Comparing soil organic matter and nitrogen content to corn field treatments utilizing no-till, tillage, and cover cropping in Waterford, Pennsylvania.

By

Adrienne S. Hanas

Dr. Casey Bradshaw-Wilson and Dr. Rich Bowden

Department of Environmental Science

Allegheny College

Meadville, Pennsylvania

April, 2025

Comparing soil organic matter and nitrogen content to corn field treatments utilizing no-till, tillage, and cover cropping in Waterford, Pennsylvania.

By

Adrienne S. Hanas

Dr. Casey Bradshaw-Wilson and Dr. Rich Bowden

Department of Environmental Science

Allegheny College

Meadville, Pennsylvania

April, 2025

Submitted in fulfillment of the senior thesis requirements of the Department of Environmental Science and Sustainability at Allegheny College and approved by the senior thesis committee.

Dr. Casey Bradshaw-Wilson and Dr. Rich Bowden
Adrienne S. Hanas

Table Of Contents

List of Tables

List of Figures

Acknowledgements

First and foremost, thank you Casey for your encouragement of my agricultural background and interests throughout the entirety of this process. Your support and advice is one of the most valuable aspects of my Allegheny career and has made me a stronger, more confident researcher and writer. When I felt lost in my passion for environmental science, you were there to guide me toward my goals. Your unconditional kindness is a light and a gift that has shone through the most challenging moments. It has inspired me to practice patience and understanding, to which I am forever grateful.

Thank you JR, for bringing me closer to agriculture and teaching me everything I know about it. Thank you for the countless hours you spent helping me study, research, and balance my school work with life. Even when I felt most discouraged, you were there to push me towards success. Your whole hearted love and support never waivered, to which I am eternally grateful.

Thank you Ben, for showing me dedication to what you love. Your love of farming radiates an indescribable work ethic, to which I value and strive to mimic. Thank you for always being proud of me and for all you’ve done for me throughout this process. I cannot express my gratitude to you for showing me pure strength, kindness, wisdom, and what a best friend truly is.

Thank you to my dad, who cheered me on when everyone else fell silent. Even from heaven, I could feel your encouragement to persevere when it was most overwhelming. Your dedication to both nature and agriculture lead me to my passion for conservation and the development of this project. I could not have done it without my guardian angel, and I owe this accomplishment to you.

Finally, a huge thank you to my mom, who has shown me what true strength is. Your success and determination is admirable, to which I attempted to mirror in the process of writing this thesis. The most devastating challenges in life never stopped you from providing a nurturing home. You never let me give up on myself, and influenced my optimistic mindset throughout my entire college career. I am beyond appreciative of your support throughout the last few years, and recognize how blessed I am to have you by my side.

Name: Adrienne Hanas Date: April, 2025

Major: Environmental Science and Sustainability

Thesis Committee: Dr. Casey Bradshaw-Wilson, Dr. Rich Bowden

Title: Comparing soil organic matter and nitrogen content to corn field treatments utilizing no-till, tillage, and cover cropping in Waterford, Pennsylvania.

Agriculture has changed throughout history into what it is today. Present large-scale grain farming operations have dominated the United States and pose concerns with soil health and environmental sustainability. Tillage of monoculture crop fields has resulted in loss of topsoil with consistent erosion, ultimately leading to devastating losses of nutrients including nitrogen and soil organic matter, both of which are responsible for soil health, and plant function. More recent sustainable treatments on large-scale fields including no-till and cover cropping help to mitigate the environmental impact of agriculture while maintaining profitable yields, but research has focused on the midwest region of the United States. This study investigates the correlation between the decision to utilize cover cropping with tillage and no-till grain farming, and soil organic matter and nitrogen content in Waterford, Pennsylvania. Results show that the combination of no-till and cover cropping field treatments supports the highest amount of both soil organic matter and nitrogen, while tillage without cover crops held the lowest. This research suggests adopting sustainable farming practices in Erie County, Pennsylvania increases soil health, which is linked to higher yields, carbon sequestration, and mitigation of soil and surrounding ecosystem degradation. Further research should be conducted on this response to yield and profitability to farmers in this area, and an economic analysis on the feasibility to transition from tillage to no-till systems.

Introduction

Across the globe, agriculture has changed in significant ways over the last few hundred years. An area of vast, rich forest that once stretched across the entirety of America is now the world's largest producer of corn and second largest for soybeans (USDA).

The history of the United States' food system began in the 1800s when people first settled this land. Indigenous people grew corn *(zea mays)*, squash *(cucurbita)*, and beans *(phaseolus vulgaris)*, or what is referred to as the 'three sisters' as these crops were best suited for the area. However, when European settlers arrived, they forcibly removed Native Americans and began clear cutting forests to grow row crops in order to feed the influx of people (Binkley 2021). The first-row crops were planted, managed, and harvested by hand or animal drawn implements. One of the more effective and well-known tools was the moldboard plow, which was pulled by livestock and used in a way that caused little to no disturbance to the soil; however, the introduction of the steam horse in 1910 meant the revolution of fossil-fueled, powerful technology and agriculture as we know it today (Lal et al. 2007). It was the first step to new and efficient equipment that made it easy to farm on large scales, or what we consider conventional farming.

During the 1900s plowing the soil dominated farms across the United States. Tillage is the act of churning the soil over itself and is used to distribute manure and clear residue, weeds, and uneven surfaces for the next growing season. While it has its benefits, tillage does cause issues with erosion, water permeability, and nutrient loss (Holland 2004). Disrupting the soil destroys root systems that hold soil particles together and prevent topsoil from running off into surrounding ecosystems. Tillage allows heavy rain, snow, and even wind to move topsoil off fields and into waterways, and is a large part of the Dust Bowl tragedy that occurred in the 1930s (Lal et al. 2007). A loss of topsoil means a loss of the vital nutrients and organic matter that plants heavily rely on to grow and produce healthy food (Cooper 2017). Tillage also aids in compaction as it only aggravates the top few inches of the soil, resulting in difficulty for plants to expand their roots deep into the ground and allow water to seep in or hold moisture in the soil (Holland 2004). The loss of nutrients and soil structure has forced farmers to invest in irrigation systems and fertilizer.

Soil organic matter (SOM) is necessary to healthy crop growth and sustainability. SOM has the ability to aid in nutrient retention and transport through soil systems and plants while also maintaining stability of them (Fisher-Power 2018). SOM is also responsible for controlling contaminants in the soil away from leaching into groundwater or harmful absorption by the plant itself (Zhang et al. 2009). On agricultural fields, pesticides are used continuously to control pests for economic benefit. However, pesticides have been linked to environmental degradation. Research shows that soil organic matter is the single most important soil constituent for pesticide absorption and control, which improves the sustainability of surrounding ecosystems and watersheds from such degradation (Farenhorst 2006).

Nitrogen works in conjunction with soil organic matter in soil to improve the health of the crop and maintain environmental sustainability. Nitrogen is necessary for soil organic matter and soil organic carbon production and availability to the plant (Oelofse et al. 2015). It increases the effectiveness of SOM and raises pH in soil, reducing acidification that can be harmful to plants and soil ecosystems (Michael et al. 2015). Plants depend on nitrogen as nutrients to promote healthy growth, development, reproduction, carbon sequestration, and photosynthesis, as well as aid in decomposition and nutrient uptake (Frank & Groffman 2009). Additionally, nitrogen assists microbial and root system relationships which in return produces higher yield, economically benefiting farmers (Frank & Groffman 2009).

No-till is a technique used in crop farming that does not require the plowing of soils, but requires specialized equipment for planting and maintaining. No-till minimizes topsoil disruption by drilling seed directly into the ground rather than churning soil over as plowing does. Less disturbance to the soil is better for water infiltration, erosion, nutrient loss, and soil organic matter (Holland 2004). In addition, no-till fields facilitate habitat for plants to disperse their root systems deep into the ground and hold their structure, which strengthens their ability to defend against harsh wind and damaging precipitation. It also allows for increased water infiltration and storage, making it much more accessible for crops. During floods, the water drains faster, and in droughts, the water is stored longer (Holland 2004).

Climate change is exacerbating weather patterns and making it difficult for farmers to prepare for such events, and is one reason many are switching to these new, sustainable methods

(Scopel 2012). Fields that are not plowed also allow microorganisms to accumulate soil organic matter without breaking bonds. Soil health is directly related to the health of crops growing, and therefore, less fertilizer is needed. Not plowing encourages roots to hold the soil particles together and keep topsoil from eroding (Holland 2004). No-till farming benefits both the environment and the farmer.

There are techniques used in coherence with no-till agriculture that makes it possible for large-scale farming including zone building, cultimulching, and cover cropping. A zone builder is used to create deep but narrow trenches in the soil to help with compaction, and is used hand in hand with a cultimulcher- an implement built of rotating wheels that is pulled across fields to flatten any uneven spaces that are hindering growth.

