Evaluation of Soil Quality and Conservation versus Conventional Tillage Methods in Trumbull County

by

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ABSTRACT

Although frequently overlooked or omitted, ecosystem services provide an environment for the survival of life on earth, including humans. Soil is a critical compartment for ecosystem services composed of solids, gasses, water, and micro and macro flora and fauna. Soil functions include water holding capacity, nutrient holding and cycling, support for microbial life, carbon capture, and other many other unseen benefits. Within society a main use of soil is agriculture for growth of food, fiber, and other necessities for civilization. Agricultural practices can consist of different techniques, two common categories are conventional and conservation methods. Conventional tillage utilizes turning of the soil to prepare the seedbed and remove unwanted plants. In conservation methods the use of no tillage or reduce tillage is used, where the soil is minimally disturbed, and the seeds are inserted into small slits or openings. Aggressive tillage can affect soil ecosystem function and limit the quality of soil health by decreasing porosity, reducing microbial processes, and increasing erosion.

Seven farm fields in Trumbull County, OH, were sampled to investigate the connection between agricultural method and soil quality characteristics that contribute to overall soil health and productivity. Composite soil samples consisting of 2.5 cm soil cores separated into top 15 cm layer and bottom layer were evaluated for organic matter, bulk density, soil texture, plant available phosphorus, pH, total nitrogen, salinity, and percent porosity using standard methods. The data composed of 32 samples, with 16 samples from the top layer and 16 from the bottom layer. The fields were ranked one to four, with a ranking of one indicating conventional methods to ranking of four with the highest amount of conservation practices applied. Statistical analyses included descriptive statistics, mean comparison, one-way ANOVA, Principal Component Analysis, and backwards linear regressions using SPSS statistical tool.

There were few clear statistical differences between soil properties and the different fields from this exploratory project. Salinity stood out as the most significant differences with the salinity decreasing as more conservation methods were used in the field. Lower salinity can promote better plant productivity in a variety of crops and increase the availability of nutrients within soil. Principal component analyses (PCA) allow data to be visualized to identify trends or clusters. PCA showed the top 15 cm of higher ranked soils (three and four) clustered together with higher nutrient concentrations as compared to lower ranked soils. Backward regression was used to determine which parameters had the greatest influence on soil nutrient levels. The rank was a significant indicator of total nitrogen along with soil organic matter, pH, and salinity whereas plant available phosphorus was only determined by pH and soil organic matter. It is recommended to continue annual seasonal sampling of these fields to further develop the relationship between soil parameters and agricultural methods. Insight into this relationship and the human impacts to soil will aid in better decision making and land management.

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Chapter 1 Introduction

In today's society there are many factors that come into play when producing food. Within these factors a major environmental concern may arise. There are many agricultural processes or techniques that are used to produce a high crop yield. Two different methods commonly used are conventional tillage of fields, and on the opposite end, no tillage of the fields. Conventional tillage utilizes turning of the soil to prepare the seedbed and remove unwanted plants. In no tillage or reduce tillage methods the soil is not disturbed, and the seeds are inserted into small slits or openings.

Conventional tillage has been commonly used throughout modern history and throughout the industrial revolution. Although farmers may have used conservational or semi-conservational techniques prior to what we know as conventional agriculture, those techniques have largely been set aside and forgotten. Within conventional agriculture the process of tillage, consisting of disturbing and turning the topsoil is common. No-tillage on the other hand is a practice that can be placed in the category of conservational agriculture which is less common but slowly spreading as more beneficial for agricultural operations. No-tillage can be a reduction of tillage, or the abandonment of tillage altogether. Not tilling or not disrupting the topsoil, allows for continuous root penetration, microbial life development, increased water holding capacity, and increased nutrient retention. This has been known to allow for better crop yield as well as providing plants that are heathier and require less maintenance. In general, there are various systems and procedures used by both agricultural methods, that can, and do produce good high-quality yields of fruits and vegetables. The problem areas surrounding the conversation or debate between agricultural methods consists of cost, impact on the environment, use of pesticides/insecticides, impact on human health, as well as soil erosion. The problem areas are more inclusive or less inclusive based on the specific geographic area of the globe, community involvement, and state/federal regulations. Another area of concern is the price of the land where the agricultural organization is located, should the quality of soil and possible yield that can be produced from the soil be considered when calculating the lot price? If someone purchases an area that was not maintained for optimum soil quality, and the conservation of the land itself, the new owner will have to implement costly procedures and mitigation efforts in order to produce a yield they desire or return the soil quality to its optimum quality. This is a considerable issue for sustaining soil quality, the surrounding land, as well as ecosystem services provided by soil and its ecosystem.

Ecosystem services can be commonly defined as the benefits people or society receive from various ecosystems. There are four categories that each ecosystem service can fall into, these are provisioning services, regulating services, habitat or supporting services, and cultural services (Reid, 2005). As our society has advanced, we have acquired certain needs, and most of the time our needs are met through the environment, either directly or indirectly, ecosystem services are generated when ecosystems contribute towards meeting these needs (Small et al., 2017). Soil generates its own internal ecosystem as well as contributes to various other ecosystems directly or indirectly, some of the ecosystem services provided by soil include improvement in water or air quality, providing food, fiber, feed, fuel production, soil erosion control, nutrient cycling, soil carbon dynamics and sequestration, and biodiversity (Blanco-Canqui, H, 2018). Soil includes the value of human society and contains millions of other species, which therefore makes its entire total value incalculable (Baveye et al., 2016). The issues surrounding soil and its ecosystem services are of major concern when also considering the battle to implement and change environmental policies for the betterment of society, the opinion or beliefs of the general public is ground zero (Millner & Ollivier, 2016).

Questions and Objectives: Considering these two different methods, how valuable is the soil within both situations? What is the economic evaluation considering both techniques? Could one technique be more valuable or contribute a higher value with respect to ecosystem services? How does the environmental value compare to the price of the lot or acreage that would be associated on the average market?

Chapter 2 Literature Review

The issue of valuation of ecosystem services is inseparable from choices and decisions that we make about land management. The valuation of ecosystems is either impossible or unwise, the process of placing a value on intangibles such as environmental aesthetics or long-term ecological benefits is unattainable, but we actually do this every day. When construction standards for highways, bridges, and other infrastructure are set, we value human life, by protecting and engineering ways to prevent accidents. In the same way, the effects of ecosystem services to human welfare can range from immediate to long-term adverse consequences. These ecosystem services can be extremely simple to identify, to exceedingly complex and difficult to predict the long-term effects. For example, forests create micro-climates through trees, soils and the moisture that they hold, all of which add to human welfare in complex, and generally noneconomic ways (Costanza et al., 1997).

Natural capital consists of items such as trees, minerals, ecosystems, the atmosphere and so on, the term natural capital sometimes refers to the overall stock of these materials on the planet. Human uses of the flow of these services many not leave the original stock intact. The opposite of natural capital, manufactured capital consists of machines, buildings, and physical bodies. Ecosystem services consist of flows of materials, energy and information from natural capital stocks which combine with manufactured and human capital services to produce human welfare (Costanza et al., 1997).

The services provided by ecological systems and the natural capital stocks that are produced are critical to the functioning of Earth's life-support system. The total economic value of the planet is partly represented by ecosystem services, such as filtration of water, production of top soil, or stabilization of climate, these services contribute to human welfare directly and indirectly. Without the services of ecological life-support systems, the financial systems of the Earth would grind to a halt, with that considered their total value to the economy is immeasurable (Costanza et al., 1997).

Ecosystem services are divided up into four categories: provisioning services, regulating services, habitat or supporting services, and cultural services (Reid, 2005). Provisioning services are any type of benefit to people that can be extracted from nature (Reid, 2005). This includes food, drinking water, and raw materials such as timber, wood, fuel, natural gas, oils, and plants that can be made into clothes and other materials, or medicinal benefits/resources. Food customarily comes from agronomy, but marine and freshwater resources also provide food for human utilization. Furthermore, wild foods from forests are often underestimated and utilized by many cultures all over the globe (The Economics of Ecosystems and Biodiversity (Van der Ploeg, S. and R.S. de Groot (2010). Regulating services include water purification, pollination, decomposition, erosion and flood control, erosion prevention, carbon storage and climate regulation, local climate and air quality control, moderation of extreme events, wastewater treatment, maintenance of soil fertility, and biological control (Reid, 2005). Habitat or supporting services include habitats for species, maintenance of genetic diversity, nutrient cycling, photosynthesis, development of soils, and the water cycle (Reid, 2005). Cultural services are derived from what the ecosystem gives to the community of humans around it (Reid, 2005). The services included are a product of creativeness born from interactions or experiences with nature; music, art, architecture, recreation, mental and physical health, tourism, aesthetic enjoyment and inspiration for cultural functions, design, spiritual experience, and sense of place (Reid, 2005).

Table 1 Ecosystem Services Chart Retrieved from www.ecetoc.org (Ecetoc, 2016).

Category	Ecosystem service	Explanation
Provisioning services	Food	Food products derived from plants, animals, and microbes.
	Fibre and fuel	Materials including wood, jute, cotton, hemp, silk, and wool. Biological materials providing sources of energy e.g. wood, dung.
	Genetic resources	Genes and genetic information used for animal and plant breeding and biotechnology.
	Biochemical / natural medicines	Medicines, biocides, food additives such as alginates.
	Ornamental resources	Animal and plant products (e.g. skins, shells, and flowers) are used as ornaments. Whole plants used for landscaping and ornaments.
	Fresh water	People obtain fresh water from ecosystems. Fresh water in rivers is also a source of energy.
Regulatory services	Pollination	Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.
	Pest and disease regulation	Ecosystem changes affect the abundance of human pathogens and disease vectors and the prevalence of crop / livestock pests and diseases.
	Climate regulation	Ecosystems influence climate both locally and globally. At a local scale, for example, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.
	Air quality regulation	Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.
	Water regulation	The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover.
	Erosion regulation	Vegetative cover plays an important role in soil retention and the prevention of landslides.
	Natural hazard regulation	The presence of coastal ecosystems (e.g. mangroves and coral reefs) can reduce the damage caused by hurricanes or large waves.
	Water purification / soil remediation / waste treatment	Ecosystems can be a source of impurities but also can help filter out and decompose organic wastes introduced into ecosystems. They can also assimilate and detoxify compounds through biological processes.
Cultural services	Spiritual and religious values	Many religions attach spiritual and religious values to ecosystems or their components.
	Education and inspiration	Ecosystems and their components and processes provide the basis for both formal and informal education in many societies. Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.
	Recreation and ecotourism	People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes.
	Cultural diversity and heritage	The diversity of ecosystems is one factor influencing the diversity of cultures. Many societies place high value on the maintenance of either historically important landscapes ('cultural landscapes') or culturally significant species.
	Aesthetic values	Many people find beauty or aesthetic value in various aspects of ecosystems.
	Sense of place	Many people value the 'sense of place' that is associated with features of their environment, including aspects of the ecosystem.
Supporting services	Primary production, photosynthesis	Primary production is the assimilation of energy and nutrients by biota. Photosynthesis produces oxygen required by most living organisms.
	Soil formation and retention	Because many provisioning services depend on soil fertility, the rate of soil formation influences human well-being in many ways.
	Nutrient cycling	Approximately 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems.

