A COMPARISON OF THE QUALITY OF FARM AND OLD GROWTH FOREST SOILS IN THE EMO-RAINY RIVER DISTRICT OF NORTHWESTERN ONTARIO

By

Libby Paleczny

FACULTY OF NATURAL RESOURCES MANAGEMENT

LAKEHEAD UNIVERISTY

THUNDERBAY, ONTARIO

April 2020

A COMPARISON OF THE QUALITY OF FARM AND FOREST SOILS IN THE EMO-RAINY RIVER DISTRICT OF NORTHWESTERN ONTARIO

By

Libby M. Paleczny

An Undergraduate Thesis Submitted in

Partial Fulfillment of the Requirements for the

Degree of Honours Bachelor of Environmental Management

Faculty of Natural Resources Management

Lakehead University

April 2020

Dr. Lense Meyer	Dr. Will Wilson
Major Advisor	Second Reader

LIBRARY RIGHTS STATEMENT

In presenting this thesis as a partial requirement for HBEM degree at Lakehead University in Thunder Bay, I agree that the University will make it freely available for inspection.

This thesis is made available by m authority solely for the purpose of private study and research and may not be copies or reproduces in whole or in part (except as permitted by the Copyright Laws) without my written authority.

_____

May 13, 2020

A CAUTION TO THE READER

This HBEM thesis has been through a semi-formal process of review and comment by at least two faculty members. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional and scientific forestry.

The reader should be aware that opinions and conclusions expressed in this document are those of the student and do not necessarily reflect the opinions of the thesis supervisor, the faculty or Lakehead University.

ABSTRACT

Paleczny, L. M. 2020. A Comparison of the Quality of farm and forest Soils in the Emo-Rainy River District of Northwestern Ontario.

Keywords: Emo-Rainy River District Northwestern Ontario, bulk density, pH, soil, soil compaction, CNS, farm fields, old-growth forest.

This thesis explores different aspects of the qualities of soils found in a farmer's hayfield and nearby forested areas on the West side of Emo, Ontario. Soil qualities of a forest and hayfield sites with multiple plots will be examined, with a focus on pH, carbon, nitrogen and sulphur content (CNS), and soil compaction (bulk density). The main purpose of this study is to discover whether soil found in each area differ from each other due to changes in land use. In order to determine significant differences between the hayfield and forested area, a one-way ANOVA was completed so to determine any significant differences ($a = 0.05$) found within any of the measured factors between the forest and hayfield site. All the factors except pH appear to have a overall significant difference between the sites. The results found are further discussed and analyzed as to why there was such a difference between the two sites. The briefness of the length of this study, would not allow for a complete representation of the total effects of current and future changes in land use due to farming practices. In conclusion from the data collected and analysed farming practices such have caused significant differences in the quality of the soils. The importance of the study has been the continuation of a baseline dataset for the soils of forested and farmland areas in Northwestern Ontario, which can be used as a foundation for further studies with research into soil qualities.

TABLE OF CONTENTS

ABSTRACT iii
TABLES v
FIGURES vi
ACKNOWLEDGEMENTS vii
1. INTRODUCTION 1
2. LITERATURE REVIEW 4
2.1 Carbon Content/Storage and its Significance to Soil 4
2.2 Soil pH and its Significance to Soil 6
2.3 Bulk Density/Soil Compaction and its Significance to Soil 8
3. OBJECTIVES 9
4. HYPOTHESES 10
5. METHODS AND MATERIAL 11
5.1 RESEARCH TIME PERIOD AND SITE SELECTION 11
5.1.1 Local Soil History 12
5.1.2 Field Data Collection 13
5.2 LAB DATA ANALYSIS 16
5.2.1 Bulk Density Sample 16
5.2.2 pH Samples 17
5.2.3 Moisture Content 19
5.2.4 Carbon, Nitrogen, and Sulfur Content 19
5.2.5 ANOVA 20
6. RESULTS 22
7. DISCUSSION 28
7.1 pH AMOUNTS 28
7.3 CARBON, NITROGEN AND SULPHUR CONTENTS 30
7.4 APPLICABILITY 31
7.5 POTENTIAL OR FUTURE RESEARCH 31
8. CONCLUSION 33
9. LITERATURE CITED 34
APPENDICES 37

TABLES

Table 1. Summary table for the ANOVA tests showing each response variable tested and their significant difference score between the two test sites (p calc < 0.05) ……22

FIGURES

Figure 1. Location of the Zimmerman Emo Holstein Farm displayed using satellite imagery from Google Maps……..11
Figure 2. Map of the study area. Hayfield plot outlined in black, and the old-growth forest plot outlined in blue……13
Figure 3. Approximate study area with buffers displayed in light grey, and sample areas represented in black……..14
Figure 4. Density driver sampler being used in a hayfield sample plot……...15
Figure 5. ATV used for transportation between sample sites, and storage of soil samples in the field…….16
Figure 6. Temperature adjustment and an Orion 9165BNWP Sureflow Combination pH electrode used to measure samples pH…….18
Figure 7: Graph representing the mean and standard deviation of the bulk density (g cm-3) between the hayfield and forest sites……...23
Figure 8. Mean and standard deviation of the two pH measurements (H20 and CaCl2) between the hayfield and forest sites……24
Figure 9: Nitrogen percentage means and standard deviation in the forest and hayfield plot sites. Pg……..25
Figure 10: Carbon % means and standard deviation in the forest and hayfield plot sites……...26
Figure 11: Sulphur percentage means and standard deviation in the forest and hayfield plot sites……27

ACKNOWLEDGEMENTS

I'd like to begin by expressing my gratitude to Bernie and Rosanne Zimmerman, the owners of Zimmerman Emo Holsteins Farm. Thankyou for generously allowing me to conduct this research on the farm, as well as sharing knowledge of the farm and the site's history.

I would now like to extend a thankyou to my thesis supervisor, Dr. Lense Meyer for his guidance, support and expertise throughout the duration of this study and the school year. I would also like to thank Dr. William Wilson for being so keen and interested in helping me through acting as the second reader. I would like to thank the Lakehead University Centre for Analytical Services (LUCAS) who where important in the measurements of the CNS percentages of samples for this thesis.

I also would like to extend great gratitude to Alan Brady, thankyou for acting as my transportation and field assistant through the collection of samples for this study.

Lastly, I would like to specially thank all of my friends and family who have shown nothing but encouragement, love and support throughout the process of this thesis and my studies at Lakehead.

1. INTRODUCTION

Farming in Northwestern Ontario is a relatively small but increasingly important industry for local farmers. Northwestern Ontario, specifically the Rainy River district, offers a high potential for farming practice as it demonstrates a significant amount of useful fertile soils, and relatively affordable lands (Chapagain, 2017).

Climate change may be a factor in the future of northwestern Ontario farming, as the climate warms, there is more days in a year for plant growth. The area is currently situated in the Hudson Bay Lowlands and is exposed to considerable extreme temperatures, the mean annual temperature is between -5C and 4C, with a relatively low rainfall (annual precipitation of 450 to 800mm) and a much shorter growing season of between 65-180 days (in comparison to southern Ontario with a growing season of 180-250 days) (Chapagain, 2017). As temperatures across the globe slowly rise, there is hope for the rainy river district as it may benefit from a warming climate, with increasing rainfall and more time for better conditions to increase crop growth in the future.

The Zimmerman Emo Holsteins Farm has been family owned and operated in the Rainy River district for two generations and for over 50 years. The farm is situated on 242 hectares of land, 15 km northwest of Emo Ontario and has been an evident presence in the annual Emo Agricultural Fair's cattle show. The farm has a total 12 fields (including both crop and pastures) where the farm produces fields of hay, grain, corn, barley and soybeans, and has solely Holsteins (dairy cattle) with an average of 36 actively milking cows at a time. Most of the crop produced is kept for the livestock over the long winter months. Over the last few years the farm has down

graded in size and the pastures are now filled with a small herd of beef cattle, and many of the farms crop fields are being rented out to neighbouring farms interested in the extra land for growing. The farm actively uses small scale machinery, such as the use of various tractors, balers (both square and round bail), mowers and fertilizer spreaders. Natural fertilizers collected from the farm's livestock are utilized to aid in increased crop growth and productivity.

The forested area sampled has not been known to have been harvested within the last 50 years of the farm's ownership. It is located beside three fields, one of which is the sample hayfield, and the other two are actively growing soybeans. The forest is a dense approximately 60 year old forest containing species of *Populus* (Balsam Poplar), *Picea* (Spruce), *Pinus* (Pine), *Abies* (Balsam Fir) and *Acer* (mountain maple), as well as various other trees, shrubs and herb species commonly found in the Great Lakes St. Lawrence forest.