Cover cropping, sometimes referred to as green manure, is used with no-till systems to incorporate nitrogen and organic matter into the soil without needing any synthetic or chemically produced additives (Otieno 2021). This entails a nitrogen fixing plant that is typically not harvested such as rye, clover, or vetch (Lowry & Brainard 2019). Cover crops act as legumes by fixing nitrogen from the atmosphere to the soil for future crops to absorb, reducing the need for synthetic fertilizer (Gardner 2009). In addition, cover crops sequester carbon dioxide from the atmosphere beyond growing seasons (Hu et al. 2024). Farmers either spray or roll crimp cover crops to kill them before planting cash crops, and the decomposition adds to the soil organic matter (Bezuidenhout et al. 2012). Research suggests a combination of sustainable practices on no-till fields works best for enhancing yields and soil health (Gardner 2009).

While there are many benefits to no-till, the return on investment may not be seen for many years. Corn stalk and cover crop residue left on fields can decrease yields, as it hinders a young seedling's ability to reach sunlight and develop new growth (Sharratt 2002). While plowing fields diminishes residue and establishes open ground for easier sprouting. This, along with financial drawbacks, is one reason many farmers have not yet adopted no-till. The cost of pesticides, specialized equipment, and risk of losses in yield and profit within the first few years makes it difficult to switch to no-till.

Farmers willing to convert to no-till will preserve topsoil and nutrients while reducing the need for fertilizer, conserving surrounding ecosystems from runoff and eutrophication and improving yields with the right combination of equipment and time (Kennedy & Schillinger 2006). Such changes will be necessary with a changing world.

Climate change is currently disrupting the weather patterns of the United States, making it difficult for farmers to be able to predict their growing seasons (Scopel 2012). The heating planet is causing exacerbated weather disasters including droughts and floods that are unusual for certain areas, and farmers are having to quickly adapt to these situations (Stokes 2010).

Erie County, Pennsylvania has been an area of crop and livestock farmland dating back hundreds of years. The diversity of soil types and topography of this region historically supplied the first settlers the ability to grow a variety of different crops including grasses, grains, fruits, and vegetables which remains similarly today (PHMC). Erie County's humid continental climate supports large-scale agriculture and sits at the tail end of the corn belt of the United States (PHMC). The government of Erie County has recognized the importance of agriculture in this area and has developed climate action plans to mitigate the impact climate change has had on farmers, including incentives to implement sustainable farming practices such as no-till (Erie Community Climate Action Plan). Today, Erie County participates in Pennsylvania's nationally recognized farmland preservation program and offers farmers the opportunity to get involved in agricultural conservation easements to protect their land (Seal of Erie County, Pennsylvania).

In a changing climate, sustainable farming practices are necessary to support agriculture as the backbone of humanity. Farmers profit and feasibility for change must be incorporated into the transition to such treatments. The goal of this study is to analyze the difference in soil organic matter and nitrogen content on tilled vs no-till fields utilizing cover crops in Waterford, Pennsylvania to determine the best combination of field treatments for soil health in this area. Research done on this topic has focused in the Midwest of the United States. This research is intended to provide critical information to all farmers in Northwestern Pennsylvania with which field treatments are most beneficial to their soil health.

Methods

This experiment took place in Waterford, Pennsylvania. In November of 2023, two farms were selected for evaluation and sampling: Jim and Jim Glover Farms and Porter Valley Farm. They are located 3 miles (4.82 km) apart from one another and share similar soil types and land attributes regarding topography, distance to French Creek, the main waterway in this area, and climate.

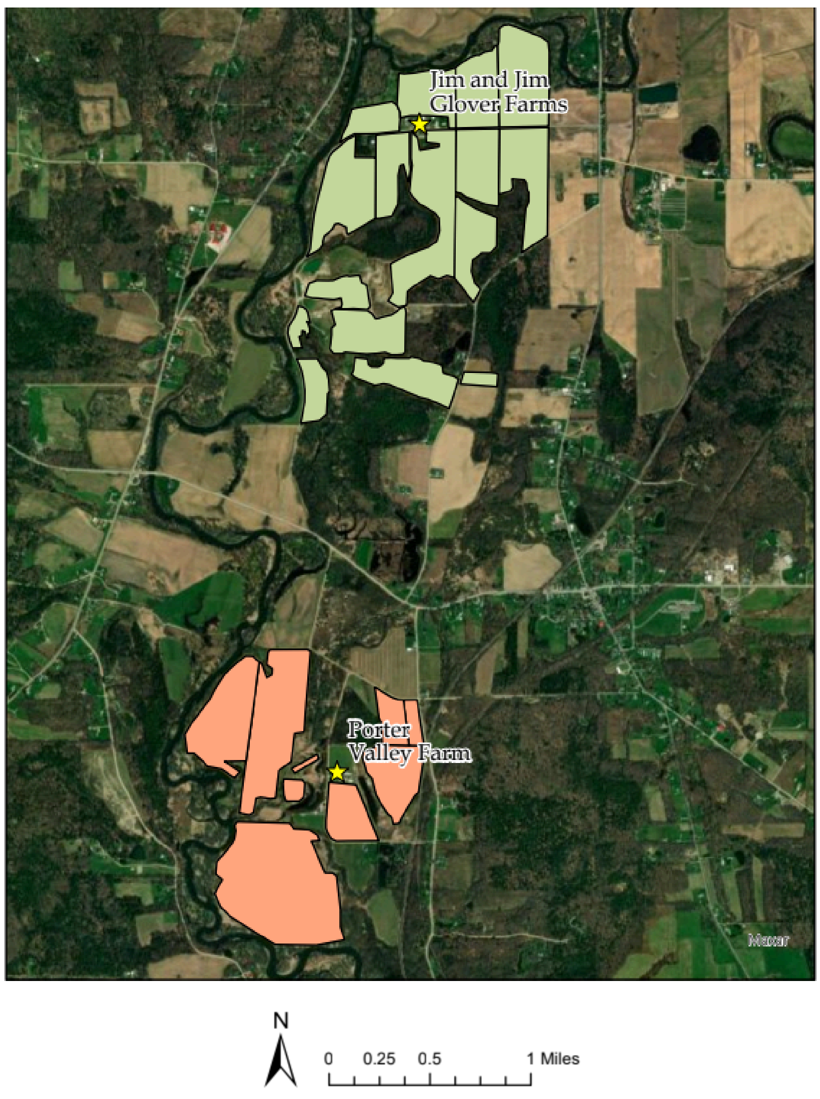

Figure 1. *Farms chosen for sampling in Erie County, Pennsylvania. Jim and Jim Glover Farms fields highlighted in green chosen for no-till sampling and Porter Valley Farm fields highlighted in orange chosen for tillage sampling.*

Jim and Jim Glover Farms use a no-till approach to planting corn while Porter Valley Farm uses tillage. On each of these farms, a combination of cover crops and no cover crops were used. The two farms were split into separate categories and assigned three fields per treatment for sampling. Each field, originally named by location, was given a coded name. Tillage without cover crops was labeled 1 with three fields subsequently named 1A, 1B, and 1C. Similarly, tillage fields with cover crops were labeled with 2 (A-C), no-till fields without cover crops as 3 (A-C), and no-till fields with cover crops as 4 (A-C).

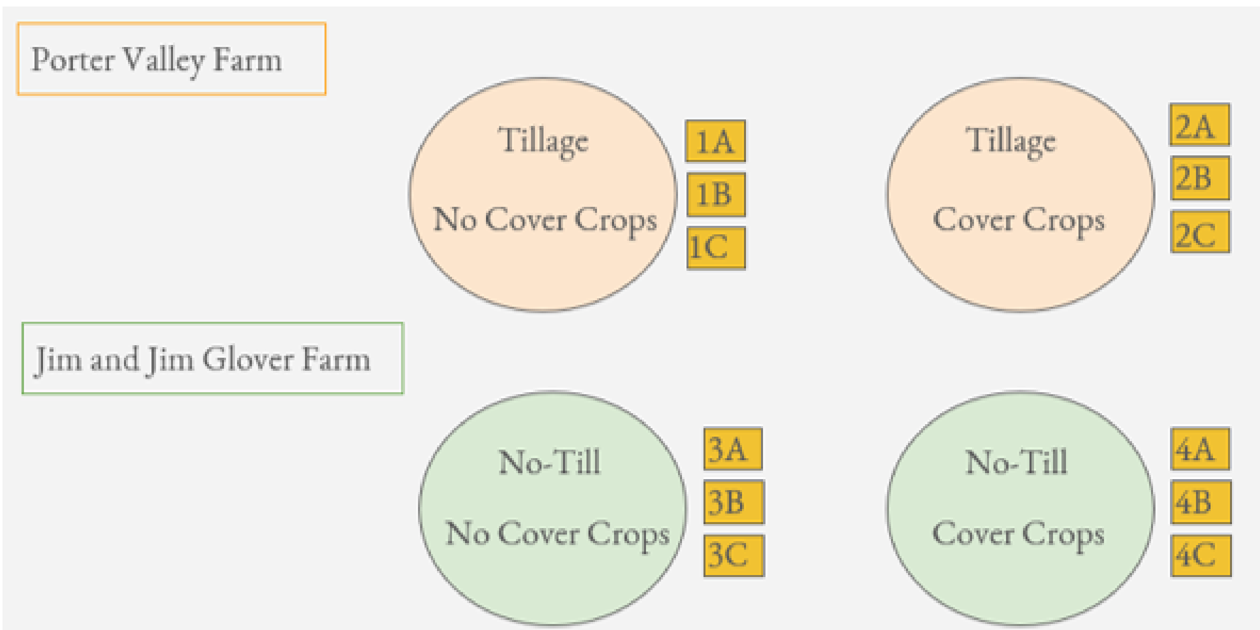

Figure 2. *Four field treatments for examination and field coding in relation to treatment for both Porter Valley Farm and Jim and Jim Glover Farms.*

Satellite images of the 12 coded fields were overlaid with a grid. The x axis was labeled 1 through 6, and the y axis was labeled A through J. A random number generator was used to choose a number and letter five times per field to arrange a random sampling of the field. The fields were divided into 6 equal longitudinal distances and 10 equal latitudinal distances. Grid lines were drawn to provide information on the travel distance needed to gather a sample at the correct place as reflected in the computer model.