All these services have a value attached to them and have a domino effect to socioeconomic problems if they are removed or altered. For example, people use nature as way to relieve stress by taking a walk, getting fresh air, or just exercising outdoors. This action has a positive effect on the mental health of the individual, without this service in place within an environment an individual might develop depression or another mental health disorder due to their biological need to connect to nature (Jennings, 2016). The cost of treatment for the number of individuals with mental health cases could outweigh the value of the service itself, thus making it more beneficial to keep the ecosystem intact and unaltered. For these scenarios to be compared a cost for the ecologic service would have to be developed, this cost would rely heavily on the society or community's willingness to trade the natural capital item or service for something of equal value or greater importance. This would be purchased with some type of currency that would place an estimated value on the ecologic service.

The ability of ecosystems to continuously supply the flow of services, directly or indirectly, for present and future communities and human needs, are threatened by ecosystem degradation, and the loss of biodiversity resulting in loss of function and resilience (Small et al., 2017; de Groot et al., 2012). The majority of the research on ecosystem services to date has concentrated on assessing the provision of ecosystem services, and concerns of ecology as well as other natural sciences (Prothero et al., 2008). Literature on ecosystem services that is least developed is the law (Prothero et al., 2008). Because laws and policies evolve slowly, they reflect past as well as current views on what is beneficial or desirable (Prothero et al., 2008). Functioning ecosystems provide a range of services that have many impending uses with different values attached. Ecosystem Service assessments are becoming common as scientists and specialists worldwide respond to the necessity for ecosystem-based management. These assessments evaluate how the ecosystem services, or the benefits people derive from nature may be affected by future societies or changes in environmental conditions (Hamel, 2017).

Soil provides various services to the environment and organisms within the environment. Some of the services provided by soil include providing food, fiber, feed, fuel production, soil erosion control, improvement in water or air quality, nutrient cycling, soil carbon changes dynamics and sequestration, and biodiversity (Blanco-Canqui, H, 2018). From the list above it can be understood how integral soil is to life and how soil contributes to various other materials or services down the line after its initial use. Soil has a prolonged effect to our quality of life, with a chain link of contributions. To get an idea of how small an impact can be to alter soil, consider changes in soil physical properties that can directly affect crop establishment or production, most specifically, physical properties related to soil compaction (Blanco-Canqui, H, 2018). The compacted physical state of soil will be affected through seeding emergence, root growth, crop production, porosity, and water infiltration (Blanco-Canqui, H, 2018). Currently the average rate of soil erosion from cropland decreased by over 30% from 1982 to 2012. Even with the improvement, the estimated rate of erosion sits at 4.6 tons per acre per year (National Science and Technology Council, 2016). According to the 2016 "The State and Future of U.S. Soils" report, the areas identified as opportunities and needs to conserve the state of U.S. soils includes; research, technology, land management, and social science (National Science and Technology Council, 2016). Items addressed in all areas include things like, better characterization of the threats that climate and environmental changes present, further research on erosivity of rainfall across the U.S., an opportunity for high-resolution monitoring of environmental change, further efforts for researching and developing best management practices for the different land uses, land cover types and climate orientated goals, as well as the need for an improved understanding of social drivers of resistance to adopting climate-smart agricultural or forestry practices (National Science and Technology Council, 2016). Currently soils and lands are managed professionally, but more can be done to attribute to a better all-around system, a system created considering more sustainability, environmental impacts, and appropriate land use.

Soil biodiversity, soil fertility, or maintenance of soil structure can be referred to as ecosystem services. Soil biodiversity refers to the variability among living things within the soil, this also includes a myriad of organisms, such as microorganisms, meso-fauna, and macro-fauna (Food and Agricultural Organization of the United Nations, n.d.). Soil fertility represents the capacity of a soil to supply nutrients to plants in adequate amounts and in appropriate quantities (Gardner, H., 1985). Soil structure is used to refer to how the particles of soil are grouped together, an effort to preserve soil structure may increase the range of soil textures acceptable for bioretention (Shanstrom, N., 2014). The total value of soil is immeasurable as it includes the value of human civilization and millions of other species (Baveye et al., 2016). Neoclassical economics is not equipped to deal with infinite capital. The recognition of this may help to encourage soils to be managed in similar ways to objects that have been determined to have equally infinite value (Baveye et al., 2016). The entirety of soil is infinitely valuable but not at the viewpoint of an individual parcel. For example, monuments, ancient structures, or natural forests or parks have been preserved and a value is assigned due to their historical or recreational value (Baveye et al., 2016). When considering something that society has placed an infinite value upon, such as the Notre Dame Cathedral in Paris, the perspective of the French government is that it is liable for maintaining the cathedral in superior shape so that future generations can enjoy it as much as the present-day society (Baveye et al., 2016). Integrating the label of "Societal Heritage" or considering soils as a legacy, could give public authorities some measure of control over what landowners do with their land (Baveye et al., 2016). Once soils are viewed as a heritage, the role of the landowner switches to that of a steward whose moral duty is to ensure that soils are transferred to the next generation in good condition (Baveye et al., 2016).

Biodiversity within soil is valued as a product of soil and as a driver of many regulating services (Comerford et al., 2013). Soil biodiversity can be valued for its own sake and for providing numerous ecosystem services (Comerford et al., 2013). The value of biodiversity stems from it being a genetic resource and representation of the potential for biologically mediated soil ecosystem services in the present as well as the future (Comerford et al., 2013). The components of value hardest to quantify from biodiversity provided by soil, include indirect use and non-use benefits (Comerford et al., 2013). Indirect uses of soil consist of things like building materials, medicine, beauty products, pottery, as well as what can be manufactured from certain crops, such as cotton and clothing. The reservoir of biodiversity is important to many soil processes, e.g., nutrient cycling, plus the many organisms serve as an essential part to the functional diversity and resilience of soil (Jónsson, 2016). Such agricultural techniques, like applying pesticides, have a proven effect on soil biodiversity, killing beneficial organisms and limiting functional diversity (Jónsson, 2016). Some agricultural processes may lead to mismanagement and degradation of the soil and future economic costs (Jónsson, 2016).

Economic value

One way to think about the value of ecosystems is to determine what it would cost to replicate them in a technologically produced, artificial biosphere (Costanza, 1997). The public perception on environmental topics is usually assessed with opinion on global warming. Surveys of public opinion show a low level of concern about environmental problems (Millner & Ollivier, 2016). People's beliefs about specific environmental problems are often heterogeneous and not stable over time. The beliefs of the general public are ground zero for the battle to implement environmental policies (Millner & Ollivier, 2016).

An important tool to raise awareness and communicate the relative importance of ecosystems and biodiversity to policy makers consist of applying value of the ecosystem services in monetary units (de Groot, 2012). Valuing ecosystem services and associated benefits is not straight forward (Small, 2017). Monetary units connected to ecosystem services could indicate the relative value current societies place on ecosystem services and provide guidance to the community leadership (de Groot et al., 2012). Governments have increasingly addressed local environmental issues, social expectations and interconnectedness, but the solutions have mainly come from specific technological advances per region and through development of decision-making plans (Primmer et al., 2012). In 2007 a global assessment of The Economics of Ecosystems and Biodiversity (TEEB) was launched to support the message, public debate, as well as policy action for the monetary value of ecosystems and biodiversity (de Groot et al., 2012). Socio-cultural values describe the way all ecosystem service values can be culturally constructed and categorized in three value domains, intrinsic value, ecological value, and relational value (Small et al., 2017). Ecosystems that are stressed by a variety of factors are likely to have impaired or reduced ecosystem services (Sandifer et al., 2015). The loss of biodiversity will negatively affect human access to reliable food, clean water, and raw materials and will likely have a larger impact on poor and at-risk people (Sandifer et al., 2015).

Many global environmental problems have characteristics that make them inherently difficult to understand. When considering issues such as climate change, biodiversity loss, and the decline in world fisheries, many people have not actually experienced any of these problems. The events are not localized, but rather long-run trends, that are slowly changing in the distribution of events. These events can be compared to environmental catastrophes such as an oil spill, where the consequences are easily captured on film and broadcasted throughout the media (Millner & Ollivier, 2016).

Laws and policies evolve slowly, they reflect past as well as current views on what is beneficial or desirable (Prothero et al., 2008). Functioning ecosystems provide a range of services that have many potential uses with different values attached (Small et al., 2017). A way to illustrate and visualize how economic services fit in within society is a Venn diagram that consist of biophysical type or natural context and beneficiary type or socio-economic context which illustrates the relationship of the two. The diagram helps to visualize where the ecosystem is in terms of societal outlook and when it crosses over to the social economic realm, it starts with the services provided. Moving from left to right in the biophysical type area is ecosystem organisms then ecosystem functioning with ecosystem services in the crossover area, used by both areas, next in the beneficiary type area is benefits then value (Small et al., 2017). The cross over area where ecosystem services is shared by the biophysical side of the conversation and the socio-economic side shows how in society, we depend on ecosystem services in two completely separated spaces that are more connected than our general views on the issue.