The Rainy-River District is known to have a high clay levels found within the soils due to being a clay belt region, which offers the area an increase of fertile lands which was formed from the draining of a glacial lake thousands of years ago (Chapagain, 2017).

In the comparison of hayfield and forest soils, I am examining the differences between the two sample sites' soil compaction (using bulk density [Db]), total carbon, nitrogen and sulphur (CNS) and pH (units are below). A comparison of the two sites will be done, and an analysis of any significant difference between the two different areas of soil. This information can potentially be used to increase

productivity of future farming, and to determine that major differences between the soils of the active fields and old growth forests.

2. LITERATURE REVIEW

The quality of soil is measured in several different forms, they each provide different views which each help in determining the soils overall health (Gregorich *et al.* 1994). Soil health and improvement has been an area of concern for scientists and agriculturalists for generations; as dependence upon agriculture has grown, there is often the high cost of the soils ecological integrity that is a reoccurring problem (Johnston *et al*. 2009).

Common indicators (Brady and Weil 2002) used (below) include the individual soil samples carbon content (C), soil pH and bulk density. This thesis will research each of these soil health indicators and their elemental role in good soil health. This will also look at the differences in soil health across all indicators when comparing an agricultural field with a natural forest soils in the same general area. This research is based on results gathered from soil samples of a farm in northwest of Emo, Ontario, and will include research outside of this area to aid in understanding the importance and impact of this research.

2.1 Carbon Content/Storage and its Significance to Soil

Carbon content and storage is considered to be the total sum of both organic carbon and carbonate carbon found within the soils (Batjes, 1996). The organics found within soils is a very important key aspect in many land ecosystems, and each different organic matter variation, abundance and composition is very important in the way it effects a number of processes that you can find occurring in each ecosystem (Batjes, 1996).

Soils are composed of two components; organic matter and mineral matter (Strahler and Strahler (1997: 492). A very large portion of the worlds carbon can be found within soils as pools of carbon sediments (Strahler and Strahler 1997: 531). Despite soil organic matter having such large effects and importance upon a terrestrial ecosystem, there is still very little known about the carbon and nitrogen pools of the world's soils (Legros *et al.* 1994).

A large area of Canada is made up of the boreal zone, and 17% of the worlds total carbon stores occurs in these soils (Bhatti *et al.* 2002). Boreal forests have a greater potential for change in the soils carbon due to having the highest accumulation of dead organic matter relative to other climatic zones (Bhatti et al, 2002). The carbon content that is found within terrestrial ecosystems is often changed markedly by impacts of human activities, which include deforestation, burning, changes in land use, and pollution (mainly aerial gas) which increase the "greenhouse effect" (Trabalka and Reichle, 1986).

When a change in land use occurs, it causes stress and change to an ecosystem and can influence differences in carbon stocks (Lal 2005). The change of soils in an area that has converted from forest to agricultural land, has been found to deplete soil organic carbon (SOC) stock by 20-50% (Davidson and Ackerman, 1993:168). The soil organic matter (SOM) is made up of SOC and is generally used as a defining factor of the soils overall health (Doran and Zeiss 2000). A meta analysis done by Lal (2005) explains that a depletion in the SOC can be caused by a great number of factors, which include a lower amount of overall biomass that is returned to the soil, changes in the soils moisture and temperature, tillage changes, and an increase in soil erosion. This has

caused agricultural soils to contain usually a lower amount of SOC stock than their soil's possible capacity. With the evidence of the large role in which agricultural lands offer for the storage of carbon and the impacts that the carbon has for the soil's health, it is increasingly important that agricultural practices are altered towards the practices that area able to maintain SOM and SOC levels (Loveland and Webb 2003; Matsuura *et al.* 2018). This is because agricultural lands have been found to be potentially large storage areas for carbon from the increasing amounts of atmospheric carbon (Matsuura *et al*. 2018).

2.2 Soil pH and its Significance to Soil

Soil pH is known to be the most informative single measurement that is often used to determine the soils characteristics, and it affects all physical, chemical, and biological properties (Brady and Weil 2002). The pH of soils is used to identify the overall acidity or basicity of a soil sample and is a measure of the pH of the water in equilibrium with the soil (Miller and Gardiner 2001). In general, it is known that an increased soil acidity significantly reduces plant production, without any affect on the soils organic carbon and nitrogen stores (Kemmitt *et al.* 2006). Crops common to the Rainy River area are optimally adapted for a soil pH of between 5.5 for organic soils, and 6.5 for mineral soils (Miller and Gardiner 2001). Soil pH is universally accepted as the main factor which soil nutrient bioavailability is regulated, as well as the regulation of plant productivity, the structure of the vegetation community, and various soil processes (Robson 1989), and helps influence the carbon and nitrogen required for plants to have productive growing rates (Batjes 1996).

Soil pH is very important in maintaining overall soil health due to the pH's large impact on the availability of nutrients in soils and the nutrient cycling that occurs (Kemmitt *et al.* 2006; Robson 1989). It is suggested that the soil pH may carry the same importance to soil health as the carbon or nitrogen concentrations with regards to influencing the size of microbial biomass (Wardle, 1992). Soil pH is recognised as a main and dominant factor which determines the microbial turn over of all organic matter found in soils (Kemmitt *et al.* 2006). Shifts in aboveground vegetation can be caused by changes in the soil pH and can completely alter the plant communities as well as evident changes to the microbial communities; reducing plant production also changes the amount of substrates that enters into the soil (Kemmitt *et al.* 2006).

Decomposition is largely dependant upon soil pH, as the pH is important in the maintenance of proper decomposition rates in the forest (Miller ad Gardiner 201: 161, Pietri and Brookes, 2008). Soil pH also plays an important role in increasing the growth of biomass, which in turn increase the extent and availability of organic matter found within the soil for decomposers (Pietri and Brookes 2008). A decrease in organic matter was found to be a result of an increase in the pH as it went form acidic to alkaline (Miller and Garnider 2001). Miller and Gardiner (2001) also found that bacterial diversity was overall lower in soils with higher acidity when compared to soils that were more neutral. Soils that have neutral pH are generally more productive when looking at the microbial activity and overall plant growth than soils with a more acidic pH (Pietri and Brookes 2008).

2.3 Bulk Density/Soil Compaction and its Significance to Soil

Strahler and Strahler (1997) defines bulk density (Db) as "the density of a volume of soil as it exists naturally and includes any air space and organic materials in the soil volume" (for more details, see below). As such, Db is a measure of soil compaction at a moment in time. Soil compaction is a large issue in agriculture, as high amounts of traffic on the soil each season occurs due to harvesting and planting increasing soil compaction that can lead to a decrease in the overall crop performance (Barzegar *et al.* 2016). As explained by Hamza and Anderson (2005), compaction is one of the largest problems that modern agriculture is facing (2005). Bulk density not only calculates the compaction in a moment in time, it can give the water storage capacity in each volume of soil sample at that time. This allows for the assessment of root penetration as well as aeration problems (Strahler and Strahler 1997). Also, Db can also be used to determine soils total nutrient contents and possible crop productivity.

In order to calculate soil total water storage capacity, bulk density is required (Straher and Strahler 1997: 71). Soil that has a high Db has been discovered to have overall negative effects on the soils crop seedling emergence, water permeability and the fields overall crop yield (Ahmadi and Ghaur 2015). Moreover, an increase in soils compaction results in a decrease in the overall crop performance (Berzegar *et al*. 2016).

The overuse of machinery on soils can cause soils to have a greater soil compaction, resulting in the soil layers being forced or pressed together from an outside force (machinery for harvesting) (Soane and van Ouwerkerk 1994). The amount of soil compaction evidently is dependant upon when the soil is heavily used. Also,the use of

machinery on wet soils can cause an increase in soil compaction in comparison to relatively the same activity being performed on soils that are drier (Flynn *et al.* 2018).

A study done by Hamza and Anderson (2005) discovered that the soil compaction is further intensified by having lower soil organic matter content. While, Willatt an Pullar (1984) found that with an increase in stocking rates, soils bulk density may increase, resulting in an overall decrease of hydraulic conductivity throughout the soil (1984). Forest soils often have a lower bulk density and compaction than those of agricultural fields because of higher organic matter content (and hence, higher C), and decreased land disturbance from farming equipment (Lal 2005).

3. OBJECTIVES

The objectives of this thesis are to analyze and compare soil data of a hayfield and forest area (100m to the north of the hayfield) situated northwest of Emo, Ontario. This study will aid in creating a data set of soils found in and around rural farm lands in Northwestern Ontario. This will be done by mimicking a similar study done by French (2019) in Murillo Ontario, and will take measurements of Db (g cm^{-3}), pH, and CNS (%) within the two different plot areas. The data observed from this thesis will aid in research in the future when looking at differences between the quality of agricultural soils and forest soils, as well to aid in determining effects that farming practices have on soil quality.