For example, Figure 3 shows field 4A and the grid overlay. The yellow dots are the randomly selected sample sites determined by the random number generator (1D, 2C, 6C, 2J, 5F). The physical field distance from 1 to 6 is 905 feet (275.84 m), and from A to J is 1,350 feet

(411.48 m). Dividing the x axis of 905 feet by 6 results approximately 150 feet (45.72m) per square, and the y axis by 10 equals 135 feet (41.15m). Using the mobile application Pace Ruler: Measuring Distances with GNSS by Takafumi AMANO, the correct distance per square across and up the field were traveled by ATV to collect a soil sample at that location.

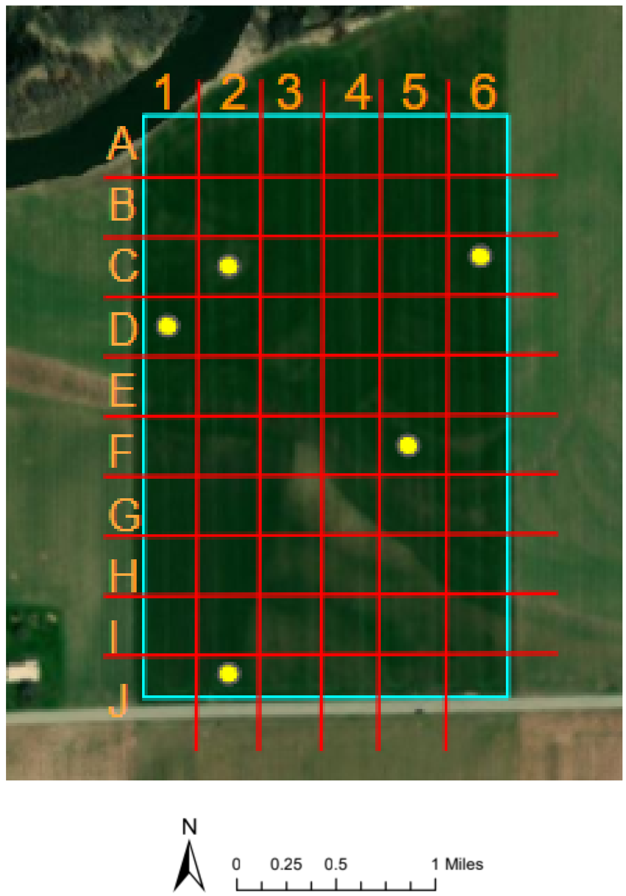

***Figure 3**. Field 4A, location Farm Creekside utilizing Treatment 4: No-till with cover crops, with grid overlay and randomly generated sampling site locations.*

A 36" stainless steel tubular t-style handle soil probe was used to extract soil core samples at the five randomly selected points across each of the 12 chosen fields. The five soil cores were placed into a cup and shaken up to evenly distribute the samples, and then transferred to a bag labeled to the associated field code.

Soil samples were sent to Penn State Agricultural Analytical Services Laboratory at The Pennsylvania State University in University Park, Pennsylvania. The samples were analyzed for soil pH, phosphorus (ppm), potassium (ppm), magnesium (ppm), calcium (ppm), acidity (meq/100g), organic matter (%), and nitrogen (%). For this experiment, the focus remains on the percentage of soil organic matter and nitrogen content.

The overall data collected includes sample date, field name, coded field ID name, field treatment 1-4, soil organic matter percentage, nitrogen content percentage, and acreage. This data was then updated in a chart for organizational purposes and used to create simplified graphics that can be compared to identify which field treatments provide the most soil organic matter and nitrogen. The results of this study will be issued to those involved with sustainable agriculture research, soil analysts, students of environmental interest, and farmers of this region. Distributing this information will provide valuable information on which treatment is most beneficial to both the farmer and the environment.

Results

Results of this study show that tillage treatments averaged higher in soil organic matter (SOM) than no-till treatments by 0.215%. Tillage treatments revealed identical averages for nitrogen content percentage as compared to no-till treatments with a result of 0.195%. The cover cropped tillage fields were higher in both with 3.4% soil organic matter and 0.21% nitrogen as compared to tillage without cover crops which averaged 3.37% soil organic matter and 0.18% nitrogen content. The no-till without cover crops scored highest for both soil organic matter with 3.47% and nitrogen content with 0.23% overall, while no-till with cover crops averaged the lowest in both categories overall with 2.87% soil organic matter and 0.16% nitrogen. Table 1 and Figures 4-5 present the averages for both soil organic matter percentage and nitrogen content percentage on each field treatment tested.

Treatment	Description	Soil Organic Matter (%)	Nitrogen (%)
1	Tillage without cover crops	3.37	0.18
2	Tillage with cover crops	3.4	0.21
3	No-till without cover crops	3.47	0.23
4	No-till with cover crops	2.87	0.16

Table 1. *Average percent organic matter and nitrogen content for each field treatment (1-4) using a combination of tillage and no-till with and without an implementation of cover crops. Three fields were sampled per treatment and the averages were calculated and recorded.*

Figures 6-9 depict the twelve soil samples conducted and the percentages of both nitrogen content and soil organic matter and include per sample data with averages of each treatment to reflect digestible trends and patterns throughout the research. Figure 6 shows the three sample sites of treatment 1, tillage without cover crops, soil organic matter and nitrogen content percentage per field. The County Line site revealed 3.1% SOM and 0.17% nitrogen, and both Jonah's I and Jonah's II 3.5% SOM and 0.19% nitrogen. Figure 7 depicts the same information for treatment 2, tillage with cover crops, revealing 3.2% SOM and 0.19% nitrogen from Waterhouse South, 3.5% SOM for both Waterhouse North I and II, while a 0.22% nitrogen content form Waterhouse North I and 0.21% from Waterhouse North II. Figure 8 shows the three sample sites of treatment 3, no-till without cover crops, where Willey Road I has 3.5% SOM and 0.23% nitrogen, Willey Road II has 3.8% SOM and 0.25% nitrogen, and Willey Road III has

3.1% SOM and 0.20% nitrogen. Figure 9 continues this pattern depicting treatment 4, no-till with cover crops, revealing 3.3% SOM and 0.19% nitrogen at the Farm Creekside location, 2.8% SOM and 0.16% nitrogen from the Old Gravel Pit site, and finally 2.5% SOM and 0.14% nitrogen from the Weber Dutchtown field site. Table 2 presents a detailed breakdown of the fields with each coded ID, description, acreage, treatment, and percent soil organic matter and nitrogen.

Fields with higher soil organic matter contained higher nitrogen, and fields with lower soil organic matter contained less nitrogen. Differences in percentages were miniscule but still present and followed somewhat of a predictable pattern.