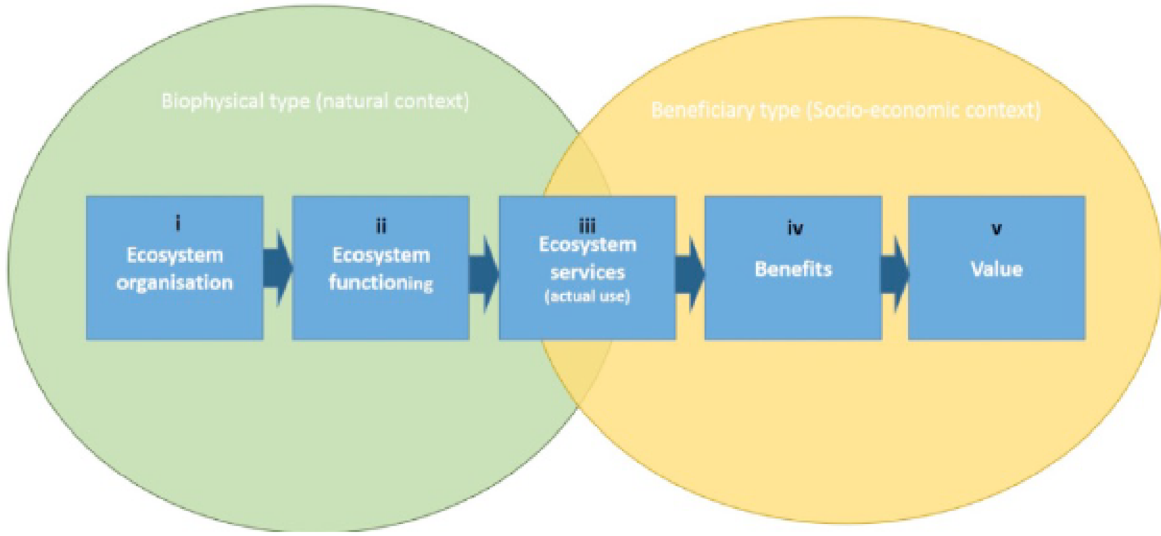

Figure 1 Venn Diagram disgned to display key aspects to understand when examining links between ecosystems and benefits derived (Small et al. 2017)

Precautionary Principle – Philosophy

Within the evaluation of economic value of environmental services there are philosophical and social issues that plague the conversation. The value of ecosystem services is compared to the proposed change in land use which is debated by regulators, the public, and others. To guide this ethical dilemma, many have turned toward the precautionary principle.

There are few pressing social issues that depend as heavily on scientific information as do environmental problems. When an activity raises threats of harm to human health or the environment, precautionary measures should be taken. Within the precautionary principle measures should be taken even if some cause and effect relationships are not fully established scientifically. Four central components of the principle include taking preventative action in the face of uncertainty, shifting the burden of proof to the proponents of an activity, exploring a wide range of alternatives to possibly harmful actions, as well as increasing public decision making. The precautionary principle supports policies that safeguard human health and the environment in the face of uncertain risks (Kriebel et al., 2001).

Ecosystems and Economics

A classic definition of economics is the science that studies human behavior with regards to the satisfaction of human needs and wants from scarce resources with alternative uses (Robbins 1932, p. 15), as cited in Barbier, 2009). The instrumental role of an asset in attaining human goals is its economic value (Barbier, 2009). This value focuses on the relationship between humans and the state of the ecosystem (Barbier, 2009). Ecosystem services cannot be stockpiled, and all economic products result from the conversion of raw materials provided by the natural world (Farley, 2012). The extraction of raw materials and the return of the waste is known as throughput (Farley, 2012). The flow of waste into the ecosystem for combustion, as well as the extraction of fossil fuels is controlled by society (Farley, 2012). A general challenge in economics is attempting to determine how much ecosystem structure should or can be converted into economic product, as well as how much should be left intact to generate ecosystem services (Farley, 2012). A sustainability viewpoint assumes that we have an ethical obligation to future generations to keep these ecosystem services intact (Farley, 2012). Plants, animals, water, minerals and so on, are the raw materials that get physically transformed into economic product, these materials serve as the structural building blocks of ecosystems (Farley, 2012). Provisioning ecosystem services are defined as the reproductive capacity of ecosystems (Farley, 2012). It is essential for humans and other species that the capacity of the ecosystem remains diverse, resilient, and that the flow of ecosystem services is maintained over time (Farley, 2012). Human activity destroying planetary ecosystems is unlikely, but that does not rule out the potential of dramatic reconfigurations that lead to flipped alternate states (Farley, 2012). Agriculture and civilization as we know them both evolved during the Holocene, which was geographically categorized as an unusually stable climate (Farley, 2012). In the current era, the Anthropocene, the effects of human actions on ecosystems are on the scale of geological forces, which is a danger to both ecological and economic sustainability (Farley, 2012). Even if the ecosystem remains resilient and eventually recoups, ecosystems may be interrupted to the point that the generation of specific services is disrupted for long enough to destroy the economies that rely on them (Farley, 2012). Many economists believe all resources have substitutes, and therefore natural resources play a negligible role in economic output. Critical Natural Capital (CNC) represents natural capital stocks that generate essential ecosystem services (Farley, 2012). Irreversible loss of CNC can occur when a threshold is crossed by a system where a very small change in economic activity can have enormous impacts (Farley, 2012). Food provision, water provision and purification, disease regulation and disturbance regulation, are some of the economic thresholds affected by ecosystem services (Farley, 2012). Technological advances that can provide substitutes are known economically as back-stop technology, where the material's marginal value cannot exceed the price of the substitute and marginal analysis remains appropriate (Farley, 2012).

The Millennium Ecosystem Assessment defines ecosystem services as the benefit people or humans receive from ecosystems (Barbier, 2009). The associated benefit streams associated with ecosystem services could possibly be used to estimate the value of the underlying ecological assets (Barbier, 2009). There are four main but broad benefit streams. These consist of provisioning services, cultural services, supporting services, and regulating services (Barbier, 2009). Provisioning services benefit streams have been the focus in much work regarding environmental and resource economics (Barbier, 2009). These include foods, fibers, fuels, water, biochemicals, medicines, pharmaceuticals, and genetic material (Barbier, 2009). The second category focuses on cultural services which consist of a range of largely non-consumptive uses of the environment and reflect the fact that the diversity of ecosystems is mirrored in the diversity of human cultures (Barbier, 2009). Cultural services usually include spiritual, religious, aesthetic, and inspirational wellbeing that people derive from the 'natural' world around them (Barbier, 2009). This category also includes totemic importance of particular landscapes, information, awareness or understanding of ecosystems and their individual components, and also plays into the aspect of ecotourism (Barbier, 2009). Support services consist of the main ecosystem processes that underpin all other services, these services include services like soil formation, photosynthesis, primary production, as well as nutrient, carbon, and water cycling (Barbier, 2009). The last set of identified ecosystem services by the Millennium Ecosystem Assessment consist of regulating services (Barbier, 2009). Regulating services include water purification and waste treatment, air quality regulation, climate regulation, erosion regulation or soil stabilization, hydrological regulation, disease regulation, pest regulation, and natural hazard regulation (Barbier, 2009). People routinely tradeoff ecosystem services. Capital includes both produced, human, as well as natural capital, and the sustainability of economic development requires maintaining the value of assets or capital stocks that are supporting economic development, understanding how the value of ecosystems may be changing in our society, relative to the value of other capital stocks is extremely important (Barbier, 2009).

Soil Economies

The land manager is the ultimate determinant of soil quality and health (Doran, 2002). Soil not only provides food but is an important component of ecosystem function and maintenance is of critical importance within local, regional, and global environmental quality (Doran, 2002). The health of soil can change over time, regarding the effects of natural events or human impacts, the soils' condition is enhanced positively or negatively by management and land use decisions (Doran, 2002). These decisions usually focus on a single function such as crop productivity (Doran, 2002). For optimal soil health a balance of productivity, environmental quality, and plant and animal health is required (Doran, 2002). An indicator of sustainable management would be the assessment of soil quality or health and direction of change with time (Doran, 2002). The various threats to the natural process that sustain the global atmosphere and life on earth include increasing human populations, decreasing resources, social instability, and environmental degradation (Costanza et al., 1992; Postel, 1994, as cited in Doran, 2002). Since grasslands and forests were converted to agriculture and cultivation was initiated, the quality of many soils in North America and elsewhere, has noticeably declined (Doran, 2002). This has occurred due to the application of past management of agriculture and other ecosystems to meet the needs of the increasing populations, which has put a damper on the resiliency of soil's natural process to maintain global balances of energy and matter (Doran, 2002). When considering society's continuous search for a higher standard of living and growing population, the most pressing concerns consist of declines in species biodiversity, species degradation, and loss of productive agricultural land (Doran, 2002). During the last decade inventories of soil productive capacity indicate that human induced degradation occurred on nearly 40% of the earth's arable land (Oldeman, 1994, as cited in Doran, 2002). This has occurred as a result of extensive soil cultivation, soil erosion, over-grazing, land clearing, salinization, atmospheric pollution, and desertification (Oldeman, 1994, as cited in Doran, 2002). The acceleration of degradation over the next century by the projected doubling of the global population is of a threatening concern to soils and other natural resources (Power, 1996; Ruttan, 1999 as cited in Doran, 2002).

When considering soil biodiversity and associated ecosystem services there are two main economic value components, output value and insurance value (Pascual, 2015). A good definition of soil biodiversity is the breadth of soil life from genes to communities and the ecological mechanisms of which they are part of, from soil micro-habitats to landscapes (Pascual, 2015). Actions of soil organisms that provide various known ecosystem processes that benefit people can be referred to as soil ecosystem services (Pascual, 2015). Various species within soil have different jobs or provide different services, some species decompose plant material which provides soil fertility and others provide soil structure through their activity (Pascual, 2015). These functions can be thought of as regulating services. While evaluating the economic viewpoint of soil biodiversity the ethical or biocentric reasoning should not be overlooked, while an attempt is made to bridge the gap between soil ecology and ecological economics

(Pascual, 2015). Soil biodiversity can be valued as a natural capital asset from which a flow of ecosystem services is provided (Pascual, 2015). This idea and evaluation suggests that there is an economic value to soil biodiversity. Depleting soil biodiversity results in an associated cost to society (Pascual, 2015). This cost increases when mitigation is implemented for environmental impacts or landowners adding costly inputs because of the decline in soil ecosystem services (Pascual, 2015). Unaccounted costs bear an effect that can have an adverse effect on soil biodiversity as well as contribute to a misguided allocation of scarce resources (Pascual, 2015). Soil ecosystem services have different values to the users of the services, the short run benefits and costs associated with running down the soil biodiversity in an area are often only realized over different time spans, which poses a difficult challenge (Pascual, 2015). Soil Natural capital in this context is considered soil biodiversity as a portfolio of resources that can be built up or depleted (Pascual, 2015). This wealth can either be maintained or reduced through investment decisions (Pascual, 2015). Through this logic soil biodiversity can be viewed as an economic asset and the flow of soil ecosystem services may be interpreted as the return of the interest we receive from that asset (Pascual, 2015). Perception of the expected net returns determines deliberate investments by famers or public governments/agencies (Pascual, 2015).