4. HYPOTHESES

This thesis has the following hypotheses (Ho & Ha):

1. Ho: There is no significant difference ($\alpha = 0.05$) of soil compaction (as measured by Db) within soil samples taken from a hayfield *vs*. samples taken from an old growth forest. (reject the Ho)

   Ha: There is a significant difference ($\alpha = 0.05$) of soil compaction within soil samples taken from a hayfield *vs*. samples taken from an old growth forest.

2. Ho: There is no significant difference ($\alpha = 0.05$) of pH within soil samples taken from a hayfield vs. samples taken from an old growth forest. (Accept the Ho)

   Ha: There is a significant difference ($\alpha = 0.05$) of pH within soil samples taken from a hayfield *vs*. samples taken from an old growth forest.

3. Ho: There is no significant difference ($\alpha = 0.05$) of carbon content within soil samples taken from a hayfield *vs*. samples taken from an old growth forest. (reject the Ho)

   Ha: There is no significant difference ($\alpha = 0.05$) of carbon content within soil samples taken from a hayfield *vs*. samples taken from an old growth forest.

5. METHODS AND MATERIAL

5.1 RESEARCH TIME PERIOD AND SITE SELECTION

The area of study is at the Zimmerman Emo Holstein Farm, a recently retired milk farm located northwest of Emo, Ontario. Figure 1 shows the relative location of the farm from Emo, Ontario, the farm is indicated by using a red dot. Currently the farm is owned and operated by the Zimmerman Family (Bernie and Rosanne), who are the second generation of Zimmerman's to own this farm The farm currently rents out lands to neighbouring farmers to grow their crops, but in the recent past has been an important part in the milk business and a big presence in the local agriculture community of the Fort Frances/Rainy River district.

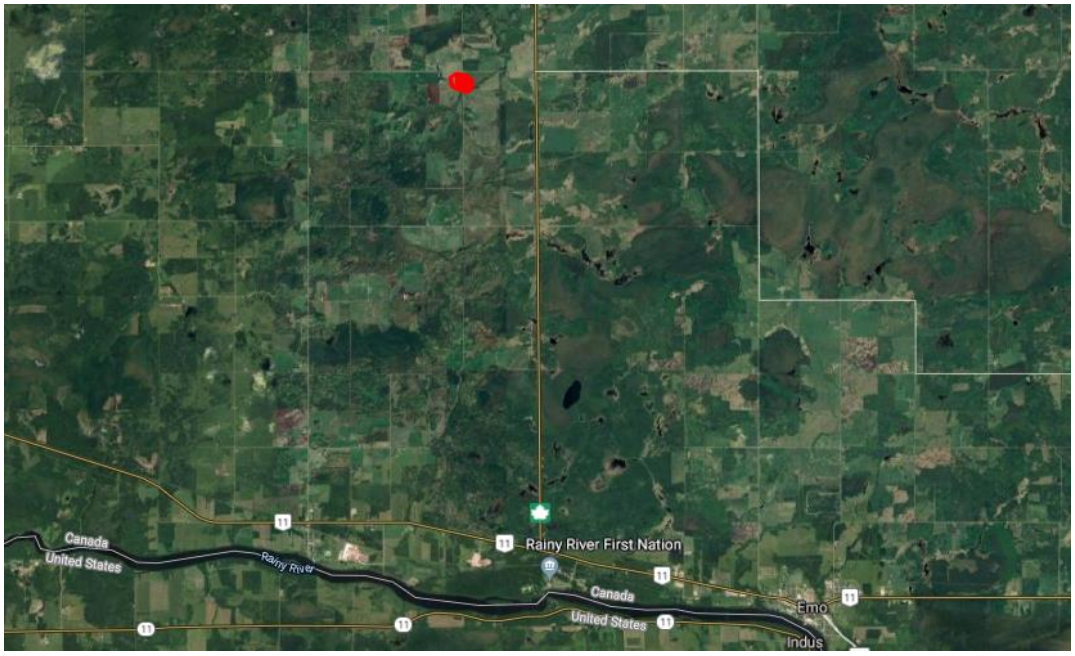

Figure 1. Location of the Zimmerman Emo Holstein Farm (red dot) displayed using satellite imagery from Google Maps.

5.1.1 Local Soil History

The Rainy River district has a great variety of soil types but is overall an area with a high clay content within the soils. For this research based on the Soils of Fort Frances - Rainy River Area Soils survey report No. 51., the forest soil type is located on the Cpcl/b1, soil type Carpenter. The texture can be clay, clay loam, silty clay loam, sandy loam. The soil materials is generally lacustrine overlying calcareous silt loam, and clay loam glacial till and the drainage is considered moderately poor; the average soil classification is gleysol. The slope is level, nonstony and the agriculture capability is 3W.

For the hayfield sample plots (Soils of Fort Frances - Rainy River Area Soils survey report No. 51) the soil type is DVSL/A0, soil type Devlin. The soil textures are defined as clay, clay loam, sandy loam, and silt loam. The soil materials overlie calcareous silt loam, and clay loam glacial till. The drainage is considered imperfect; the average soil classification is Gray luvisol. The slope is gentle, it is nonstony and the agriculture capability is 2C to 3F (Ontario Institute of Pedology 1984). Only a small area of the farm was sampled for this study, two 10,000 m^2 plots were chosen from a current hay friend and old growth forested area. Figure 2 displays a closer image of the study area, outlining the hayfield plot in black and the old growth forest plot in blue. This area was located to the north west of the farmhouse. The field data collection for this study occurred on October 5, 2019, while the lab analysis began on October 11, 2019, and was completed on February 4, 2020.

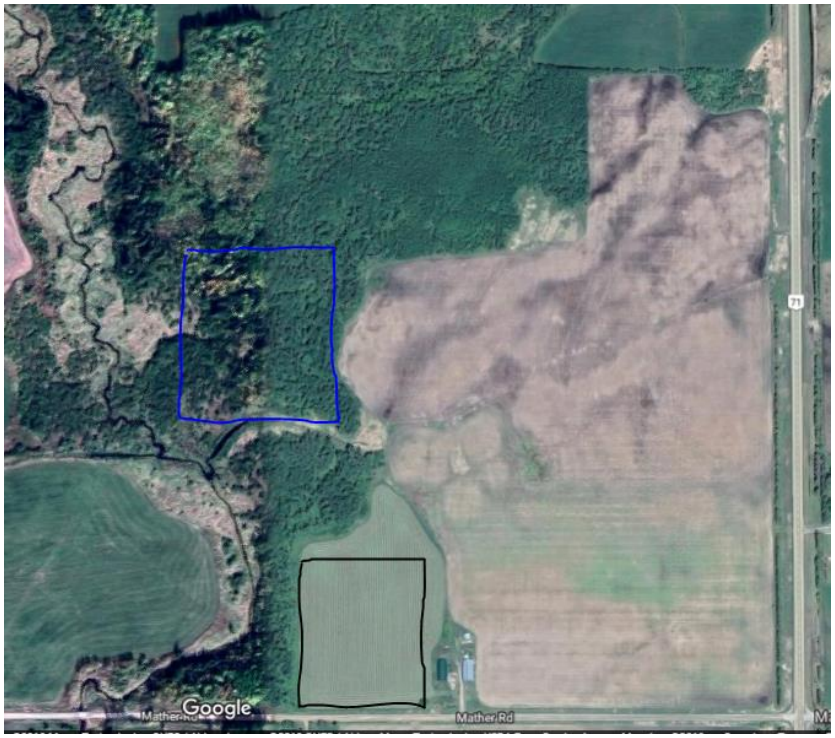

Figure 2. Map of the study area. The hayfield plot is outlined in black, and the old-growth forest plot outlined in blue.

5.1.2 Field Data Collection

The soil collection for this study was done on October 5th, 2019 and a total of 64 soil samples were collected from the Zimmerman Emo Holsteins Farm and the forested area. In total, 16 samples of bulk density and 16 samples for CNS and pH were collected from each of the hayfiled and forest (*i.e.*, 32 samples total for Db and 32 samples total for pH, CNS soil analyses). The exact location of the samples taken can be seen in Figure 3 and follows the design of French (2019).