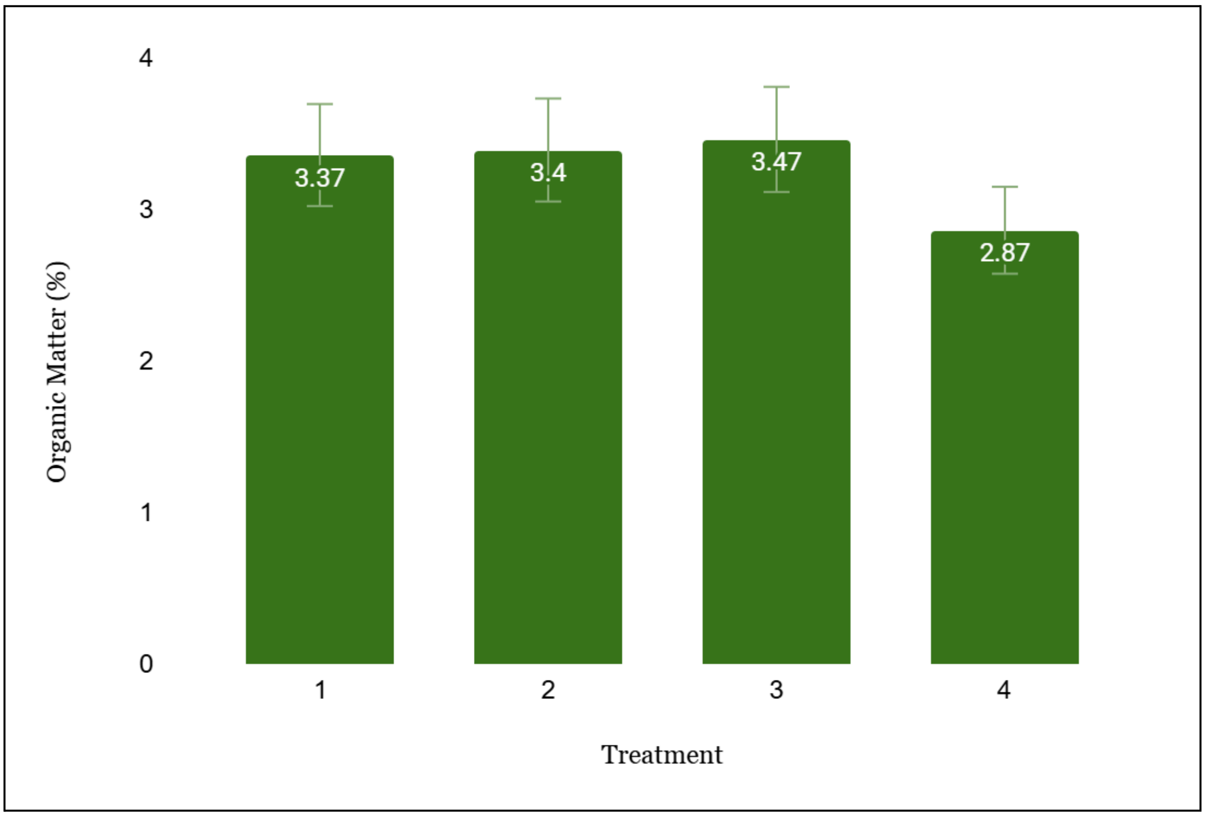

Figure 4. *The average soil organic matter percentages per field treatment. Treatment 1: Tillage without cover crops, Treatment 2: Tillage with cover crops, Treatment 3: No-till without cover crops, Treatment 4: No-till with cover crops.*

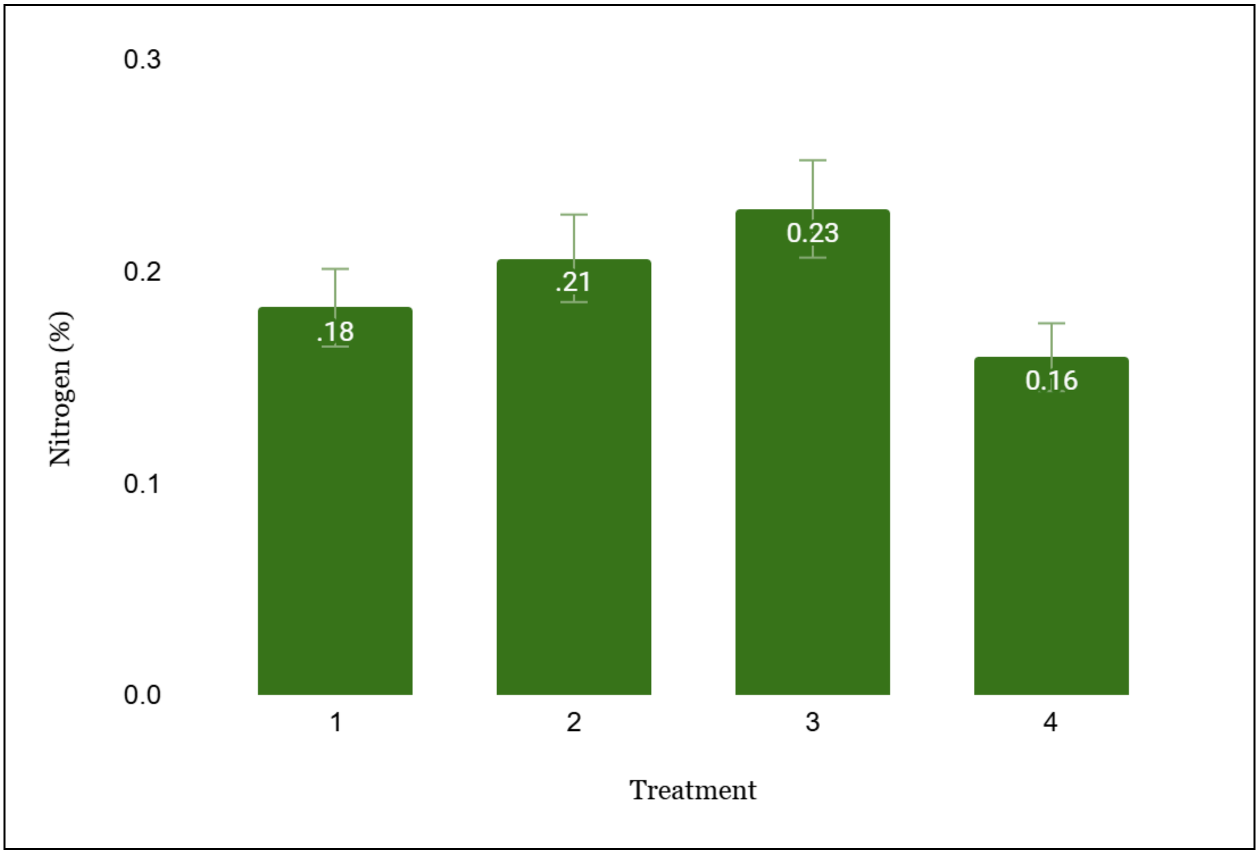

Figure 5. *The average nitrogen content percentages per field treatment. Treatment 1: Tillage without cover crops, Treatment 2: Tillage with cover crops, Treatment 3: No-till without cover crops, Treatment 4: No-till with cover crops.*

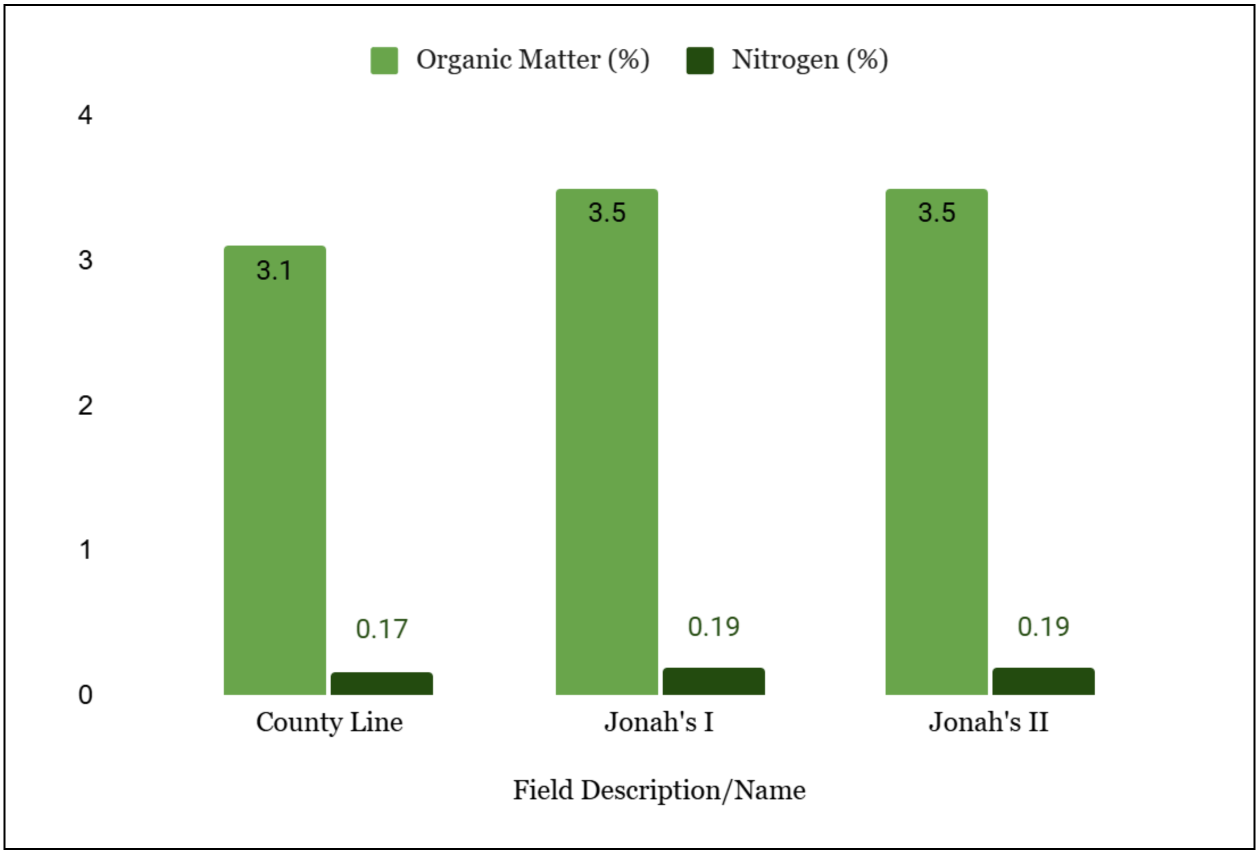

Figure 6. *Three sample sites of Treatment 1: Tillage without cover crops. Results show percent soil organic matter and percent nitrogen content.*