To estimate economic values of soil biodiversity it is necessary to have quantitative evidence linking soil biodiversity with ecological processes and soil functioning that leads to ecosystem services (Pascual, 2015). To link different value components of soil biodiversity and ecosystem services, the Total Economic Value (TEV) of soil biodiversity is used (Pascual, 2015). The change in TEV that is used is the change in the stock of soil biodiversity that is quantified as the value changes now in the future (Pascual, 2015). The different economic yields associated with tangible benefits provided by soils in a given state is referred to as the Total Output Value (TOV) (Pascual, 2015). When utilizing the TEV analogy the TOV is then largely dependent on its use value (Pascual, 2015). Another main element of the value of soil biodiversity consists of its capability to maintain the production of ecosystem services over time, with consideration to risk and uncertainty (Pascual, 2015). This conceptual component is known as the Natural Insurance Value (NIV) and is closely linked to the idea of socio-ecological resilience (Pascual, 2015). "The total economic value of soil biodiversity is the sum of TOV and NIV, i.e., the value of the expected mean flow of ecosystem services plus its variance reducing ability," (Pascual, 2015). Changes in agricultural soil biodiversity and ecosystem services have impacts on public and private values within different timescales (Pascual, 2015). This affects the influences of environmental and economic risk for farmers or land managers (Pascual, 2015). A change in management strategies that impacts the production system can indirectly change soil biodiversity, and thus change its value (Pascual, 2015). A good example is fuel taxation. Private natural insurance value is "the changes in management that can and will improve the agricultural ecosystems' capacity of producing the flow of ecosystem services," (Pascual, 2015). Improvements can include increasing water filtration, increasing soil organic matter, or increasing water holding capacity, as well as growing more variety of crops that can better cope with adverse climatic environments (Pascual, 2015).

Soil Importance

The importance of soil to society is understandable but, the value allocated to the environmental services that are supported by soil may not be equated to the entire value of the soil or to various environments the soil contributes its influence. Soil and the land provide more than 99% of human food through farming and cultivation of grazing animals (Jónsson, 2016). Soils also provide the nutrients needed for vegetation growth, as well as a filter to clean our drinking water (Jónsson, 2016). Millions of species call soil home, and soil even provides soil biota that decomposes dead organic material and waste. Twice as much carbon is stored in the soil as the biosphere and the atmosphere (Jónsson, 2016). Soils also help to prevent floods and regulate water flows. The structural foundation for human building activities usually starts with soil (Jónsson, 2016). Various building materials including clay, rock, sand, etc. are provided by soil. Many current medicines including probiotics and antibiotics, are sourced from soil (Jónsson, 2016). Soil provides more than direct ecosystem services; soil provides society with a foundation to human history and cultural development as well as places of recreation (Jónsson, 2016).

Agricultural Methods

Tillage of soil is used to prepare a seedbed, kill weeds, incorporate nutrients, and manage crop residues (University of Nebraska-Lincoln, 2019). The goal of a tillage system is to provide an appropriate environment for seed germination and root growth for crop production (University of Nebraska-Lincoln, 2019). Throughout time, tilling techniques have changed due to new technologies along with the increased cost of fuel and labor (University of Nebraska-Lincoln, 2019). During the process, conventional tillage methods breaks up soil structure and destroys plant residue while turning the soil (University of Nebraska-Lincoln, 2019).

No-till conservation practices is an agricultural method that does not disturb the soil by tilling. No till technology can be considered a leading approach to sustainable crop production, that can address soil quality as well as environmental concerns, within agricultural applications (Blanco-Canqui, H, 2018). No-till management disturbs soil less, leaves more residues on the soil surface than conventional tillage systems, and also increases plant available water in most cases (Blanco-Canqui, H, 2018). Thousands of pores will be created by roots, fungal hyphae, surface and deep dwelling earthworms, and many other types of organisms, leaving the soil matrix firm yet perforated (Natural Resources Conservation Service Pennsylvania, n.d.). Microbes are an important indicator of soil health, and some of these microbes are highly sensitive to tillage (Natural Resources Conservation Service Pennsylvania, n.d.). Tillage can disrupt the microbial biomass and the soil biological community has to rebuild itself after being tilled (Natural Resources Conservation Service Pennsylvania, n.d.).

Other common conservation methods consist of Cover Crops, and Crop Rotation. Crop rotation can be defined as a systematic or recurrent sequence of crops grown over a number of cropping seasons (Reeves, 1994). A cropping season should be considered a unit of time rather than years (Reeves, 1994). The growing season allows for more than one crop to be grown per year (Reeves, 1994). Crops used within crop rotations are generally determined by ecological and economic factors (Reeves, 1994). Crop rotation provides a principal mechanism for building healthy soils, a major way to control pests, and a variety of other benefits (Mohler, 2009). To effectively perform good crop rotation long-term strategic planning needs to be implemented (Mohler, 2009). Farmers design the field rotations to earn income, increase soil quality, or build soil value (Mohler, 2009). Rotations for expert farmers consist of key cash crops, "filler" or "break" crops, and cover crops (Mohler, 2009). Farmers must manage rotations for each field they manage, and the reality of that management is applying the needs to individual fields or beds, because each field tends to have its own distinct sequence, of crops, tillage and amendments, as well as its own cropping history (Mohler, 2009).

Cover crops are grown specifically for covering the ground to protect the soil from erosion and loss of plant nutrients through leaching and runoff (Parker, 1915; Pieters and McKee, 1938, as cited by Reeves, 1994). Cover crops increase surface residue, aide in the reduction of soil erosion, improve water holding capacity, and increase the effectiveness of N fertilizer (Lu, 2000). The use of cover crops is an old application that has been used throughout history (Lu, 2000). In earlier times cover crops were used to be ploughed under as green manures or used as animal feed within drought seasons (Lu, 2000). In modern times the use of cover crops has transitioned into uses within no-tillage, or reduced tillage agricultural management processes (Lu, 2000). Within these modern practices cover crops are used to replace plastic mulches, suppress weeds, reduce soil erosion, maintain soil moisture, and make better use of the existing nutrient content (Lu, 2000). Cover crops can be considered short-term rotations (Reeves, 1994). The main types of cover crops consist of legumes, and non-legume crops (Reeves, 1994). Some common non-legume cover crops are wheat, barley, and rye, or other cereals (Reeves, 1994). Some common legume cover crops are clovers, peas, lupins, and vetch (Reeves, 1994).

To address the economic value of soils under various agricultural practices, soil properties can be compared as a baseline for soil health. In addition, consideration of ecosystem services that are affected and real-estate land values must be taken into consideration. It is well known that soil is the foundation to life, with economic value only being associated to land value, while there is obvious impact of ecosystem services to the surrounding environment as well as yield potential in agricultural settings.

Soil Parameters

Bulk Density

Bulk density is considered the weight of soil in a given volume. Soils that have a bulk density of 1.6g/cm3 tend to restrict root growth (Brown, & Wherrett, A. 2021). Soil bulk density and soil porosity reflect the size, shape and arrangement of particles or voids within that particular soil's structure (Brown, & Wherrett, A. 2021). A more desirable soil should have a low bulk density, which allows for optimum movement of air and water throughout soils (Brown, & Wherrett, A. 2021). Sandy soils tend to have higher bulk densities at (1.3-1.7g/cm3) due to larger, but fewer pore spaces (Brown, & Wherrett, A. 2021). Silty and clay soils have bulk density concentrations of (1.1-1.6g/cm3) (Brown, & Wherrett, A. 2021). Within clay soils that have good soil structure, there is a greater amount of pore space because of smaller particles, and the increase of pore spaces that fit in-between them (Brown, & Wherrett, A. 2021). Soils that are rich in organic matter can have bulk densities of less than 0.5g/cm3 (Brown, & Wherrett, A. 2021). Bulk density increases with compaction at depth. The factors that are considered the most critical within excessively compacted soils are aeration and penetration resistance (Allmaras et al., 1988; HaÊkansson et al., 1988; Boone and Veen, 1994; Lipiec and Simota, 1994, as cited in Håkansson, 2000). Soils are composed of solids such as minerals and organic matter, as well as pores that hold air and water (Chaudhari, 2013). Bulk density varies with soil structure conditions (Chaudhari, 2013). Bulk density increases with profile depth, due to changes in organic matter, porosity, and compaction (Chaudhari, 2013). In an ideal situation the soil would be capable of holding sufficient air and water to meet the needs of plants with adequate porosity for favorable root penetration, while the mineral particles of soil provide physical support as well as plant essential nutrients (Chaudhari, 2013). Bulk density is influenced by the amount of organic matter, soil texture, constituent minerals, and soil porosity (Chaudhari, 2013). Within management of land and agricultural processes it is essential to have knowledge of soil bulk density, and soil compaction (Chaudhari, 2013).