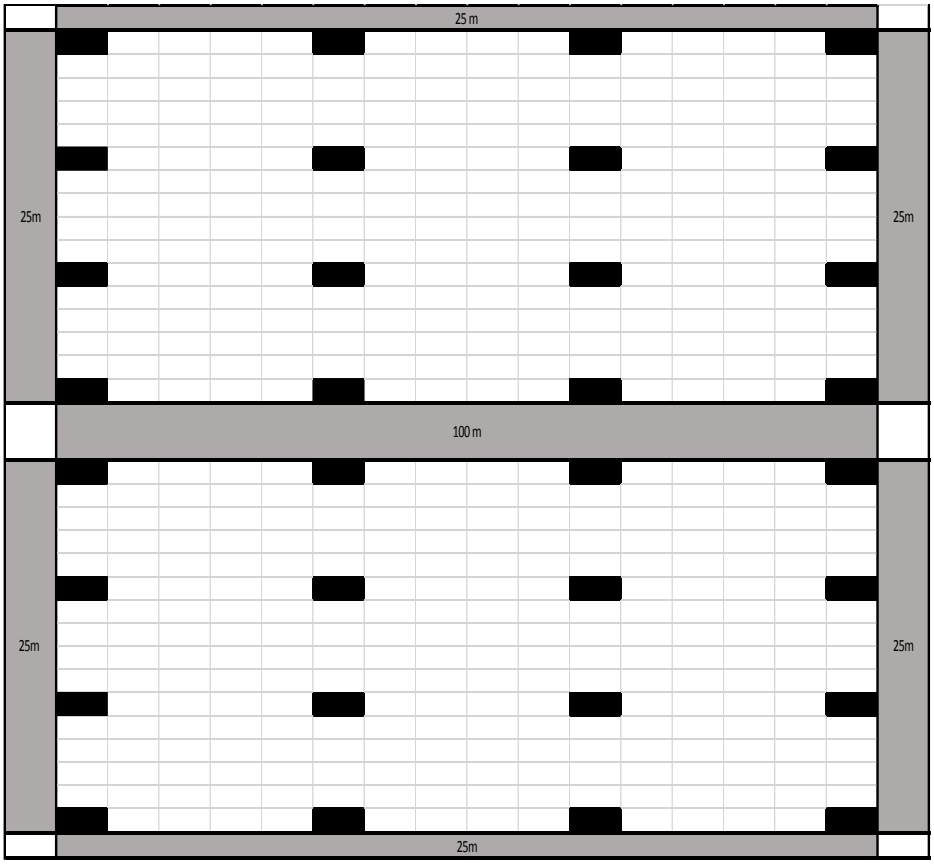

Figure 3: Approximate study area with buffers displayed in light grey, and sample areas represented in black.

In order to collect soil samples a pointed shovel was used to move the very top layer of soil which contained hay or forest vegetation (e.g Moss, leaves), which allows for proper soil samples to be taken from a soil depth of 0.10 meters. The Db samples were taken separately from the pH/ CNS samples but in the same plot area. In order to take the Db, a density drive sampler was used (Figure 4, French 2019).

Figure 4: Density driver sampler being used in a hayfield sample plot

In order to collect the soil samples for the pH and CNS, a regular shovel was used. The soil was then placed into labeled Ziploc bags; a precise measurement of the collected soil was not measured, as the measurement will be done in the lab for the analysis. For the samples of bulk density, the density drive sampler was used with a measured core size of 231.7cm^3; the soil was stored in labeled paper bags that had been previously weighed in the soil's lab and which could be safely heated to 105 °C. Transportation between sample areas was done by using a four-wheeler (ATV) with mattracks (Figure 5), which also served as a storage place for all the samples while collecting out in the field. The transportation to and from the study site was done using a personal vehicle.

Figure 5: ATV used for transportation between sample sites, and storage of soil samples in the field.

5.2 LAB DATA ANALYSIS

5.2.1 Bulk Density Sample

After returning to Thunder Bay from the field, the soil samples were moved and stored in the soil's lab at Lakehead University. The paper bags of bulk density samples were put into a drying oven (105°C) by Dr. Meyer over the reading week to dry the soils for 48 hours. After the soil samples had been completely dried and cooled off, they were stored until the end of the reading break (October 21st, 2019). Upon return, the samples were weighed, with the weights recorded in g, the weight of the sample was subtracted from the weight of the paper bag (previously weighed) in order to obtain the weight of just the sample soil. This was done for both the hayfield and forest samples (Equation 1).

DB = Ms/Vb **Eq[1]**

Where;

Db = Bulk Density (g/cm^3)

Ms = Mass (g) of oven dry soil (105°C), and

Vb = Bulk volume (cm^3) of the container ($231.7cm^3$ for all samples)

5.2.2 pH Samples

Using the Ziploc bag soil samples gathered, the soil was removed in the LU Forest Soils Lab and dried at room temperature (20°C) for one week (7 days, or 168 hours) and was then gently ground by a mortar and pestle to pass though a 2 mm sieve. The ground soil was then placed into a separate Ziploc bag, and the remaining soil (Large rocks and material > 2 mm) was returned to the original Ziploc bag. All morter, pestles and seives were cleaned after every sample (to prevent cross contamination) by using a paper towel.

When each of the soil samples had been ground, two separate 10 g samples (later corrected by moisture content – see below) were taken from each bag and was placed into small plastic cups. Two 10 g containers of each sample was weighed, and in one container 20 ml of distilled H_2O was added, and 20 ml of 0.01M of $CaCl_2$ was added to the second container. All the samples were stirred often (about every 10 minutes) over a total of thirty minutes.

After the thirty minutes had passed, an Accumet research AR20 pH/Conductivity meter with temperature adjustment and an Orion 9165BNWP Sureflow Combination pH electrode (Figure 6) was used to record each of the samples pH's.

Figure 6: Temperature adjustment and an Orion 9165BNWP Sureflow Combination pH electrode used to measure samples pH.

The pH value was recorded when the machine beeped by indicating the pH reading was stable and accurate. Once recorded, the sample was removed, and the pH electrode and temperature adjustment were cleaned with distilled water and kim-wipes (to remove excess water). Once cleaned, the next sample was able to be properly measured. The pH values ($pH = -\log[H^+]$ and $[H+] = 10^{(-pH)}$) were recorded in Microsoft Excel, and an ANOVA (see below) was completed to have a comparison of the samples pH's to see whether there was a significant statistical difference (alpha = 0.05) between the hayfields plot and old growth forest plot.

5.2.3 Moisture Content

The moisture content (for correction) for all samples was done by weighing the ground soil out into 10 g samples from the Ziploc bags of soils that was used to measure pH and the CNS. The measured sample of soil was put into a metal tin, then placed into a oven for drying at a temperature of 105°C for 48 hours. The metal tins were placed into the oven at the same temperature (105°C) for 24 hrs prior to adding soil, and their empty weight was recorded immediately after removal from the oven. After the 18 hours when the samples had completely and properly dried, they were taken out of the oven and immediately weighed with each of the values being entered into Microsoft Excel. The following equation was utilized to determine the correct percentages of CNS for any moisture the samples contained (Equation [##])

$$\mathbf{X = \%/Sd*Sm}$$

Where X = Percent of CNS in the soil corrected for moisture

% = Original percentage value for CNS

Sd = Weight of dried soil (g)

Sm = Weight of undried soil (g)

5.2.4 Carbon, Nitrogen, and Sulfur Content

In order to measure CNS content of the soil, a portion (25-100 g) of the ground samples were sent to the Lakehead University's LUCAS lab to be analyzed. The results from the LUCAS lab was received and the information as recorded in a Microsoft Excel sheet. The data included each samples percentages of CNS, corrected for moisture

content and the lab analyzed the samples for significant differences by using SPSS software. This data (raw and moisture corrected) is found in the Appendix 1 section of this paper.

All the data collected were tested for skewness and kurtosis (Appendix 2) using Lakehead University's IBM SPSS program.

To measure the concentrations of carbon, nitrogen and sulfur in the samples, ANOVA's were run to find any significant differences between to two plots (hayfield and old growth forest).

Originally (before the Covid-19 virus – spring 2020) the Db and CNS data were to be used to estimate the amounts (kg ha^{-1}) based on a 10 cm depth and used for an ANOVA analysis. However, these calculations were not done at this time due to the inaccessibility of the SPSS program

5.2.5 ANOVA

For purposes of this thesis, kurtosis was considered adequate if it fell between -3 to 3, and skewness was adequate between -0.8 to 0.8 (Joanes and Gill 1998). For each part of the soil quality analysis (bulk density, CNS content, and pH) a one-way ANOVA was completed with a significance of alpha = 0.05.

The following model was used for the ANOVAs for the response variables of Db (g cm^{-3}), pH, and CNS (%) data that had been okayed for skewness/kurtosis and corrected for moisture content (see appendices)

$$Y_{ijk} = \mu + L_i + \varepsilon_{(i)j} \quad \text{Eq[2}$$

i = 2; hayfield and forest; j replicates = 16
where
Y_{ij} = the measured response variable of the j_{th} replicate of the i_{th} level of factor L
μ = the overall mean for the response variable tested
L_i = the fixed effect of the i_{th} of 2 levels of factor L (hayfield and forest)
$\varepsilon_{(i)j}$ = the random effect of the j_{th} (16 replicates) in the i_{th} treatment (2 levels, hayfield and forest). The $\varepsilon_{(ij)k}$ are assumed to be IID $N(0, \sigma_2)$.