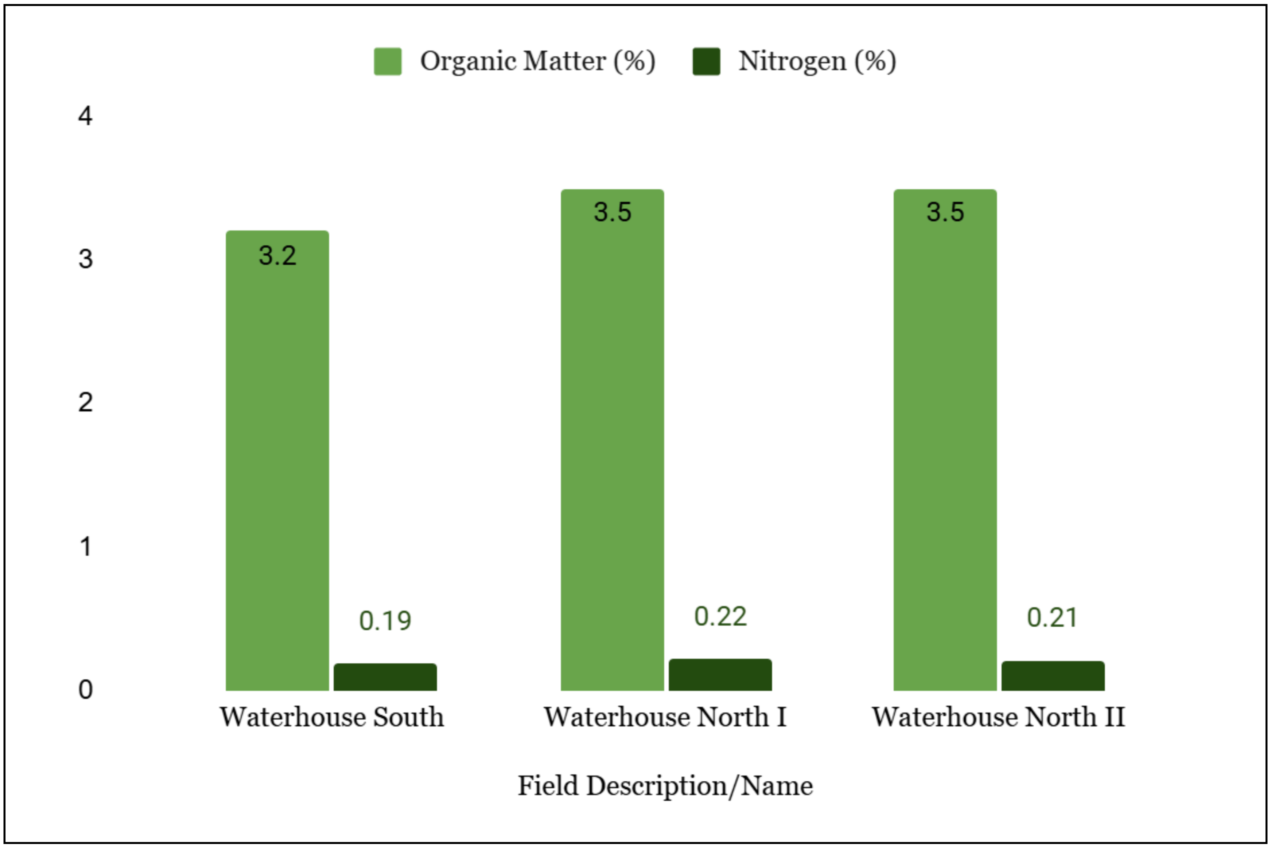

Figure 7. *Three sample sites of Treatment 2: Tillage with cover crops. Results show percent soil organic matter and percent nitrogen content.*

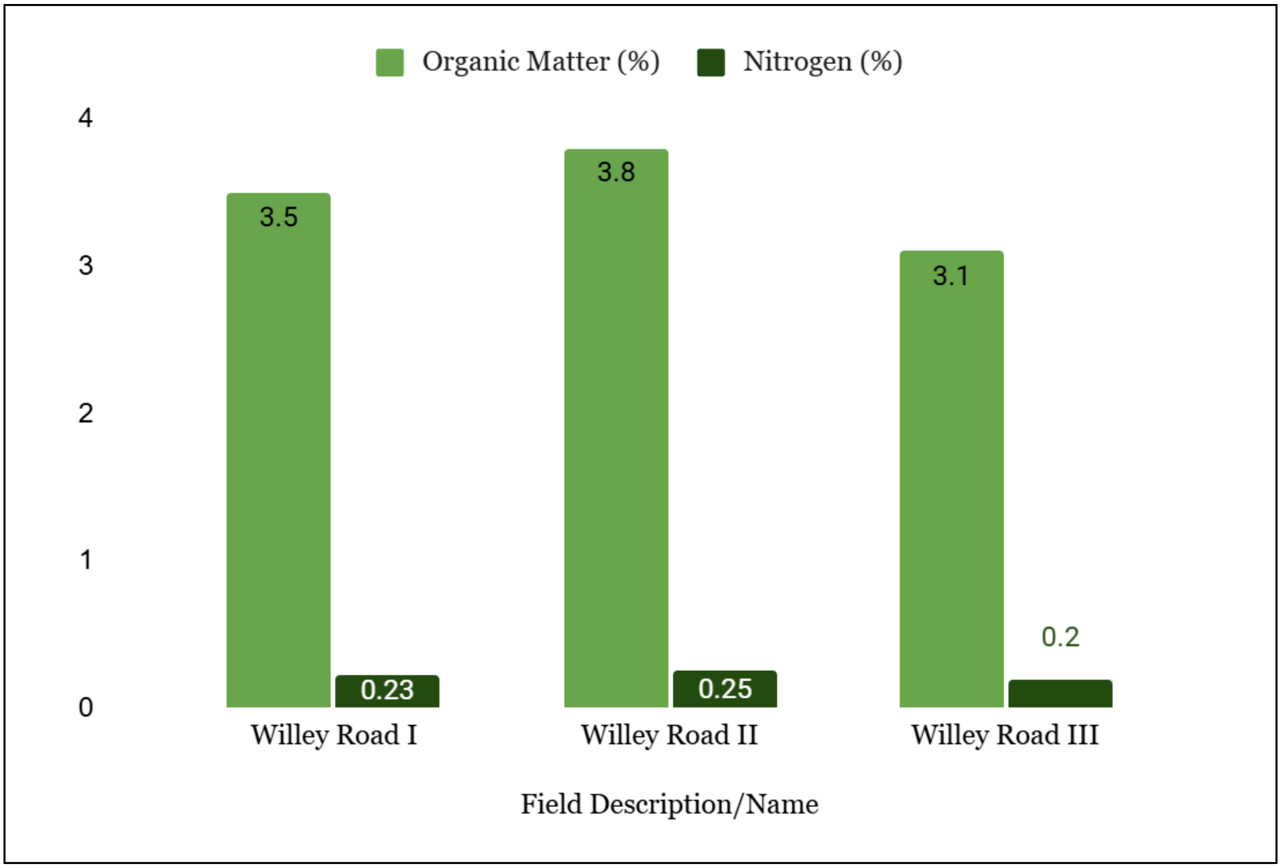

Figure 8. *Three sample sites of Treatment 3: No-till without cover crops. Results show percent soil organic matter and percent nitrogen content.*

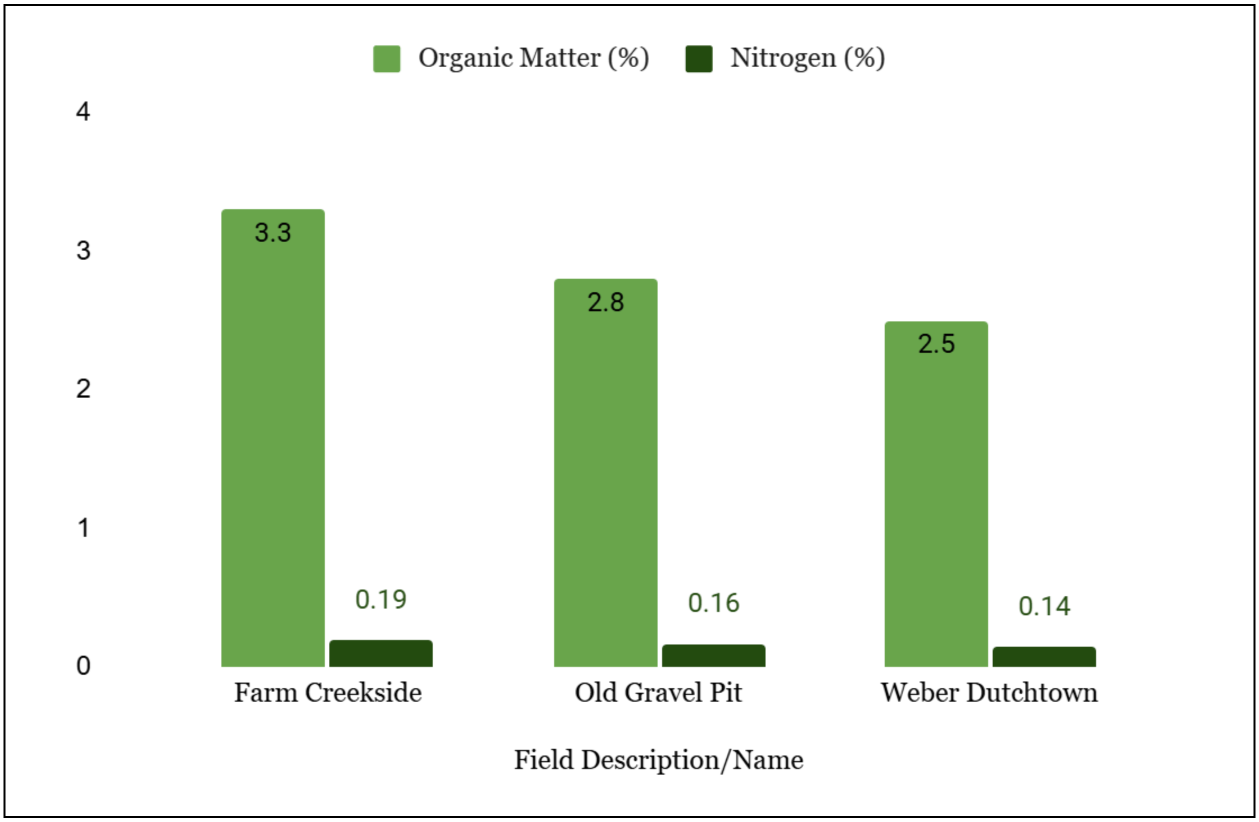

Figure 9. *Three sample sites of Treatment 4: No-till with cover crops. Results show percent soil organic matter and percent nitrogen content.*