Porosity

Pore characteristics influence numerous functions in soils (Lipiec, 2006). An important function of soil is movement of water, which directly affects plant productivity as well as the environment (Lipiec, 2006). The infiltration of water increases water storage for plants (Lipiec, 2006). Water infiltration also increases ground water recharge and reduces erosion (Lipiec, 2006). Pore size distribution and the stability of pores or pathways controls the rate of infiltration (Kutı´lek, 2004, as cited by (Lipiec, 2006). A soil matrix with macro-pores offers greater potential for undisturbed root growth (Lipiec, 2006). Roots can bypass the zones of high resistance (Glin´ski and Lipiec, 1990; Lipiec and Hatano, 2003, as cited by (Lipiec, 2006). Macro pores are relatively impervious to vertical compression (Alakukku, 1996, as cited by (Lipiec, 2006). Soils managed under conventional tillage methods, generally have lower bulk density, and associated higher porosity within the plow layer than under no-till management methods (Lipiec, 2006). Changes in total porosity are related with alterations in pore size distribution (Lipiec, 2006).

pH

Soil pH influences a myriad of soil biological, chemical, physical properties, and processes that affect plant growth as well as biomass yield (Neina, 2019). The bigeochemical processes of soil are heavily influenced by soil pH values (Neina, 2019). pH to soil can be compared to a human's temperature when being medically diagnosed (Neina, 2019). Soil pH can give hints of the soil state and the expected direction of many soil processes (lecture statement, Emeritus Prof. Eric Van Ranst, Ghent University, as cited by Neina, 2019). pH in soil is controlled by the leaching of basic cations consisting of Ca, Mg, K, Na, which leaves H+ and A3+ to be the dominant exchangeable cations (Neina, 2019). Soil biology and biological processes can be controlled by pH (Neina, 2019). The pH within soil causes implications for nutrient recycling, and availability for crop production, and distribution of harmful substances in the environment, with regards to their removal or translocation (Neina, 2019). Biogeochemical processes that pH has an effect on include: biodegradation of organic pollutants, rhizosphere processes, organic amendments, dissolution of organic matter and heavy metals, nitrification and denitrification, microbial ecophysiological indicators, soil enzyme activities, precipitation or organic matter and heavy metals, ammonia volatilization, as well as mineralization of organic matter (Neina, 2019). Soil pH is a measurement of soil acidity or alkalinity (Natural Resources Conservation Service, n.d.). Natural soil pH reflects the combined effects of soil forming factors (Natural Resources Conservation Service, n.d.). These factors include: parent material, time, relief or topography, climate, and organisms (Natural Resources Conservation Service, n.d.). Newly formed soils' pH is determined by minerals in the soil's parent material (Natural Resources Conservation Service, n.d.). pH can affect crop yields, crop suitability, plant nutrient availability, and soil micro-organism activity (Natural Resources Conservation Service, n.d.). The temperature and rainfall in an area control leaching intensity and soil mineral weathering (Natural Resources Conservation Service, n.d.). When in warm and humid climates soil pH decreases over time within a process referred to as soil acidification (Natural Resources Conservation Service, n.d.). Within dryer climates soil weathering and leaching are less intense and pH can be neutral or alkaline (Natural Resources Conservation Service, n.d.). Higher clay and organic matter content soils have the ability to resist a drop or rise in pH better than sandier soils (Natural Resources Conservation Service, n.d.).

Salinity

Salinization can affect vital ecological and non-ecological soil functions. Natural and the man-made environment can be drivers of salinization (Daliakopoulos, 2016). The term salinization refers to soils that can be categorized as saline, sodic, and alkaline (van Beek and Tóth, 2012 as cited by Daliakopoulos, 2016). These soils can be defined as high salt concentration, high sodium cation concentration, and high pH (Daliakopoulos, 2016). High salinization levels can eventually evolve into sociocultural or human health issues due to the result of emerging resources, goods and services of soil affecting agricultural production as well as environmental health (Daliakopoulos, 2016). Soil salinization covers 932.2 Mha globally and is a widespread phenomenon (Rengasamy, 2006, as cited by Daliakopoulos, 2016). Soil salinization hotspots around the world include Pakistan, China, United States, India, Argentina, Sudan, and many countries in central and western Asia (Aquastat, 2016; Ghassemi et al., 1995, as cited by Daliakopoulos, 2016). The development of salts through natural processes which includes physical or chemical weathering as well as transport from parent material, geologic processes or via ground water can be referred to as primary salinization (Daliakopoulos, 2016). Secondary salinization also exists, and consists of human involvements, mainly irrigation with saline water, or other ill-suited irrigation practices coupled with poor drainage conditions (Fan et al., 2012; Trnka et al., 2013, as cited by (Daliakopoulos, 2016). No land is invulnerable from salinization. Salt affected soils usually have low biological activity (Pessarakli, 1999). This is due to osmotic and ionic effects of salts and limitation of carbonaceous substrates (Pessarakli, 1999). Salt affected soils are affected in the development of physical, chemical, and biological characteristics eventually effecting the soil's fertility (Pessarakli, 1999). High electrolyte concentration is the common feature between all salt effected soils (Pessarakli, 1999).

Soil Texture

The formation of soil is the result of soil forming factors. Soil forming factors consist of parent material, climate, biological activity, topography, and time (Jaja, 2016). One of the most important properties of soil is texture (Jaja, 2016). Soil texture affects crop production, land use, and management (Jaja, 2016). The texture of a soil is considered a permanent soil attribute (Brady and Weil 2007, as cited by Jaja, 2016). There are 12 different soil textural classes from the USDA-NRCS soil triangle that a soil can be categorized in (Jaja, 2016). Generally, soil can be categorized in four major textural classes (Jaja, 2016). The classes are sands, silts, loams, and clays (Berry et al.

2007, as cited by Jaja, 2016). A soil's characteristic is determined by the dominant particle within each class (Jaja, 2016). Soil texture influences soil properties including drainage, water-holding capacity, aeration, susceptibility to erosion, organic matter content, cation exchange capacity, pH buffering capacity, as well as soil tilth (Berry et al. 2007, as cited by Jaja, 2016). Soil texture can help to understand the age of the soil, as well as the soil development process (Hristov, 2013). Studying soil texture in the field and laboratory is the first necessary step in research of soil as a natural body (Dilkova, 1989, as cited by Hristov, 2013).

Nutrients

Plants require 14 mineral elements for adequate nutrition outside of oxygen, carbon dioxide and water (Marschner, 1995; Mengel et al., 2001, as cited by White, 2010). When there is a deficiency in any of these elements there can be a reduction of plant growth (White, 2010). The elements Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, and Sulfur are required in large amounts within soil. Other elements such as: Chlorine, Boron, Iron, Manganese, Copper, Zinc, Nickel, and Molybdenum are required in soil within smaller amounts (White, 2010). In areas where these elements are less available, fertilizers are usually applied to increase yield (White, 2010). When used in agriculture, fertilizers also contribute to environmental pollution (White, 2010). A major contributor to eutrophication process in waters is the use of N and P fertilizers (Conley et al., 2009; White and Hammond, 2009, as cited by White, 2010).

<u>Phosphorus</u>

The second most important crop nutrient after nitrogen is Phosphorus. Phosphorus plays a role in photosynthesis, respiration, energy storage, transfer, cell division, cell enlargement, and nitrogen fixation (Mwende Muindi, 2019). Phosphorus also plays an important role within seed germination, seedling establishment, root, shoot, flower, and seed development (Mwende Muindi, 2019). A key nutrient for higher sustained agricultural productivity is phosphorus and is a limiter for plant growth in many soils (Mwende Muindi, 2019). The most common nutritional stress in the world is phosphorus deficiency (Mwende Muindi, 2019). Phosphorus deficiency causes poor plant root formation, slow development, poor seed set and fruit formation, as well as low and poor crop yields (Mwende Muindi, 2019).

Nitrogen

One of the main elements that have a vital importance within biological life on earth is Nitrogen (Li, 2014). Nitrogen exists in the lithosphere, atmosphere, hydrosphere, and the biosphere (Li, 2014). An in-between sphere containing soil is referred to as the pedosphere and helps to be a transfer point for nitrogen (Li, 2014). Nitrogen is an essential constituent for a plant's needed protein. Nitrogen increases crop yield, and improves food quality (Leghari, 2016). An optimum rate of nitrogen can increase photosynthetic processes, leaf area production, leaf area duration, the maximum leaf area, and the total leaf biomass of plants (Leghari, 2016). All plants require a balanced amount of nitrogen for vigorous growth and developmental processes (Leghari, 2016). Nitrogen stimulates root growth, imparts dark green color in plants, promotes leaves, stem and other vegetative part's growth and development (Leghari, 2016). A deficiency in nitrogen can cause reduced growth, appearance of chlorosis, appearances of red and purple spots on the leaves, as well as the restriction of lateral bud growth (Leghari, 2016). Nitrogen is applied to plants through soil and then added back to soil through plant residue during the decomposition process (Leghari, 2016).

Table 1. *Critical leaf concentrations for sufficiency and toxicity of mineral elements in non-tolerant crop plants*

Element	Essentiality		Critical leaf concentrations (mg g^{-1} DM)	
	Plant	Animal	Sufficiency	Toxicity
Nitrogen (N)	yes	yes	15 – 40	
Potassium (K)	yes	yes	5 – 40	> 50
Phosphorus (P)	yes	yes	2 – 5	> 10
Calcium (Ca)	yes	yes	0·5 – 10	> 100
Magnesium (Mg)	yes	yes	1·5 – 3·5	> 15
Sulphur (S)	yes	yes	1·0 – 5·0	
Chlorine (Cl)	yes	yes	0·1 – 6·0	4·0 – 7·0
Boron (B)	yes	suggested	$5 - 100 \times 10^{-3}$	0·1 – 1·0
Iron (Fe)	yes	yes	$50 - 150 \times 10^{-3}$	>0·5
Manganese (Mn)	yes	yes	$10 - 20 \times 10^{-3}$	0·2 – 5·3
Copper (Cu)	yes	yes	$1 - 5 \times 10^{-3}$	$15 - 30 \times 10^{-3}$
Zinc (Zn)	yes	yes	$15 - 30 \times 10^{-3}$	$100 - 300 \times 10^{-3}$
Nickel (Ni)	yes	suggested	$0{\cdot}1 \times 10^{-3}$	$20 - 30 \times 10^{-3}$
Molybdenum (Mo)	yes	yes	$0{\cdot}1 - 1{\cdot}0 \times 10^{-3}$	1
Sodium (Na)	beneficial	yes	–	2 – 5
Selenium (Se)	beneficial	yes	–	$10 - 100 \times 10^{-3}$
Cobalt (Co)	beneficial	yes	–	$10 - 20 \times 10^{-3}$
Iodine (I)	–	yes	–	$1 - 20 \times 10^{-3}$
Fluorine (F)	–	suggested	–	0·1
Lithium (Li)	–	suggested		$10 - 200 \times 10^{-3}$
Lead (Pb)	–	suggested	–	$10 - 20 \times 10^{-3}$
Arsenic (As)	–	suggested	–	$1 - 20 \times 10^{-3}$
Vanadium (V)	–	suggested	–	$1 - 10 \times 10^{-3}$
Chromium (Cr)	–	suggested	–	$1 - 2 \times 10^{-3}$
Silicon (Si)	beneficial	suggested	–	nd
Aluminium (Al)	beneficial	–	–	$40 - 200 \times 10^{-3}$
Cadmium (Cd)	–	–	–	$5 - 10 \times 10^{-3}$
Mercury (Hg)	–	–	–	$2 - 5 \times 10^{-3}$

Essential elements for plants and animals are indicated. Mineral elements considered beneficial to plants, which improve the growth of various taxa under certain environmental conditions, are also indicated. The critical concentration for sufficiency is defined as the concentration in a diagnostic tissue that allows a crop to achieve 90 % of its maximum yield. The critical concentration for toxicity is defined as the concentration in a diagnostic tissue above which yield is decreased by more than 10 %. Data are taken from MacNicol and Beckett (1985), Brown *et al.* (1987), Marschner (1995), Mengel *et al.* (2001), White *et al.* (2004) and Pilon-Smits *et al.* (2009). It should be recognized that critical tissue concentrations depend upon the exact solute composition of the soil solution and can differ greatly both between and within plant species. The latter differences reflect both ancestral habitats and ecological strategies.