6. RESULTS

All data satisfied the skewness/kurtosis criteria and did not need to be transformed except for sulphur (see below and Appendices). When analyzing the results from each ANOVA listed in table 1 below, the Db and CNS factors had a significant difference (sig < 0.05) between the hayfield and the old growth forest plots. Although the pH values (which met skewness/kurtosis criteria as transformed data; *i.e.*, pH were already log values of the H+) were close, they did not meet our criteria (sig < 0.05) between the two soil sites.

Table 1. Summary table for the ANOVA tests showing each response variable tested and their significant difference score between the two test sites (p calc < 0.05)

Response Variable	p calc
Db	0.000
C	0.001
N	0.000
S	N/A
pH H_20	0.125
pH $CaCl_2$	0.087

In looking at the bulk density data between the two sites, there is clear difference from the hayfield and the old growth forest (sig =0.000; Table 1). Figure 7 shows that the average (or mean) bulk density for the hayfield plot was 1.49 with a standard deviation of 0.15. While the old growth forest site had a mean bulk density of 0.72 with a standard deviation of 0.19.

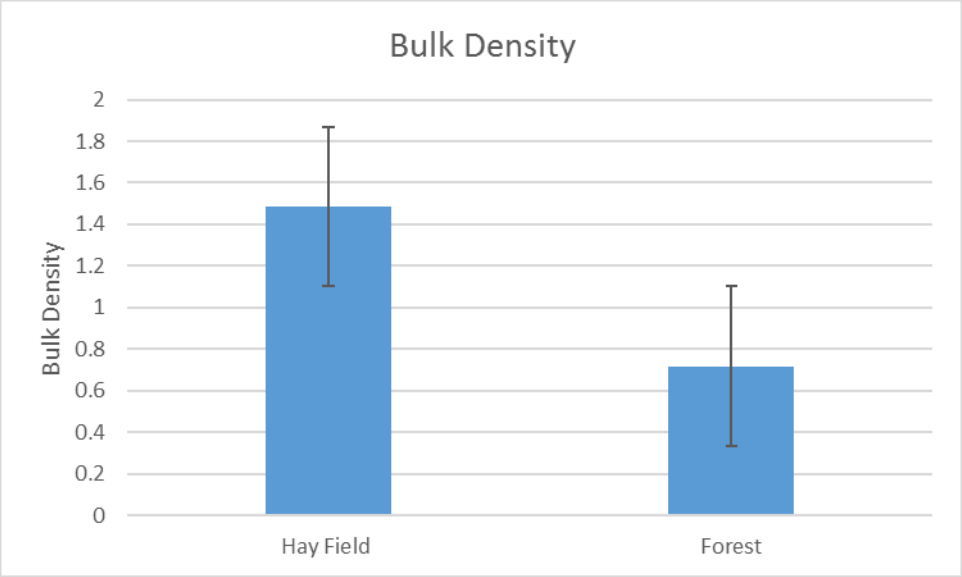

Figure 7: Graph representing the mean and standard deviation of the bulk density (g cm-3) between the hayfield and forest sites.

The pH tested in both H_20, and $CaCl_2$ appear to be statistically not different (p = 0.125 and 0.087 respectively; Table 1 above)). In H_2O, (Figure 8) the forest site had an average soil pH of 6.18 with a 0.34 standard deviation and the hayfield had a pH average of 6.38 and a standard deviation of 0.37. In the $CaCl_2$, the forest site shows an average of 5.49 and a standard deviation of 0.39 compared to the hayfield site average pH of 5.7 with a standard deviation of 0.48.

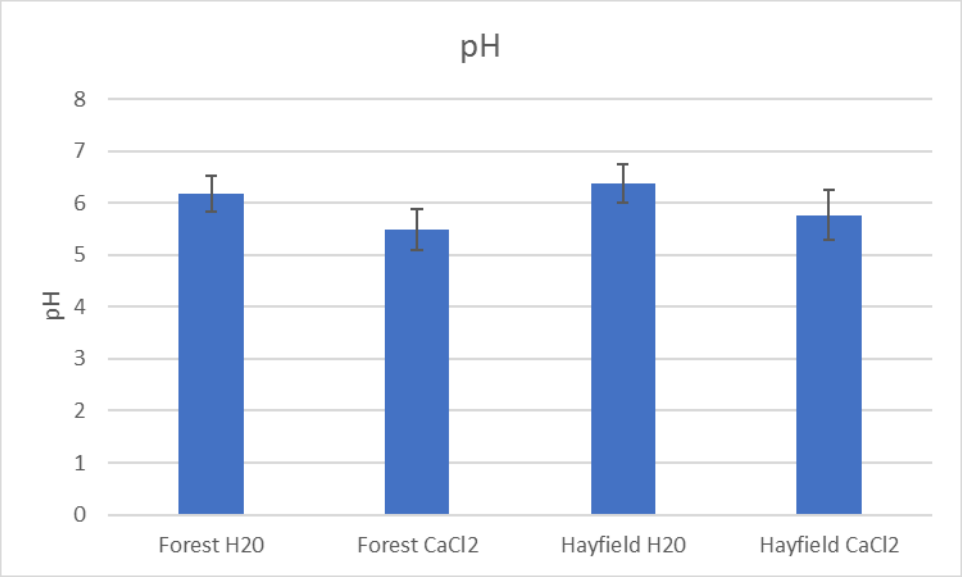

Figure 8. Mean and standard deviation of the two pH measurements (H_20 and $CaCl_2$) between the hayfield and forest sites.

The N % (Figure 9) in the soil between the two plot sites are significantly different with a p value of 0.000 (Table 1). The forest site had significantly more average N % (an average of 0.47% and a standard deviation of 0.21) than the hayfield site (an average of 0.22% and a standard deviation of 0.04).

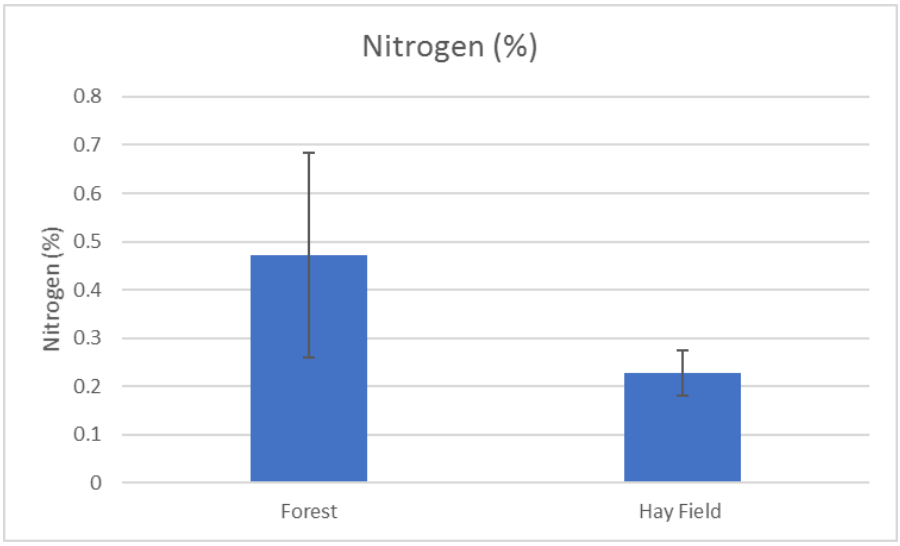

Figure 9: Nitrogen percentage means and standard deviation in the forest and hayfield plot sites

The C % (Figure 9) of the soil in the old growth forest and hayfield plots show a statistically significant difference with a p calc values of 0.001 (Table 1). The forest site had significantly more C % (an average of 6.5 % and a standard deviation of 3.54) than the hayfield site (an average of 2.33 % and a standard deviation of 0.51).