Discussion

The results of this study suggest that the most successful field treatment for soil organic matter and nitrogen content on corn fields in Waterford, Pennsylvania is no-till without cover crops revealing the highest percent of both with an average of 3.47% SOM and 0.23% nitrogen (see figures 4-5). No-till minimizes disruption to the soil which reduces erosion, leading to the likeliness of treatment 3: no-till without cover crops, revealing the strongest percentage of both.

Overall, there is a pattern of lower soil health on tillage fields compared to no-till, and cover cropping on tillage fields is more successful for soil health than tillage without cover cropping. Field corn (*Zea mays)* is known to extract and deplete nutrients in the soil at greater quantities than other conventional crops such as wheat (*Triticum aestivum*) or soybeans (*Glycine max*) (Liebig et al. 2022). For this reason, many farmers use sustainable practices to reverse these effects such as crop rotation, no-till, and cover crops which have been examined by this study. Each of the corn fields sampled were on rotation with soybeans in the previous growing year (2023) leaving a similar rotational soil baseline.

Of the tillage results that were revealed in this study, cover crops were more effective than no cover crops. Soil organic matter percentage averaged slightly higher on cover crop fields than ones without in the tillage category by 0.03%, suggesting that the decomposition of the cover crops aided the amount of SOM that could be available to the corn on these fields. Soil organic matter increases a crop's ability to retain and absorb nutrients while simultaneously controlling harmful contaminants in the soil (Zhang et al. 2009). Soil microbial health is necessary to produce a healthy crop (Jat et al. 2021).

Nitrogen percentage was higher per each field and averaged higher on fields receiving tillage with cover crops versus tillage without cover crops as well. While having many benefits of its own such as promoting a plant's ability to develop, photosynthesize, and reproduce (Oelofse et al. 2015), nitrogen also aids soil organic matter in its function (Michael et al. 2015).

Of the no-till treatments, this case study suggests that no-till without cover crops is best for the soil organic matter and nitrogen content on fields in Waterford, Pennsylvania. No-till field treatments avoid disruption of the soil, leading to lesser amounts of potential erosion and runoff into surrounding ecosystems (Holland 2004). This benefits the farmers from losing topsoil that is necessary for growing healthy crops and having high yields, as well as biodiversity in these ecosystems that would otherwise be negatively affected by the chemicals in the runoff (Allen et al. 2021). This includes both chemical poisoning from harmful sprays and eutrophication from fertilizers. It also leaves the crop residue that was harvested the previous year lying on the field to decompose, creating layers of soil organic matter to be available for the next crop (Holland 2004). Fields receiving treatments 3 (A-C) and 4 (A-C) provide better chances for surrounding ecosystems to thrive in these environments away from runoff due to the utilization of no-till, and further research should be conducted to test such a response.

Unexpectedly, the lowest percentage of both nitrogen and soil organic matter across all treatments resulted from no-till with cover crops. Personal communication with Jim and Jim Glover Farms revealed this could possibly be due to the previous field treatments that were conducted on the no-till cover cropped sampled fields (Hanas & Glover 2024). Studies show that conversion from tillage to no-till can take soil up to 15-20 years to accumulate measurable and long-term benefits (Chief, 2019). It is likely that the lack of nitrogen and soil organic matter on these sampled fields compared to the rest is a result of minimal time for the soil conditions to adjust and regenerate since the transition from tillage.

Limitations to this study include constraints on time, information, and a lack of control groups. This study was conducted within a one year period from soil sampling to analysis, and therefore had to be taken from working farms and their availability, not in a controlled environment. This leaves room for error in constants regarding equipment type, quantity and quality of fertilizers and pesticides, and finally differences in farming history. Soil samples were taken on the most accurate and closely related available fields utilizing the four treatment types within Waterford, Pennsylvania for this study.

In response to this study, future research should analyze the effects of no-till versus tillage and cover cropping field techniques in areas of differing soil types and climates. This study was conducted on gravel ground in an area that was historically formed by glaciers (Department of Conservation and Natural Resources 2025). Other places with varying soil types such as sand or clay ground would likely reveal different results in best farming practices. Climate also varies across the United States which in turn varies the length of growing seasons and crop suitability (Cerdà 2000). Further research on soil microbial and nutrient health should be done for treatment recommendations on corn fields in other climate regions. Additionally, correlation between yield and soil health should be analyzed in order to determine the highest profitability to farmers in this particular area, supporting the importance of benefiting both people and the environment.

The future of a sustainable planet begins with a sustainable food system. Environmental degradation by humans include negative impacts on habitat, overexploitation of resources, and climate change, which can all be connected to conventional agriculture. The importance and relevance of sustainable practices in large scale agriculture is growing as environmental degradation does simultaneously. Improvements in agricultural sustainability such as no-till and cover cropping practices are dominating conventional farming and feasible to implement on large scales (Scopel 2012). This study shows that no-till without cover cropping was revealed to be the most successful treatment on corn fields in Waterford, Pennsylvania for soil health regarding soil organic matter and nitrogen content.

References

(2023). *Soil Improving Cropping Systems for Sustainable and Profitable Farming in Europe*. https://doi.org/10.3390/books978-3-0365-6254-4

Agriculture in the settlement period, c. 1800 – c. 1840. (n.d.). https://www.phmc.pa.gov/Preservation/Pennsylvania-Agricultural-History-Project/Documents/agriculture_in_the_settlement_period.pdf

Allen, J., Gross, E. M., Courcoul, C., Bouletreau, S., Compin, A., Elger, A., Ferriol, J., Hilt, S., Jassey, V. E. J., Laviale, M., Polst, B. H., Schmitt-Jansen, M., Stibor, H., Vijayaraj, V., & Leflaive, J. (2021). Disentangling the direct and indirect effects of agricultural runoff on freshwater ecosystems subject to global warming: A Microcosm study. *Water Research*, *190*, 116713. https://doi.org/10.1016/j.watres.2020.116713

Bezuidenhout, S. R., Reinhardt, C. F., & Whitewell, M. I. (2012). Cover crops of oats, stooling rye and three annual ryegrass cultivars influence maize and cyperus esculentus growth. *Weed Research*, *52*(2), 153–160. https://doi.org/10.1111/j.1365-3180.2011.00900.x

Binkley, D. (2021). *Forest ecology: An evidence-based approach*. WILEY-BLACKWELL.

Chief, E. in. (2019, September 20). *16 biggest pros and cons of no-till farming*. ConnectUS. https://connectusfund.org/16-biggest-pros-and-cons-of-no-till-farming

Cerdà, A. (2000). Aggregate stability against water forces under different climates on agriculture land and scrubland in southern Bolivia. *Soil and Tillage Research*, *57*(3), 159–166. https://doi.org/10.1016/s0167-1987(00)00155-0

Cooper, R. J., Hama-Aziz, Z., Hiscock, K. M., Lovett, A. A., Dugdale, S. J., Sünnenberg, G., Noble, L., Beamish, J., & Hovesen, P. (2017). Assessing the farm-scale impacts of cover crops and non-inversion tillage regimes on nutrient losses from an arable catchment. *Agriculture, Ecosystems & Environment*, *237*, 181–193. https://doi.org/10.1016/j.agee.2016.12.034

Farenhorst, A. (2006). Importance of soil organic matter fractions in soil‐landscape and regional assessments of pesticide sorption and leaching in soil. *Soil Science Society of America Journal*, *70*(3), 1005–1012. https://doi.org/10.2136/sssaj2005.0158

Feed grains sector at a glance. USDA ERS - Feed Grains Sector at a Glance. (n.d.). https://www.ers.usda.gov/topics/crops/corn-and-other-feed-grains/feed-grains-sector-at-a-glance/#:~:text=The%20United%20States%20is%20the%20largest%20producer%2C%20consumer%2C,of%20the%20crop%20grown%20in%20the%20Heartland%20region

Fisher-Power, L. M., & Cheng, T. (2018). Nanoscale Titanium Dioxide (ntio2) transport in natural sediments: Importance of soil organic matter and Fe/Al Oxyhydroxides. *Environmental Science & Technology*, *52*(5), 2668–2676. https://doi.org/10.1021/acs.est.7b05062

Frank, D. A., & Groffman, P. M. (2009). Plant rhizospheric n processes: What we don't know and why we should care. *Ecology*, *90*(6), 1512–1519. https://doi.org/10.1890/08-0789.1

Gardner, J. B., & Drinkwater, L. E. (2009). The fate of nitrogen in grain cropping systems: A meta‐analysis of 15N field experiments. *Ecological Applications*, *19*(8), 2167–2184. https://doi.org/10.1890/08-1122.1

Glacial geology. Department of Conservation and Natural Resources| Commonwealth of Pennsylvania. (n.d.). https://www.pa.gov/agencies/dcnr/conservation/geology/geology-of-pa/glacial-geology.html

Gruber, S., Pekrun, C., Möhring, J., & Claupein, W. (2012). Long-term yield and weed response to conservation and stubble tillage in SW Germany. *Soil and Tillage Research*, *121*, 49–56. https://doi.org/10.1016/j.still.2012.01.015

Hanas, A. S., & Glover, J. R. (2024, September). personal.