Figure 2 Table showcasing essential elements for plants and animals (White, 2010).

%Soil Organic Matter

A key component to soil ecosystems is soil organic matter (Spain, 1983). Variations in soil organic matter has profound effects on many of the processes that occur in the system (Spain, 1983). Included in soil organic matter is any plant, or animal material that returns to the soil and goes through the decomposition process (Bot, 2005). Organic matter also provides nutrients and habitats to organisms living in the soil (Bot, 2005). Another function of soil organic matter is that it binds soil particles into aggregates and improves water holding capacity (Bot, 2005). It is essential to soil fertility that nutrient exchanges between organic matter, water, and soil be maintained for sustainable production purposes (Bot, 2005). Soil fertility often declines with exploitation of soil organic matter for crop production (Bot, 2005). When this happens without repairing the organic matter and nutrient contents, maintaining a good structure and nutrient cycles are broken, as well as the agro-ecosystem becoming destroyed (Bot, 2005). Ploughing, disc-tillage, and vegetation burning increase the speed of the decomposition of soil organic matter as well as leaves the soil susceptible to wind and water erosion (Bot, 2005). Soil organic material content is a function. This function includes inputs of residues and roots and litter decomposition (Bot, 2005). The organic component of soil is known as SOM or Soil Organic Matter. Soil organic matter consists of three primary parts: small plant residues and small living organisms (flesh), decomposing organic matter (active), and stable organic matter (humus) (National Resources Conservation Service, USDA, n.d.). The services provided by soil organic matter include: a reservoir of nutrients for crops, provides soil aggregation, increases nutrient exchange, retains moisture, reduces compaction, reduces surface crusting, and increases water infiltration into soil (National Resources Conservation Service, USDA, n.d.). Organic matter decomposition is affected by climatic conditions such as rainfall, temperature, moisture, and soil aeration (National Resources Conservation Service, USDA, n.d.). Naturally organic matter decomposes faster in warm and humid climates than it does in cool and dry climates (National Resources Conservation Service, USDA, n.d.). Under average conditions and within temperate regions it is estimated that 1.5% of SOM mineralizes yearly for most crops, while maintaining current organic matter levels in soils in-between 2-5% SOM (Doran 2012, as cited by (National Resources Conservation Service, USDA, n.d.).

Hypothesis:

Different agricultural processes can impact soil's overall quality and sustainability. Agricultural practices that can influence soil health include conventional tillage vs. no-till methods and use of other conservation methods such as plant residue, cover crops, and crop rotation. Utilization of conservation practices will improve the soil quality as measured by select soil parameters.

Objectives:

1) Identify agricultural land that has a variety of conventional and conservation tillage systems.
2) Using soil composite samples, analyze soil with respect to characteristics that indicate soil health such as organic material, nutrients (total nitrogen and plant available phosphate), pH, salinity, and bulk density.
3) Compare soil parameters with respect to ecosystem services and cost of agricultural practice.

Chapter 3: Methodology

Trumbull County, Ohio consists of a combination of urban and rural communities. Trumbull County is located in the northeast corner of the state of Ohio (Trumbull County, n.d.). The county was established on July 10, 1880, and named after Jonathan Trumbull, who was the Governor of Connecticut, and once owned the land in this region (Trumbull County, n.d.). Trumbull County is now considered part of the Youngstown-Warren-Boardman-OH-PA Metropolitan Statistical area. The total area of the county is 625 square miles, Trumbull County is the only square county in the entire state of Ohio, with each side approximately 25 miles (Trumbull County, n.d.). There are seven cities inside the county. They are Cortland, Girard, Hubbard, Newton Falls, Niles, Warren, and Youngstown (Trumbull County, n.d.). There are also five villages these are Lordstown, McDonald, Orangeville, West Farmington, and Yankee Lake (Trumbull County, n.d.). Trumbull County consists of 123,654 acres of farmland (United States Department of Agriculture, 2019).

Site Description

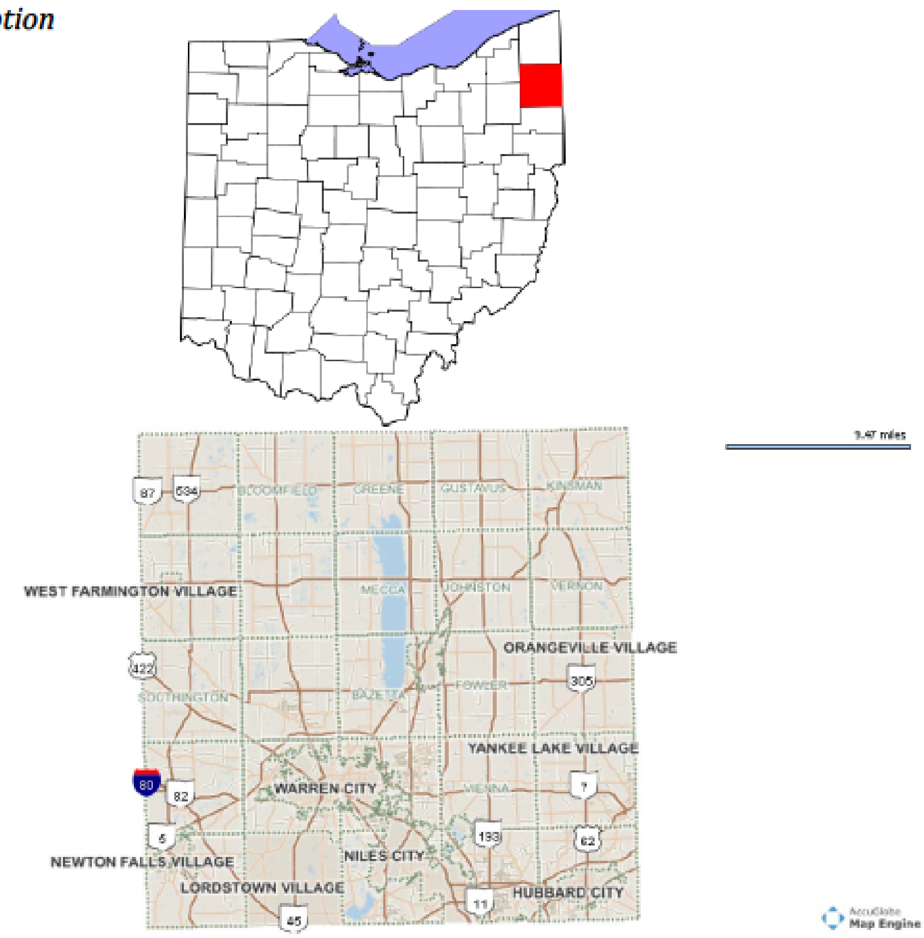

Figure 3 Identifying Tested area of Trumbull County, Ohio (Top image from *Retrieved from: https://en.wikipedia.org/wiki/Trumbull_County,_Ohio; Bottom image from:* *https://trumbulloh-auditor-classic.ddti.net/Map.aspx*)

Kinsman Ohio, located in Trumbull County, is home to 616 people, and within the township 1,943 (2010 US Census). Named after John Kinsman, Kinsman is now part of the Youngstown-Warren-Boardman, OH-PA Metropolitan Statistical Area (Kinsman Township Ohio, n.d.). At its finding in 1799, Kinsman had 16,664 acres and cost $12,903.23 (Kinsman Township Ohio, n.d.). Kinsman is situated on two creeks, the Stratton and the Pymatuning. Early evidence proved that Kinsman had been a place of Native American residence, and small tribes frequently visited to hunt, trap, and trade with Mr. Kinsman (Kinsman Township Ohio, n.d.). In 1804 John Kinsman returned to his home in Connecticut, after establishing this small community (Kinsman Township Ohio, n.d.).

Bloomfield Township is one of 24 townships within Trumbull County (Wikipedia, 2020). The township is governed by a three-member board of trustees (Wikipedia, 2020). Bloomfield townships is a total of 25.4 square miles, and 100% of that is land (Wikipedia, 2020). According to the 2000 census Bloomfield has a population of 1,097 people (Wikipedia, 2020).

Various agriculturally managed fields were selected, and soil quality characteristics were tested. Several farmers in Trumbull County agreed to participate in the research. Each field location (GPS) and the type of farming method was recorded. Composite soil samples were taken using five or more 30 cm by 2 cm cores, spaced out 3m or more and divided into top and bottom 15 cm. In addition, a bulk density core was taken from each field. Other relevant observations were noted. Samples were taken to the lab at Youngstown State University and analyzed.

Sampling Sites

The initial field testing was done working with a farmer named, Jeff, and his farm in Trumbull County near Kinsman, where three fields were identified with various conservative agricultural methods (Figure 5-7). Soil cores and bulk density were taken from each of the fields.

Two additional farms were used, both stayed inside Trumbull County. The two farms were Shady Maple, and Miller's Farm, The Miller Farm was totally conventionally managed (Figure 11). Miller's farm and tested field were located in the same township (Kinsman) as the first fields tested (Figure 8-10). Shady Maple is located in Bloomfield township, and had various conservation agricultural methods within its management. Soil cores and bulk density were taken from each of the fields.