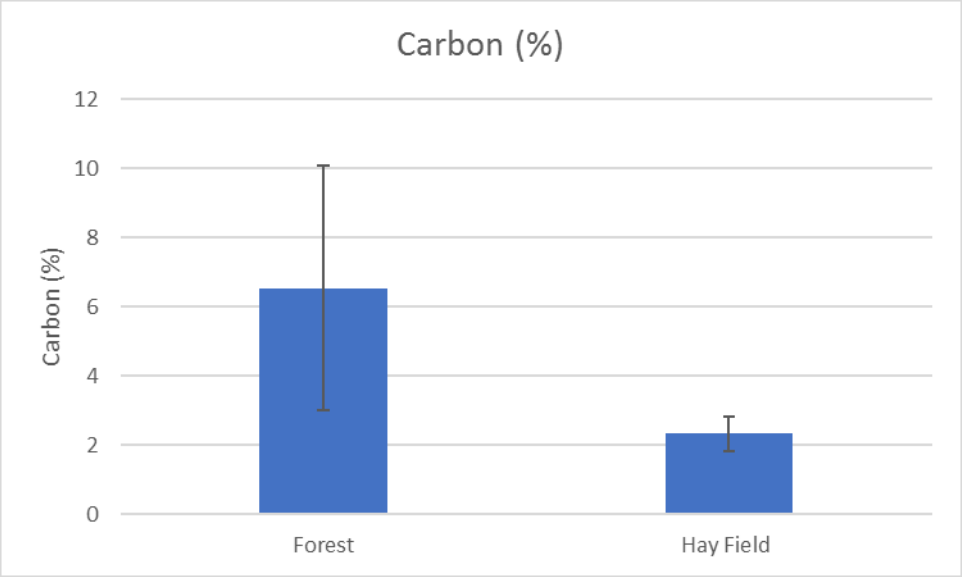

Figure 10: Carbon % means and standard deviation in the forest and hayfield plot sites.

The S % had a high skewness and kurtosis, so the data (Appendix 1) was unable to be transformed and used with an ANOVA. For the purpose of results, it is not known statistically if the two data plots are significantly different. But in using the raw data we can discover that there also appears to be a large difference between the percent of sulphur found within the forest site, then that of the hayfield site. The forest sites sulphur percentage average was 0.039%, with a standard deviation of 0.017. The hayfield site has a sulphur percentage average of 0.021% with a standard deviation of 0.005. Below is the data for sulphur percentage graphed.

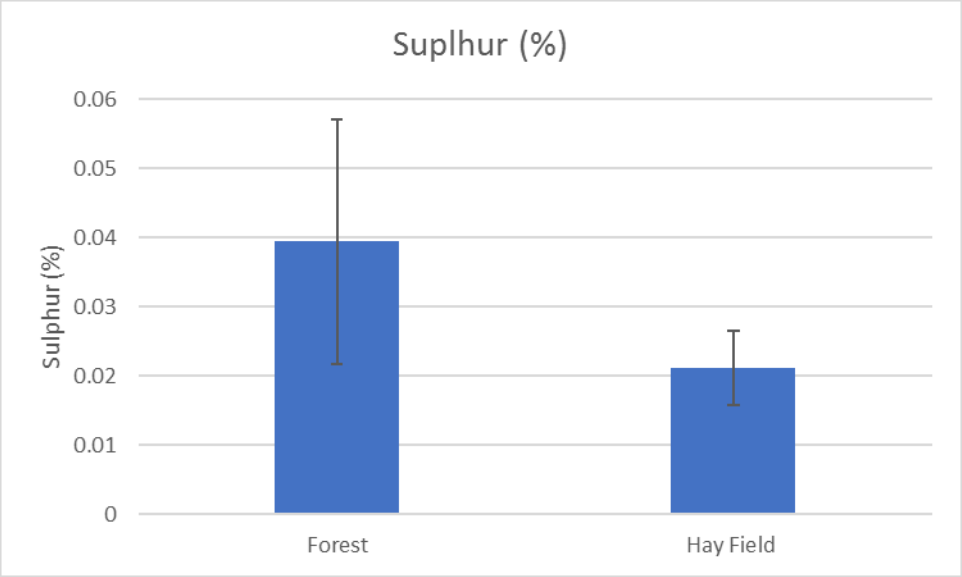

Figure 11: Sulphur percentage means and standard deviation in the forest and hayfield plot sites.

7. DISCUSSION

The results from the previous section demonstrates the conditions of the hayfield and old growth forest sites. The results show that there is a statistically significant difference in all aspects except the soils pH between the two sites. This information is important in understanding the effects of farming practices on soil, as well as how soil is altered through changes in land use. This data information is important as it both provides knowledge to farmers about field soil conditions, as well as knowledge as to how forest and agriculture soils significantly differ. This data also adds to baseline data for future researchers when studying the past conditions of the soils. These results can help in understanding how land use change and farming practices may affect a soils pH, CNS levels, and soil compaction. This research allows for an addition to existing baseline data and will contribute to ameliorating certainty when determining the impacts of farming and land use changes on Northern Ontario soils, as well as forest soil conditions.

The measurement showing no significant difference between the sites was the soil pH, but the Db and CN showed statistically significant differences. An overall conclusion, that the two sites are significantly different can be made with the results analysed from this research. However, as a caveat, it should be noted that the amount of C and N may not be so different when the Db is factored in with a constant depth (as previously mentioned, this was not done for this thesis due to inaccessibility of SPSS)

7.1 pH AMOUNTS

The forest and hayfield site resulted in being not significantly different with very similar pH amounts found. The old growth forest site was found to have an average overall pH level of 6.18. The hayfield sites pH levels were at an average of 6.38. The pH

measurements obtain a small standard deviation falling between 0.34 and 0.48, this indicates that the pH values of the soils are well represented through the data analysis. Acidity is important for plant growth as it have a significant impact on the nutrient availability and nutrient cycling, while changed in the soils pH can significantly affect the soils rate of carbon and nitrogen cycling (Kemmit *et al.* 2006; Xi *et al*. 2017). Soil pH is important in the maintenance of decomposition rates within the soils (Miller and Gardiner 2001: 161) and is vital in stimulation overall biomass growth that results in the increase in the availability of organic matter for soil decomposers (Pietri and Brookes 2008). Miller and Gardiner (2001) state that a pH of 5.5 for organic soils, and 6.5 for mineral soils is most suitable for plant growth. Knowing this, one can assume that as the levels of soil fall within the suitable pH, that both sites are expected to sustain plant growth, and have an overall good soil health.

7.2 SOIL COMPACTION/BULK DENSITY

The results show that there is a significant difference between the soil compaction (DB) of the old growth forest and the hayfield sites. In speaking with the owner of the land, he explained the hayfield has been agriculturally used for at least 50 years, and the forest has generally been left untouched. This would describe the differences between the two sites bulk densities as being caused by intensive agricultural practices, as the hayfield is often used to grow one to two crops per season (summer). This indicates that there has been no significant change in the use of either plots in the past 20 years, though the type of vegetation grown in the field may have differed some years.

Since the forest has been untouched for the known past, the soil has not undergone any stresses that would cause an effect on the soil compaction. In agricultural

circumstances soil compaction is caused by many factors defined by Barzegar *et al.* (2006) as activities such as high amounts of traffic from tilling, seeding, and harvesting the fields, associated with overall crop performance. These activities taken place often twice in a growing season results in what Soanne and van Ouwerkerk (1994) describe as the soils layers being forced or pressed together from outside forces such as farming machinery, and this is a major cause in the increase in the soils compaction.

7.3 CARBON, NITROGEN AND SULPHUR CONTENTS

The results gathered from the CNS % data shows a significant difference in the soils' C and N %, with a statistically unknown difference in the S %. The forest site shows a large significant difference in the C % and N %.

The significant difference in the C % in the forest and hayfield sites would back up Lal' research (2005) stating that the depletion of the soils organic carbon (SOC) is caused by many factors, including tillage changes and a lower amount of overall biomass that is returned to the soil. Explaining that there would be a large difference in the forest site when compared to the hayfield, as the field undergoes annual tillage (and other farming practices) and changes to the soil. This result reinforces the evidence presented by Davidson and Ackerman (1993) that changes in soils areas that have transitioned from forest land to agricultural land use sees a significant depletion of the SOC stock by 20-50%. These results make it evident that agriculture practices are a large factor into the lower C % within the soil when compared to forest soils.

Though an ANOVA was not able to be completed for the S %, the raw data shows that there is a large difference in the average percentage of S found in the forest site

(average 0.039%) than the average sulphur percentage found in the hayfield site (average 0.021%).

7.4 APPLICABILITY

With the data showing significant overall differences between the forest and hayfield site with exception to the soils pH, this data can be used in a few different ways. In comparing the values discovered in this paper with values that are considered desirable based on literature, the bulk density, pH levels, and CNS levels all fall within the spectrum of what is considered correct from the literature (Lal 2005, Batjes 1996). This result shows that the soil within the hayfield site has a current state of soil productivity and has the ability to support annual agricultural needs. As this data is based on one sample time, it does not show any information as to if the soil is currently improving, declining or remaining the same.

7.5 POTENTIAL OR FUTURE RESEARCH

This thesis was designed to create and add to a baseline of data for farm and forest soils in northwestern Ontario. Following a similar thesis from French (2019) of a comparison of hayfield and pasture soils in the Thunder Bay district. These data sets can be used to understand how farming practices impact soils, as well as understand the old growth forests' overall soil health. French found that the hayfield and pasture sites examined to be nearly identical (2019) and the data collected for Carbon and Nitrogen in this thesis show that the hayfield site is also nearly identical to the data of the French (2019) thesis. The forest site shows significantly lower means for Db and larger means for C % and N %, which can be attributed to the lack of farming practices on these soils.