Heckman, J. R., Jokela, W., Morris, T., Beegle, D. B., Sims, J. T., Coale, F. J., Herbert, S., Griffin, T., Hoskins, B., Jemison, J., Sullivan, W. M., Bhumbla, D., Estes, G., & Reid, W. S. (2006). Soil test calibration for predicting corn response to phosphorus in the Northeast USA. *Agronomy Journal*, *98*(2), 280–288. https://doi.org/10.2134/agronj2005-0122

Holland, J. M. (2004). The environmental consequences of adopting conservation tillage in Europe: Reviewing the evidence. *Agriculture, Ecosystems & Environment*, *103*(1), 1–25. https://doi.org/10.1016/j.agee.2003.12.018

Home. Seal of Erie County, Pennsylvania. (n.d.). https://eriecountypa.gov/departments/planning-and-community-development/programs/agricultural-land-preservation/

Hu, Q., Zhang, Y., Cao, W., Yang, Y., Hu, Y., He, T., Li, Z., Wang, P., Chen, X., Chen, J., & Shi, X. (2024). Legume cover crops sequester more soil organic carbon than non-legume cover crops by stimulating microbial transformations. *Geoderma*, *450*, 117024. https://doi.org/10.1016/j.geoderma.2024.117024

Jat, S. L., Suby, S. B., Parihar, C. M., Gambhir, G., Kumar, N., & Rakshit, S. (2021). Microbiome for sustainable agriculture: A review with special reference to the corn production system. *Archives of Microbiology*, *203*(6), 2771–2793. https://doi.org/10.1007/s00203-021-02320-8

Kennedy, A. C., & Schillinger, W. F. (2006). Soil Quality and water intake in traditional‐till vs. No‐till paired farms in Washington’s Palouse Region. *Soil Science Society of America Journal*, *70*(3), 940–949. https://doi.org/10.2136/sssaj2005.0160

Lal, R., Reicosky, D. C., & Hanson, J. D. (2007). Evolution of the plow over 10,000 years and the rationale for no-till farming. *Soil and Tillage Research*, *93*(1), 1–12. https://doi.org/10.1016/j.still.2006.11.004

Lankoski, J. (2006). No-till technology: Benefits to farmers and the environment? theoretical analysis and application to Finnish agriculture. *European Review of Agricultural Economics*, *33*(2), 193–221. https://doi.org/10.1093/erae/jbl003

Liebig, M. A., Saliendra, N. Z., & Archer, D. W. (2022). Carbon fluxes from a spring wheat–corn–soybean crop rotation under no‐tillage management. *Agrosystems, Geosciences & Environment*, *5*(3). https://doi.org/10.1002/agg2.20291

Lowry, C. J., & Brainard, D. C. (2019). Strip intercropping of rye–vetch mixtures: Effects on weed growth and competition in strip-tilled Sweet Corn. *Weed Science*, *67*(1), 114–125. https://doi.org/10.1017/wsc.2018.83

Michael, P. S., Fitzpatrick, R. W., & Reid, R. J. (2015). The importance of soil carbon and nitrogen for amelioration of Acid Sulphate soils. *Soil Use and Management*, *32*(1), 97–105. https://doi.org/10.1111/sum.12239

Oelofse, M., Markussen, B., Knudsen, L., Schelde, K., Olesen, J. E., Jensen, L. S., & Bruun, S. (2015). Do soil organic carbon levels affect potential yields and nitrogen use efficiency? an analysis of winter wheat and spring barley field trials. *European Journal of Agronomy*, *66*, 62–73. https://doi.org/10.1016/j.eja.2015.02.009

Otieno, N. E., Jacobs, S. M., & Pryke, J. S. (2021). Small-scale traditional maize farming fosters greater arthropod diversity value than conventional maize farming. *Journal of Insect Conservation*, *26*(3), 477–489. https://doi.org/10.1007/s10841-021-00330-x

Read the community climate action plan. Read the Community Climate Action Plan | Community Climate Action Plan. (n.d.). https://www3.erie.gov/climateaction/public-comment-action-plan

Reckling, M., Bergkvist, G., Watson, C. A., Stoddard, F. L., & Bachinger, J. (2020). Re-designing organic grain legume cropping systems using systems agronomy. *European Journal of Agronomy*, *112*, 125951. https://doi.org/10.1016/j.eja.2019.125951

Scopel, E., Triomphe, B., Affholder, F., Da Silva, F. A., Corbeels, M., Xavier, J. H., Lahmar, R., Recous, S., Bernoux, M., Blanchart, E., de Carvalho Mendes, I., & De Tourdonnet, S. (2012). Conservation agriculture cropping systems in temperate and tropical conditions, performances and impacts. A Review. *Agronomy for Sustainable Development*, *33*(1), 113–130. https://doi.org/10.1007/s13593-012-0106-9

Sharratt, B. S. (2002). Corn stubble height and residue placement in the northern US corn belt. *Soil and Tillage Research*, *64*(3–4), 253–261. https://doi.org/10.1016/s0167-1987(01)00259-8

Stokes, C., & Howden, M. (2010). *Adapting agriculture to climate change: Preparing Australian Agriculture, Forestry and Fisheries for the Future*. CSIRO.

Weather averages Erie, Pennsylvania. Temperature - Precipitation - Sunshine - Snowfall. (n.d.). https://www.usclimatedata.com/climate/erie/pennsylvania/united-states/uspa0509

Zhang, D., Zhu, D., & Chen, W. (2009). Sorption of nitroaromatics to soils: Comparison of the importance of soil organic matter versus clay. *Environmental Toxicology and Chemistry*, *28*(7), 1447–1454. https://doi.org/10.1897/08-406.1

Appendix

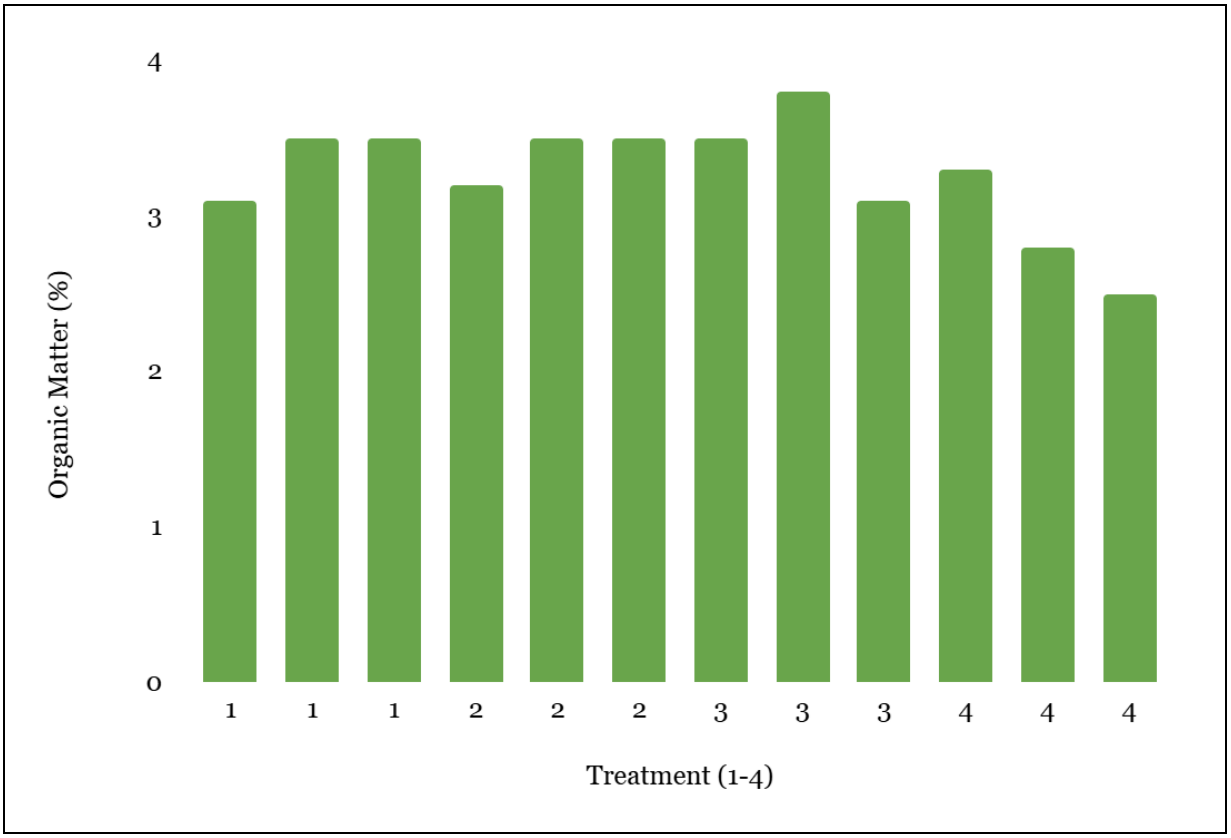

Figure 10. *Twelve individual sample sites with soil organic matter percentage results. Treatment 1: Tillage without cover crops, Treatment 2: Tillage with cover crops, Treatment 3: No-till without cover crops, and Treatment 4: No-till with cover crops.*