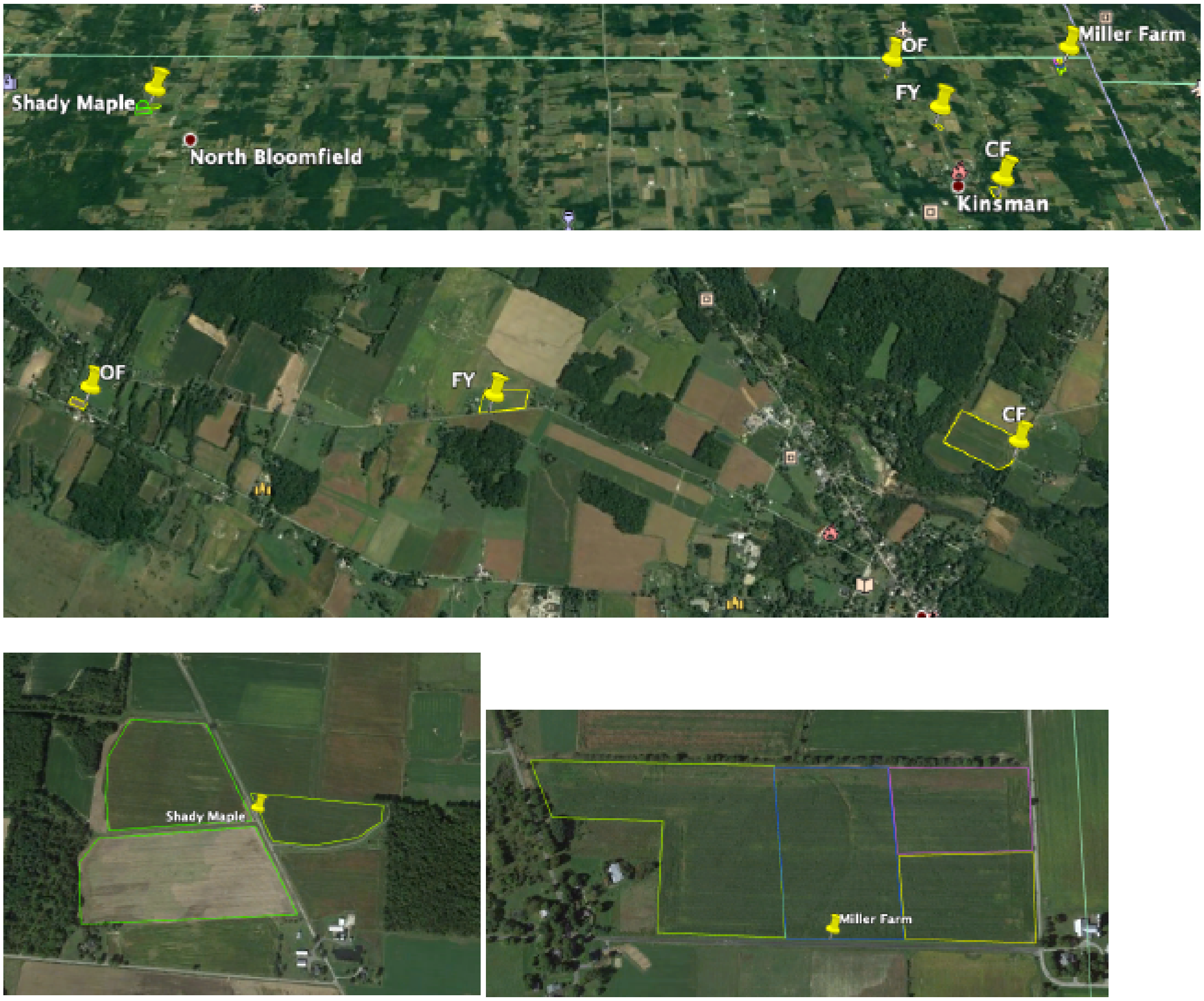

Figure 4 Google map image indicating location of the fields identified with conservative farm methods

Figure 5 First Conservative method Test Field (OF)

Figure 6 Second conservative method test field (FY)

Figure 7 Third conservation methods test field (CF)


Figure 8 Fourth conservation methods test field (Shady Maple)


Figure 9 Fifth conservation methods test field (Shady Maple)

Figure 10 Sixth conservation methods test field (Shady Maple)

Figure 11 Seventh conservation methods test field (Millers Farm)

Soil Analysis

Soil was analyzed for organic matter using loss on ignition (LOI) method (Nelson et al., 1996). This method consisted of heating a representative sample to 550°C for 16 hours. The change in mass reflects the amount of soil organic material in the soil sample. The soil samples from LOI was used to determine the inorganic particle size or soil texture using the Cilas 1190 laser particle size analyzer. This method uses a beam of light to measure the size distribution of individual particles in a soil sample (Gee, 1986).

Total nitrogen was performed by Agricultural Analytical Services Lab at Penn State University which utilizes the combustion method (Bremner, J.M, 1996 and Pella, E. 1990). Results were received as % Nitrogen within an excel spreadsheet and added to the master data spreadsheet.

Plant available phosphate was determined by extracting the soil with Mehlich 3 then analyzing for phosphate using the Ascorbic Acid Method (Kuo et al., 1996). Once extracted, 20 ml of sample was mixed with the combined reagent. Combined reagent is composed of ascorbic acid, ammonium molybdate, sulfuric acid and antimony potassium tartrate (Kuo et al., 1996). After 10 min a measurement for 880nm was read against a blank.

Soil pH determines how much of each nutrient will be bioavailable to the plant and microorganisms in the soil. To test for pH, 20g of sample was mixed with 40 ml of deionized water (and 0.01M $CaCl_2$). The mixture was shook for 2 hours, allowed to sit for 10-30 minutes and the pH read of the supernant (Reeuwijk, 2002).

Salinity results for the soil samples were collected with 20g of sample mixed with 40 ml of deionized water, shook for 2 hours, allowed to sit for 10-30 minutes and the salinity was read and recorded with the HACH Sension 5 conductivity meter.

Bulk density 8 cm rings were used to test for soil compaction by driving the ring into the soil using the hand mallet. The ring was removed with soil intact, and soil on the outside of the ring was removed, then the ring contents were bagged., The soil was dried and weighted to determine bulk density (g/cm3). Testing for bulk density allowed for the calculation of percent of porosity (Eq. 1). These various soil properties were used to determine overall soil quality (NRCS 2015).

$$\text{Porosity} = 1 - (\text{bulk density}/\text{particle density}) \qquad \text{Eq.}$$

Figure 12 Undergraduate student Caden Barone, separating a soil composite sample in the field (on the left), & a soil core sample with collection buckets (on the right).

Statistics

A ranking system was used to code the agricultural methods that existed on each sampled field. The ranking system started at 1 and went to 4, where 1 consisted of conventional agricultural methods and 4 represented those fields with the most conservation methods employed. The rankings were developed on the basis that rank 1 was a starting point of the methods, for this research rank 1 consisted of the least conservational methods applied. This meant that rank 1 housed fields that were conventionally managed, and as the rankings increase so did the combination of conservational methods applied. Rank 4 was the highest available rank and contained all fields that applied a no-till conservation method. Ones were distributed to all the fields that used conventional tillage methods. Those fields that did conventional tillage and crop rotation were also ranked as 1 since the crop rotation alone will not provide enough benefit to improve soil quality. The ranking of 2.0 was given to fields that practiced a known crop rotation, plant residue, and included reduced till. A rank of 3.0 was used for fields that included a crop rotation process, reduced tillage, plant residue, and a record of cover crops. One field (Shady Maple Field 1) was considered a 3 even though it employed many conservation methods because it was in its inaugural year of implementing a cover crop. A ranking of 4.0 was given to any field that included no-till and multiple other conservation methods including cover crop, crop rotation, and plant residue. These fields all had a combination of conservation methods but to achieve the highest score they also needed to include no-till within their methods.

The program that was used to analyze the data for statistical purposes was IBM's SPSS. This program was chosen because of its commonness and frequency of being used with environmental science data. SPSS offers a wide variety of data analyzations able to be implemented with this data set.

Various statistical analysis were performed including correlation matrix, a mean comparison one-way ANOVA, Principal Component Analysis, and backwards linear regressions. The statistical analysis that was chosen to review the data visually was the Principal Component Analysis. The Principal Component Analysis runs an analysis to explain the total variance, then creates coefficients of variance for each variable, to then be able to plot these on a multi-dimensional plane, depending on the data. This allows the data to be visualized and compared to where each sample exists on a map, where each corner is an extreme high point for the variance between particular variables.

Chapter 4 Results

The averages of each soil characteristic per agricultural method ranking were done on the 7 fields sampled and resulting 32 soil samples. The rankings spanned from 1-4. Rank 1 had 12 samples; rank 2 only applied to 4 samples; rank 3, and 4 both consisted of 8 samples. Out of the 7 fields, one (Millers Farm) was a contiguous larger field which was separated into 4 subsections. This divided the field samples into 16 sections. Of the 16 samples, another division of top 15 cm and bottom 15 cm was applied for the soil core. The top sections were investigated for bulk density and percent porosity. Statistical analysis was completed to identify various statistical trends between ranking categories and between soil layer (top and bottom of soil core).

Descriptive Statistics:

Table 2 contains the descriptive statistics for all the variables involved including number of observations per each variable, the minimum and maximum recorded data point, the mean and standard deviation. Percent porosity and bulk density were only recorded for the top and is why the number of observations is listed at 16. The other misnomer in this table is percent soil organic matter that had 31 observations instead of 32 because there was an error/loss of sample from one sample.

Table 2 Descriptive statistics of each parameter for all soil samples collected from agricultural fields in Trumbull County, Ohio.

Variable	Observations	Minimum	Maximum	Mean	Std. Deviation
Agricultural Method Ranking	32	1	4	NA	NA
Bulk Density, g/cm3	16	0.943	1.37	1.20	0.122
% Porosity	16	48.33	64.42	54.67	4.59
pH 1:1 Water	32	4.70	5.76	5.167	0.250
pH 1:2 CaCl2	32	4.24	5.30	4.760	0.304
PO4-P, mg/kg	32	6.90	103.1	45.59	26.87
Salinity, mS/cm	32	0.136	0.860	0.435	0.208
%SOM	31	2.43	5.60	3.594	0.869
% Sand	32	14.12	76.91	32.84	17.27
% Silt	32	21.51	81.42	63.04	16.14
% Clay	32	1.57	7.08	4.115	1.472
TN%, mg/kg	32	0.063	0.247	0.125	0.047

Table 3 includes descriptive statistics for the soil samples separated into top and bottom categories. In this table, the top 15 cm layer = 1, and bottom 15 cm layer = 2. The descriptive statistics in Table 3 include number of observations per each variable, the minimum and maximum recorded data point, the mean and standard deviation.

