Average Cone Index Vs. Opimized grain yield at 15% moisture content. The orange square indicates yield from transect T2 which are not included in the regression model.**

## SUMMARY AND CONCLUSION

This paper investigates the effects of soil compaction by wheel traffic on corn growth, development and yield in a no-till field. The CI measurement from different depth suggests that the study field had significant compaction at depths of 48 cm or more, and there were some differences in soil compaction profile between the different transects. Soil compaction resulted in early emergence of corn plants in trafficked rows by 150% compared to non-trafficked rows. The plant height was not influenced by the variability in compaction levels or soil types. The grain yield was influenced by soil types, but not by compaction levels. It is important to note that the study field hasn't been tilled for more than 10 years. Collecting subsequent years of data will help to know the effects of soil compaction on crop, and impact of weather cycle on soil compaction. Future plan involves analyzing the effect of winter freeze-thaw cycle on soil compaction as well as studying soil compaction in conventionally tilled and no-till fields.

## REFERENCES

Bicki, T. J., and J. C. Siemens. 1991. Crop response to wheel compaction. Trans. ASAE. 34(3): 909-913

Gelder, B.K., R.M. Cruse, and X.Y. Zhang. 2007. Comparsion of track and tire effects of planter tractors on corn yield and soil properties. Transactions of the ASABE. Vol. 50(2): 365−370.

Jabro, J., R. Evans, and W. Iversen. 2012. Freeze-thaw cycles effects on soil compaction in a clay loam. Geophysical Research Abstracts. Vol. 14, EGU2012-1688.

Kasper, T. C., S. D. Logsdon, and M. A. Prieksat. 1995. Traffic pattern and tillage system effects on corn root and shoot growth.Agronomy J.87(6): 1046-1051.

Lowery, B., and R.T. Schuler. 1994. Duration and effects of compaction on soil and plant growth in Wisconsin. Soil Tillage Res. 29(2–3):205–210.

Murdock, L.W., and J. James. 2008. Compaction, tillage method, and subsoiling effects on crop production. Retrieved April 2014. http://www2.ca.uky.edu/agc/pubs/agr/agr197/agr197.pdf

Ngunjiri, G.M.N., and J.C. Siemens. 1995. Wheel traffic effects on corn growth. Trans ASAE. 38(3):691–9.

Richard, D.T., and W.K. Won. 2013. The Corn Industry's Impact on North Dakota's Economy. Center for Agricultural Policy and Trade Studies, North Dakota State University,
AGRICULTURAL POLICY BRIEF No. 29.

USDA Economic Research Service. Retrieved March 2014. http://www.ers.usda.gov/topics/crops/corn/background.aspx#.U1U3mhCTKOw

Voorhees, W. B. 1983. Relative effectiveness of tillage and natural forces in alleviating wheel-induced soil compaction. Soil Sci.Soc.Am. J.47:129-133.

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