There is a great potential to utilize the findings in data of this thesis for further research. Firstly, it can be used to increase the knowledge and data on soil health within Old Growth forests of northwestern Ontario and the Great Lakes St. Lawrence forest as well as being a benchmark dataset for future research looking at the same variables. These comparisons may allow future research into a better understanding of how farming practices have such significant effects on the soils pH, soil compaction and CNS levels.

8. CONCLUSION

The data of the forest and hayfield sites displays an overall significant difference (a = 0.05) across all measurements with the exception of the soil's pH and S%. These results offer an increased knowledge and data availability for the condition and differences of both sites. The results demonstrate an excellent baseline of data for future studies for the areas soil, both farmlands and natural old growth forests. Differences in the soil compaction and CN percentages show that the forest area contains overall higher amounts of carbon, nitrogen, and has a much lower soil compaction. The pH values being not significantly different support the soils health and ability to sustain plant life.

The potential of this research and data can be reached through further expansion and addition to similar data sets and future research. Nevertheless, this data is valuable to the knowledge and understanding of soil heath, predominantly when a land use change has occurred. This data also adds to existing research pertaining to current soil qualities of agricultural fields. As the data was collected over a very limited time and limited spatial extension, it does not affect the quality of the samples, it is evident that a larger sample size for both time and area would offer a more extensive insight into the soil's health and contrasts.

This thesis has successfully displayed a significant difference between an old growth forests soils to that of an annually cultivated hayfield in the Rainy River area of Northwestern Ontario.

9. LITERATURE CITED

Agriculture and Agri-Food Canada-AAFC. Canada Land Inventory-Land Capability Class Descriptions for Agriculture. Available online: http://sis.agr.gc.ca/cansis/nsdb/cli/classdesc.html (accessed on October 16, 2019).

Ahmadi, I. and H. Ghaur. 2015. Effects of soil moisture content and tractor wheeling intensity on traffic-induced soil compaction. Journal of Central European Agriculture 16(4): 489-502.

Batjes, N.H. 1996. Total carbon and nitrogen in the soils of the world. European Journal of Soil Science 47(2).

Barzegar, A., A. Yousefi and N. Zargoosh. 2016. Water stress and soil compaction impacts on clover growth and nutrient concentration. Eurasian Journal of Soil Science 5(2): 139-145.

Bhatti, J.S., Apps, M.J., Tarnocai, C., Karjalainen, T., Stocks, B.J., Shaw, C., 2002. Estimates of soil organic carbon stocks in central Canada using three different approaches. Can. J. Forest Res. 32, 805–812

Brady, N.C., Weil, R.R. 2002. The Nature and Properties of Soil, 13th ed. Springer Netherlands, 249 pp.

Chapagain, T. 2017. Farming in Northern Ontario: untapped potential for the future. Agronomy 7(3): 59-72.

Crins, J.W.; Gray, A.P.; Uhlig, C.P.W.; Wester, C.M. 2009. The Ecosystems of Ontario, Part 1: Ecozones and Ecoregions; Technical Report SIB TER IMA TR-01; Ontario Ministry of Natural Resources, Queen's Printer for Ontario: Toronto, ON, Canada.

Davidson, E.A., Ackerman, I.L. 1993. Changes in soil carbon inventories following cultivation of previously untilled soils. Biogeochemistry 20, 161–193.

Doran, J.W. and M.R. Zeiss. 2000. Soil health and sustainability: managing the biotic component of soil quality. Applied Soil Ecology 15(1): 3-11.

Flynn, M.G., J.M. Finnan, E.M. Curley and K.P. McDonnell. 2018. Effect of harvest timing and soil moisture content on compaction, growth and harvest yield in a *Miscanthus* cropping system. Agriculture 8(10):148.

French, B.C. 2019. A comparison of the quality of hayfield and pasture soils on a Northwestern Ontario farm. 63 Pp. HBEM Thesis, Lakehead University.

Gregorich, E.G., M.R. Carter, D.A. Angers, C.M. Monreal and B.H. Ellert. 1994. Towards a minimum data set to assess soil organic matter quality in agricultural soils. Canadian Journal of Soil Science 74(4): 367-385.

Green, T.R., L.R. Ahuja and J.G. Benjamin. 2003. Advances and challenges in predicting agricultural management effects on soil hydraulic properties. Geoderma 116(1-2): 3-27.

Hamza, M.A. and W.K. Anderson. 2005. Soil compaction in cropping systems: A review of the nature, causes and possible solutions. Soil and Tillage Research 82(2): 121-145

Hart, S.C., Sollins, P. 1998. Soil carbon and nitrogen pools and processes in an old growth conifer forest 13 years after trenching. Can. J. Forest Res. 28 (8), 1261–1265

Johnston, A.E., P.R. Poulton and K. Coleman. 2009. Chapter 1 soil organic matter: its importance in sustainable agriculture and carbon dioxide fluxes. Advances in Agronomy 101:1-57.

Kemmitt, S.J., D. Wright, K.W. Goulding and D.L. Jones. 2006. pH regulation of carbon and nitrogen dynamics in two agricultural soils. Soil Biology and Biochemistry 38(5): 898-911.

Lal. R. (2005). Forest soils and carbon sequestration. Forest Ecology and Management 220: 242-258

Loveland, P. and J. Webb. 2003. Is there a critical level of organic matter in the agricultural soils of temperate regions: a review. Soil and Tillage Research 70(1): 1-18.

Miller, R.W., and D.T. Gardiner. 2001. Soils in our Environment (9th ed.). Prentice Hall, New Jersey.

Molnar-Irimie, A. 2016. Finite element method study on stress state in soil induced by agricultural traffic. Bulletin of University of Agricultural Sciences and Veterinary Medicine 73(2): 275-279.

Ontario Institute of Pedology. 1984. Soils of Fort Frances – Rainy River Area Ontario. Soil survey report. No. 51. Ontario Ministry of Agriculture and food. (MAP)

Pietri, J.C. and P.C. Brookes. 2008. Relationships between soil pH and microbial properties in a UK arable soil. Soil Biology and Biochemistry 40(7): 1856-1861.

Soane, B.D. and C. van Ouwerkerk. 1994. Chapter 1 – Soil compaction problems in world agriculture. Developments in Agricultural Engineering 11: 1-21.

Strahler, A., and A. Strahler. 1997. Physical Geography: Science and Systems of the Human Environment. John Wiley & Sons, Inc., New York

Thomas, G.W. 1996. Soil pH and soil acidity. Methods of Soil Analysis 3(16): 475.

Wardle, D.A. 1992. A comparative assessment of factors which influence microbial biomass carbon and nitrogen levels in soil. Biological Reviews 67(3): 321-356

Willatt, S.T. and D.M. Pullar. 1984. Changes in soil physical properties under grazed pastures. Australian Journal of Soil Research 22(3): 343-348

Xi, R., X.E. Long, S. Huang and H. Yao. 2017. pH rather than nitrification and urease inhibitors determines the community of ammonia oxidizers in a vegetable soil. AMB Express 7(1): 1-14.

APPENDICES

Appendix I Raw Data

Table 1: List of the pH values for the Hayfield (A) and the old growth forest (B) samples. Both samples were measured using H_2O and $CaCl_2$ solutions in separate containers.

	A (Hayfield)		B (Old Growth Forest	
Sample #	H2O	CaCl2	H2O	CaCl2
1	6.05	5.27	6.02	5.11
2	6.13	5.51	6.35	5.5
3	5.76	5.09	6.2	5.58
4	6.2	5.57	6.74	6.18
5	6.22	5.88	6.46	5.83
6	6.59	5.6	6.24	5.69
7	6.57	6.15	6.54	5.91
8	6.44	5.69	6.06	5.55
9	6.35	6.02	6.4	5.77
10	6.43	5.86	5.79	5.2
11	6.75	6.24	5.94	5.3
12	6.65	6.14	6.18	5.42
13	6.45	5.84	5.68	4.93
14	7.13	6.56	5.96	5.11
15	5.65	4.7	5.6	6.05
16	6.73	6.26	6.72	4.86

Table 2: Soil sample weights in grams for the Hayfield (A) sample site. The value used in the bulk density calculation is Soil Weight.