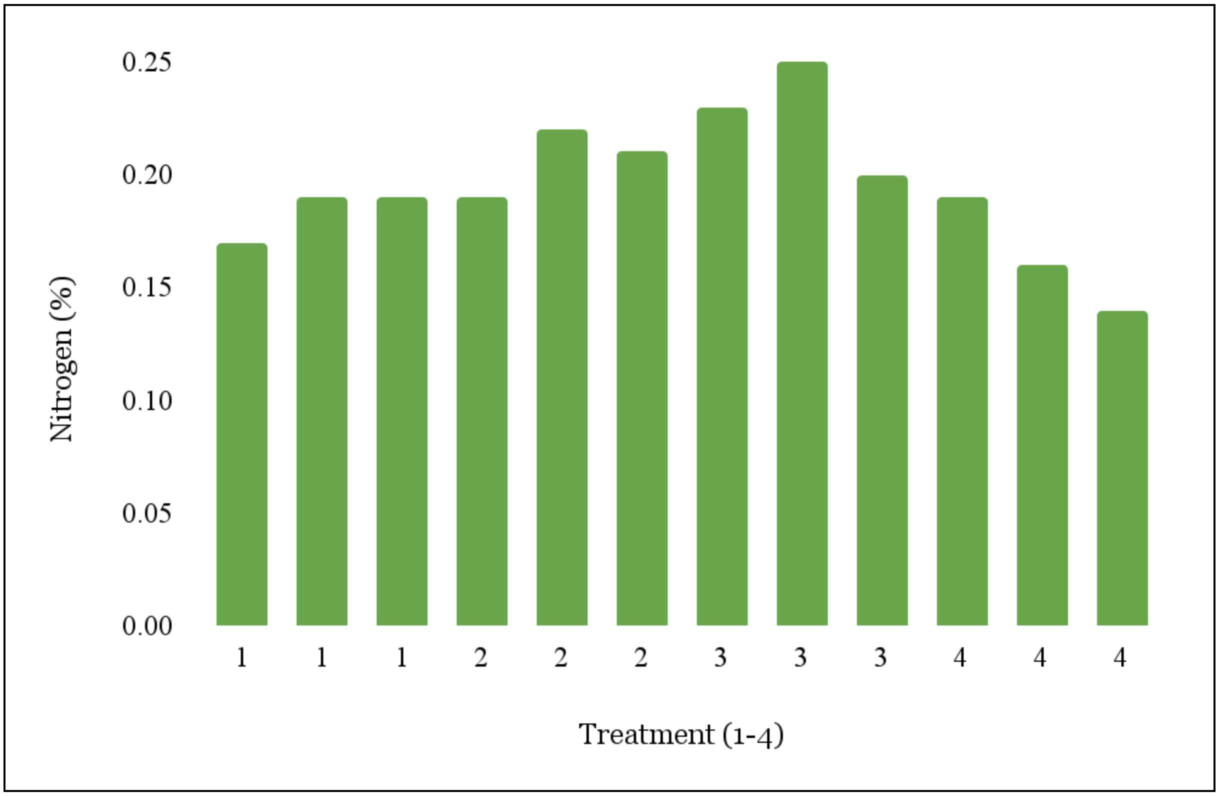

Figure 11. *Twelve individual sample sites with nitrogen content percentage results. Treatment 1: Tillage without cover crops, Treatment 2: Tillage with cover crops, Treatment 3: No-till without cover crops, and Treatment 4: No-till with cover crops.*

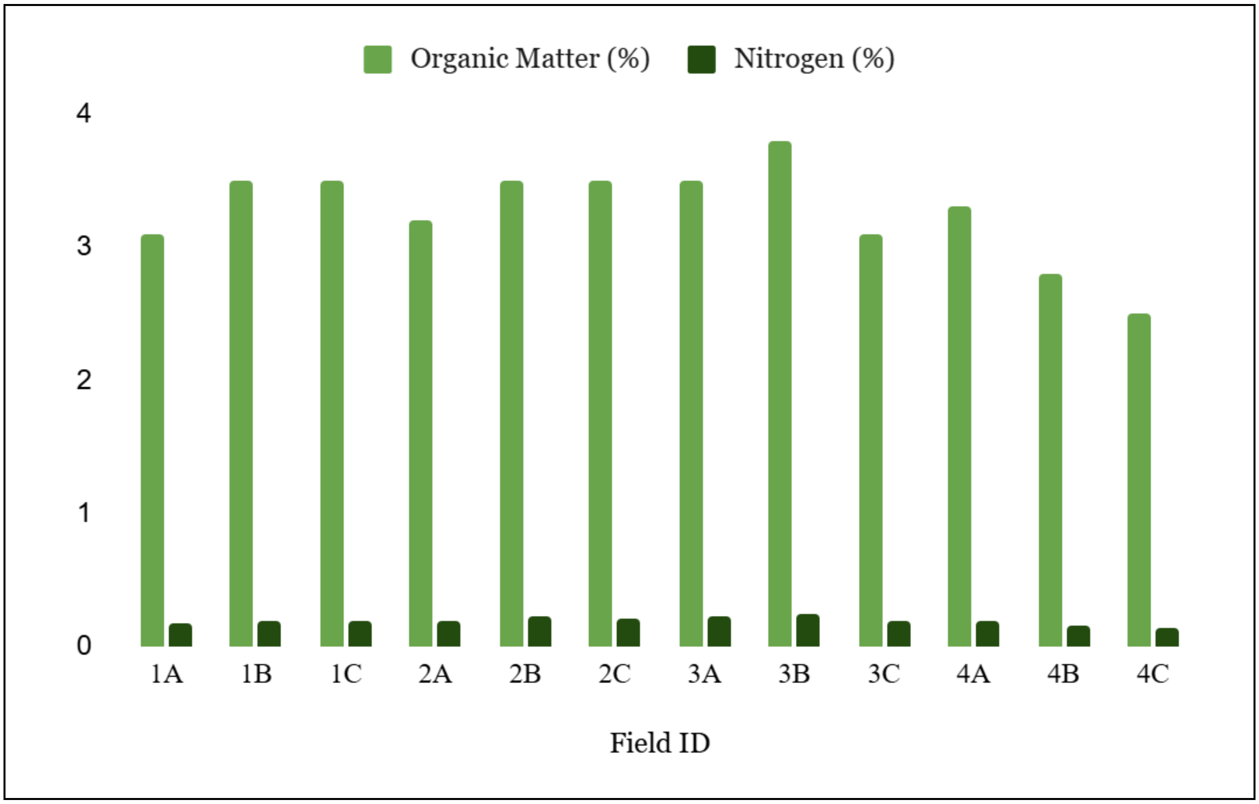

Figure 12. *Twelve individual field sample sites by coded Field ID with both soil organic matter percentage and nitrogen content percentage results. Treatment 1: Tillage without cover crops, Treatment 2: Tillage with cover crops, Treatment 3: No-till without cover crops, and Treatment 4: No-till with cover crops. ABC refers to the three varying sites within each field treatment method behind 1-4 (reference table 2 for detailed breakdown of location name).*

Sample Date	Field Description or Name	Field ID	Treatment (1-4)	Organic Matter (%)	Nitrogen (%)	Acreage
5/6	Cell Tower County Line	1A	1	3.1	0.17	12
5/6	Jonah's I	1B	1	3.5	0.19	3
5/6	Jonah's II	1C	1	3.5	0.19	13
5/6	Waterhouse South	2A	2	3.2	0.19	8.2
5/6	Waterhouse North I	2B	2	3.5	0.22	12.4
5/6	Waterhouse North II	2C	2	3.5	0.21	12
5/6	Willey Rd I	3A	3	3.5	0.23	12
5/6	Willey Rd II	3B	3	3.8	0.25	13
5/6	Willey Rd III	3C	3	3.1	0.20	14
5/6	Farm Creekside	4A	4	3.3	0.19	26
5/6	Old Gravel Pit	4B	4	2.8	0.16	43
5/6	Weber Dutchtown	4C	4	2.5	0.14	20

Table 2. *Sampling date, fields chosen by description and or location name as labeled by Jim and Jim Glover Farms or Porter Valley Farm, coded Field ID by treatment and varying location, results of soil organic matter and nitrogen content percentage, and field site acreage.*