A (Hayfield)			
Sample #	Combined Weight	Bay Weight	Soil weight
1	407.46	16.63	390.83
2	385.75	16.81	368.94
3	426.3	16.62	409.68
4	410.52	16.71	393.81
5	353.82	16.57	337.25
6	356.13	16.51	339.62
7	375.02	16.45	358.57
8	285.53	16.47	269.06
9	332.9	16.61	316.29
10	336.29	16.64	319.65
11	370.2	16.58	353.62
12	354.17	16.56	337.61
13	348.95	16.69	332.26
14	349.77	16.71	333.06
15	339.55	16.42	323.13
16	338.18	16.35	321.83

Table 3: Soil sample weights in grams for the Old Growth Forest (B) sample site. The value used in the bulk density calculation is Soil Weight.

B (Old Growth Forest)			
Sample #	Combined Weight	Bag Weight	Soil weight
1	201.14	16.37	184.77
2	234.11	16.32	217.79
3	231.51	16.42	215.09
4	168.63	16.52	152.11
5	131.74	16.70	115.04
6	212.55	16.61	195.94
7	249.3	16.56	232.74
8	122.62	16.64	105.98
9	198.6	16.35	182.25
10	111.92	16.26	95.66
11	109.62	16.31	93.31
12	155.32	16.44	138.88
13	191.06	16.39	174.67
14	180.88	16.43	164.45
15	212.39	16.31	196.08
16	207.85	16.25	191.6

Table 4: The Bulk density values of each sample plot.

A (hayfield)	B (Forest)
1.69	0.80
1.59	0.94
1.77	0.93
1.70	0.66
1.46	0.50
1.47	0.85
1.55	1.00
1.16	0.46
1.37	0.79
1.38	0.41
1.53	0.40
1.46	0.60
1.43	0.75
1.44	0.71
1.39	0.85
1.39	0.83

Table 5: The Hayfield CNS values displayed before and after adjustments for moisture content.

	Original Values			Adjusted for Moisutre Content		
Sample #	C(%)	N(%)	S(%)	C(%)	N(%)	S(%)
1	2.040	0.200	0.019	0.618	0.061	0.006
2	1.780	0.170	0.017	1.095	0.105	0.010
3	1.390	0.140	0.013	0.981	0.099	0.009
4	1.510	0.160	0.014	1.065	0.113	0.010
5	1.930	0.190	0.016	1.188	0.117	0.010
6	2.560	0.240	0.033	0.860	0.081	0.011
7	2.930	0.290	0.030	0.984	0.097	0.010
8	2.460	0.230	0.020	0.431	0.040	0.004
9	2.970	0.270	0.023	1.115	0.101	0.009
10	2.340	0.230	0.021	0.783	0.077	0.007
11	2.330	0.230	0.021	0.948	0.094	0.009
12	2.190	0.210	0.019	0.974	0.093	0.008
13	2.520	0.260	0.021	1.305	0.135	0.011
14	2.820	0.290	0.024	0.912	0.094	0.008
15	2.350	0.240	0.020	0.917	0.094	0.008
16	3.150	0.290	0.027	1.055	0.097	0.009

Table 6: The Old Growth Forests CNS values displayed before and after adjustments for moisture content.

	Original Values			Adjusted for Moisture Content		
Sample #	C(%)	N(%)	S(%)	C(%)	N(%)	S(%)
1	7.110	0.480	0.046	2.468	0.167	0.016
2	3.170	0.270	0.025	3.491	0.297	0.028
3	4.910	0.390	0.032	1.182	0.094	0.008
4	0.000	0.000	0.000	0.000	0.000	0.000
5	16.090	1.020	0.084	4.073	0.258	0.021
6	6.470	0.480	0.052	2.334	0.173	0.019
7	6.530	0.490	0.040	2.111	0.158	0.013
8	9.590	0.590	0.052	2.084	0.128	0.011
9	6.730	0.490	0.040	2.630	0.191	0.016
10	6.270	0.440	0.034	0.423	0.030	0.002
11	10.650	0.780	0.059	2.209	0.162	0.012
12	7.370	0.550	0.041	1.771	0.132	0.010
13	3.990	0.310	0.027	1.442	0.112	0.010
14	3.700	0.280	0.025	1.508	0.114	0.010
15	3.140	0.290	0.018	0.951	0.088	0.005
16	2.440	0.210	0.016	1.088	0.094	0.007

Appendix II – SPSS results tables and descriptive statistics for the above raw data.

Table 1: Bulk Density descriptive statistics with skewness and kurtosis

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Bulk Density	32	0.403	1.768	1.101	0.426	-0.129	0.414	-1.390	0.809
Valid N (listwise)	32								

Table 2: Bulk Density descriptive statistics (Mean, Standard Deviation, and N)

Descriptive Statistics

Dependent Variable:

Sample	Mean	Std. Deviation	N
F	0.717	0.193	16
H	1.485	0.150	16
Total	1.101	0.426	32

Table 3: Bulk Density ANOVA Table

Tests of Between-Subjects Effects

Dependent Variable:

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.724[a]	1	4.724	157.734	0.000
Intercept	38.774	1	38.774	1294.590	0.000
Sample	4.724	1	4.724	157.734	0.000
Error	0.899	30	0.030		
Total	44.397	32			
Corrected Total	5.623	31			

a. R Squared = .840 (Adjusted R Squared = .835)

Table 4: PhH_20 descriptive statistics with skewness and kurtosis

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
pH H20	32	5.60	7.13	6.2806	0.36968	-0.021	0.414	-0.372	0.809
Valid N (listwise)	32								

Table 5: PhH20 Descriptive statistics (Mean, Standard Deviation, and N)

Descriptive Statistics

Dependent Variable:

Sample	Mean	Std. Deviation	N
F	6.1800	0.34438	16
H	6.3813	0.37714	16
Total	6.2806	0.36968	32

Table 6: PhH20 ANOVA table

Tests of Between-Subjects Effects

Dependent Variable:

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.324[a]	1	0.324	2.484	0.125
Intercept	1262.280	1	1262.280	9678.639	0.000
Sample	0.324	1	0.324	2.484	0.125
Error	3.913	30	0.130		
Total	1266.517	32			
Corrected Total	4.237	31			

a. R Squared = .076 (Adjusted R Squared = .046)

Table 7: PhCaCl2 descriptive statistics with skewness and kurtosis

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
pH CaCl2	32	4.70	6.56	5.6366	0.45405	-0.154	0.414	-0.557	0.809
Valid N (listwise)	32								

Table 8: PhCaCl2 Descriptive statistics (Mean, Standard Deviation, and N)

Descriptive Statistics

Dependent Variable:

Sample	Mean	Std. Deviation	N
F	5.50	0.395	16
H	5.77	0.480	16
Total	5.64	0.454	32

Table 9: PhCaCl2 ANOVA table

Tests of Between-Subjects Effects

Dependent Variable:

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.602[a]	1	0.602	3.121	0.087
Intercept	1016.667	1	1016.667	5268.733	0.000
Sample	0.602	1	0.602	3.121	0.087
Error	5.789	30	0.193		
Total	1023.058	32			
Corrected Total	6.391	31			

a. R Squared = .094 (Adjusted R Squared = .064)

Table 10: Carbon moisture content (CMC) descriptive statistics with skewness and kurtosis

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
LOGCMC	32	0.00000	1.24924	0.66278	0.24661	0.130	0.414	0.968	0.809
Valid N (listwise)	32								

Table 11: CMC descriptive statistics (Mean, Standard Deviation, and N)

Descriptive Statistics

Dependent Variable:

Sample	Mean	Std. Deviation	N
F	0.800	0.283	16
H	0.525	0.071	16
Total	0.663	0.247	32

Table 12: CMC ANOVA table

Tests of Between-Subjects Effects

Dependent Variable:

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.603[a]	1	0.603	14.110	0.001
Intercept	14.057	1	14.057	328.881	0.000
Sample	0.603	1	0.603	14.110	0.001
Error	1.282	30	0.043		
Total	15.942	32			
Corrected Total	1.885	31			

a. R Squared = .320 (Adjusted R Squared = .297)

Table 13: Nitrogen Moisture Content (NMC) descriptive statistics with skewness and kurtosis

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
LOGNMC +1	32	0.000	0.314	0.125	0.063	1.088	0.414	1.877	0.809
Valid N (listwise)	32								

Table 14: NMC descriptive statistics (Mean, Standard Deviation, and N)

Descriptive Statistics

Dependent Variable:

Sample	Mean	Std. Deviation	N
F	0.1697	0.0614	15
H	0.0909	0.0174	16
Total	0.1291	0.0592	31

Table 15: NMC ANOVA table

Tests of Between-Subjects Effects

Dependent Variable:

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.048[a]	1	0.048	24.310	0.000
Intercept	0.526	1	0.526	266.251	0.000
Sample	0.048	1	0.048	24.310	0.000
Error	0.057	29	0.002		
Total	0.622	31			
Corrected Total	0.105	30			

a. R Squared = .456 (Adjusted R Squared = .437)