Table 3 Descriptive statistics of each parameter for all soil samples separated between top and bottom layers from agricultural fields in Trumbull County, Ohio

Report

RankLayer		Bulk Density, g/cm3	% Porosity	pH 1:1 Water (Avg)	pH 1:2 CaCl2	PO4-P, mg/kg (Avg)	Salinity, mS/cm (Avg)	%SOM	% Sand	% Silt	% Clay	TN%, mg/kg
1.00	Mean	1.201	54.671	5.182	4.825	63.206	.499	4.187	28.194	67.298	4.508	.156
	N	16	16	16	16	16	16	16	16	16	16	16
	Std. Deviation	.122	4.589	.267	.309	25.944	.221	.725	11.913	10.960	1.424	.043
	Minimum	.943	48.333	4.700	4.320	18.048	.209	3.278	14.150	34.205	1.570	.093
	Maximum	1.369	64.420	5.760	5.300	103.060	.860	5.598	64.230	81.420	7.080	.247
2.00	Mean			5.151	4.695	27.971	.371	2.961	37.488	58.790	3.723	.095
	N			16	16	16	16	15	16	16	16	16
	Std. Deviation			.240	.296	12.522	.178	.474	20.704	19.490	1.456	.028
	Minimum			4.710	4.240	6.904	.136	2.428	14.240	21.510	1.580	.063
	Maximum			5.500	5.140	54.040	.583	4.053	76.910	80.650	6.690	.166
Total	Mean	1.201	54.671	5.166	4.760	45.588	.435	3.594	32.841	63.044	4.115	.125
	N	16	16	32	32	32	32	31	32	32	32	32
	Std. Deviation	.122	4.589	.250	.3044	26.869	.208	.869	17.274	16.144	1.472	.047
	Minimum	.943	48.333	4.700	4.240	6.904	.136	2.428	14.150	21.510	1.570	.063
	Maximum	1.369	64.420	5.760	5.300	103.060	.860	5.598	76.910	81.420	7.080	.247

Backwards Linear Regression:

Backwards linear regressions were run to identify what variables were predictors of nutrient quality. Nitrogen and phosphorus were both analyzed for backwards linear regressions due to the identified significance and correlations identified within the correlation matrix and mean comparisons Figure 39 in the Appendix. Table 4 shows percent total nitrogen as the dependent variable. In this model the agricultural method rank, percent soil organic matter, and pH were identified as predictors of percent total nitrogen.

Table 4 Coefficients for Linear Regression Model to determine the % total nitrogen for soil samples collected from agricultural fields in Trumbull County, Ohio.

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.043	.052		.821	.420
	RANKNUMBERS	.013	.004	.347	3.674	.001
	% Clay	.000	.004	.015	.113	.911
	% Silt	.000	.000	-.039	-.339	.738
	%SOM	.038	.005	.704	7.643	<.001
	pH 1:2 CaCl2	-.030	.011	-.185	-2.736	.012
	Salinity, uS/cm (Avg)	.143	.032	.621	4.518	<.001
2	(Constant)	.045	.047		.952	.350
	RANKNUMBERS	.013	.003	.346	3.775	<.001
	% Silt	-8.128E-5	.000	-.028	-.442	.662
	%SOM	.038	.004	.709	8.746	<.001
	pH 1:2 CaCl2	-.030	.010	-.188	-3.011	.006
	Salinity, uS/cm (Avg)	.141	.025	.612	5.739	<.001
3	(Constant)	.035	.040		.858	.399
	RANKNUMBERS	.013	.003	.356	4.091	<.001
	%SOM	.037	.004	.692	9.815	<.001
	pH 1:2 CaCl2	-.029	.009	-.179	-3.079	.005
	Salinity, uS/cm (Avg)	.143	.024	.620	6.016	<.001

a. Dependent Variable: TN%, mg/kg

Table 5 showcases the same analysis only with plant available phosphorus set as the dependent variable. In this model percent soil organic matter, and pH were identified as predictors of phosphorus. Although the agricultural method ranking did not make it into the final set of variables of predictability it fell into the second to last category, showing it is somewhat important when predicting phosphorus.

Table 5 Coefficient Table for Linear Regression Model to determine the plant available phosphorus for soil samples collected from agricultural fields in Trumbull County, Ohio

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	96.979	66.884		1.450	.160
	RANKNUMBERS	3.566	4.546	.164	.784	.440
	% Clay	2.658	5.537	.138	.480	.636
	% Silt	-.249	.425	-.149	-.585	.564
	%SOM	27.837	6.387	.886	4.358	<.001
	pH 1:2 CaCl2	-33.307	13.888	-.359	-2.398	.025
	Salinity, uS/cm (Avg)	9.785	40.545	.073	.241	.811
2	(Constant)	101.651	62.804		1.619	.118
	RANKNUMBERS	2.782	3.121	.128	.891	.381
	% Clay	1.840	4.296	.096	.428	.672
	% Silt	-.205	.378	-.123	-.543	.592
	%SOM	28.885	4.593	.920	6.289	<.001
	pH 1:2 CaCl2	-33.658	13.549	-.363	-2.484	.020
3	(Constant)	108.842	59.560		1.827	.079
	RANKNUMBERS	3.471	2.634	.159	1.318	.199
	% Silt	-.077	.228	-.046	-.339	.738
	%SOM	28.969	4.516	.922	6.415	<.001
	pH 1:2 CaCl2	-35.695	12.487	-.385	-2.859	.008
4	(Constant)	98.817	50.829		1.944	.062
	RANKNUMBERS	3.639	2.543	.167	1.431	.164
	%SOM	28.280	3.964	.901	7.134	<.001
	pH 1:2 CaCl2	-34.176	11.460	-.368	-2.982	.006
5	(Constant)	102.477	51.705		1.982	.057
	%SOM	26.908	3.918	.857	6.868	<.001
	pH 1:2 CaCl2	-32.116	11.580	-.346	-2.773	.010

a. Dependent Variable: PO4-P, mg/kg (Avg)

Table 6 and 7 showcase linear regression models for nutrients, nitrogen, and phosphorus, but within these tables the layer of the soil core was investigated for predictability of each dependent variable. Table 6 displays the analysis with nitrogen as the dependent variable. Within this table the layer became an excluded variable in an earlier stage of the models created than rankings did in Table 4 which is also looking at nitrogen as a dependent variable. The other predictors of % nitrogen stayed consistent within this model and the model in Table 4, which were %SOM, pH, and salinity. Although the layer did not declare itself as a predictor of nitrogen concentration in these samples, the analysis gave some insight for future investigations, such as whether or not the layer investigation is necessary for all soil characteristics.

Table 6 Coefficient Table for Linear Regression Model to determine the plant available nitrogen for soil samples between top and bottom layers collected from agricultural fields in Trumbull County, Ohio

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.098	.072		1.367	.184
	% Clay	-.003	.006	-.102	-.573	.572
	% Silt	-3.892E-5	.000	-.014	-.087	.931
	%SOM	.043	.007	.803	6.236	<.001
	pH 1:2 CaCl2	-.027	.013	-.167	-1.990	.058
	Salinity, uS/cm (Avg)	.057	.028	.248	2.048	.052
	RankLayer	-.006	.010	-.063	-.565	.577
2	(Constant)	.099	.068		1.451	.159
	% Clay	-.004	.003	-.115	-1.313	.201
	%SOM	.043	.007	.802	6.397	<.001
	pH 1:2 CaCl2	-.027	.013	-.168	-2.051	.051
	Salinity, uS/cm (Avg)	.056	.021	.242	2.629	.014
	RankLayer	-.006	.009	-.067	-.662	.514
3	(Constant)	.080	.062		1.307	.203
	% Clay	-.003	.003	-.102	-1.208	.238
	%SOM	.046	.005	.851	8.546	<.001
	pH 1:2 CaCl2	-.027	.013	-.169	-2.092	.046
	Salinity, uS/cm (Avg)	.054	.021	.236	2.605	.015
4	(Constant)	.038	.051		.740	.465
	%SOM	.042	.005	.785	9.350	<.001
	pH 1:2 CaCl2	-.019	.011	-.121	-1.705	.100
	Salinity, uS/cm (Avg)	.066	.018	.288	3.602	.001

a. Dependent Variable: TN%, mg/kg

Table 7 displays the same analysis but with phosphorus as a dependent variable. Contrary to Table 6 and nitrogen concentration, the layer of the soil core held more weight and was more of a predictor for phosphorus concentration. Even though the layer category did not make it into the final model again, it was placed in the second to last model, showing the layer of the soil core has some significance when predicting phosphorus concentration. %SOM and pH stayed consistent in both Table 7 and Table 5 when predicting plant available phosphorus within the model.

Table 7 Coefficient Table for Linear Regression Model to determine the plant available phosphorus for soil samples between top and bottom layers collected from agricultural fields in Trumbull County, Ohio

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	146.021	72.799		2.006	.056
	% Clay	-1.054	5.989	-.055	-.176	.862
	% Silt	-.051	.454	-.031	-.112	.911
	%SOM	25.045	7.081	.798	3.537	.002
	pH 1:2 CaCl2	-32.732	13.642	-.353	-2.399	.025
	Salinity, uS/cm (Avg)	-18.722	28.391	-.140	-.659	.516
	RankLayer	-12.219	10.452	-.227	-1.169	.254
2	(Constant)	147.840	69.564		2.125	.044
	% Clay	-1.636	2.958	-.085	-.553	.585
	%SOM	24.952	6.892	.795	3.620	.001
	pH 1:2 CaCl2	-32.894	13.295	-.354	-2.474	.020
	Salinity, uS/cm (Avg)	-20.746	21.519	-.155	-.964	.344
	RankLayer	-12.672	9.456	-.236	-1.340	.192
3	(Constant)	124.589	54.673		2.279	.031
	%SOM	23.819	6.492	.758	3.669	.001
	pH 1:2 CaCl2	-29.409	11.549	-.317	-2.546	.017
	Salinity, uS/cm (Avg)	-15.456	19.016	-.116	-.813	.424
	RankLayer	-11.507	9.095	-.214	-1.265	.217
4	(Constant)	130.204	53.892		2.416	.023
	%SOM	21.042	5.486	.670	3.836	<.001
	pH 1:2 CaCl2	-29.417	11.476	-.317	-2.563	.016
	RankLayer	-13.167	8.807	-.245	-1.495	.146
5	(Constant)	102.477	51.705		1.982	.057
	%SOM	26.908	3.918	.857	6.868	<.001
	pH 1:2 CaCl2	-32.116	11.580	-.346	-2.773	.010

a. Dependent Variable: PO4-P, mg/kg (Avg)

Averages per Rank:

Figure 13 shows a comparison of nutrients within the 4 agricultural method rankings as well as the average between them. The nutrients within this graph consist of phosphorus, nitrogen, and salinity. Phosphorus ranged from 31 – 65, with an average of 45.47 mg/kg. Percent nitrogen ranged from 0.096 – 0.139, with an average of 0.124. Salinity fell within the range of 0.211 – 0.602mS/cm, and had an average of 0.438 mS/cm.

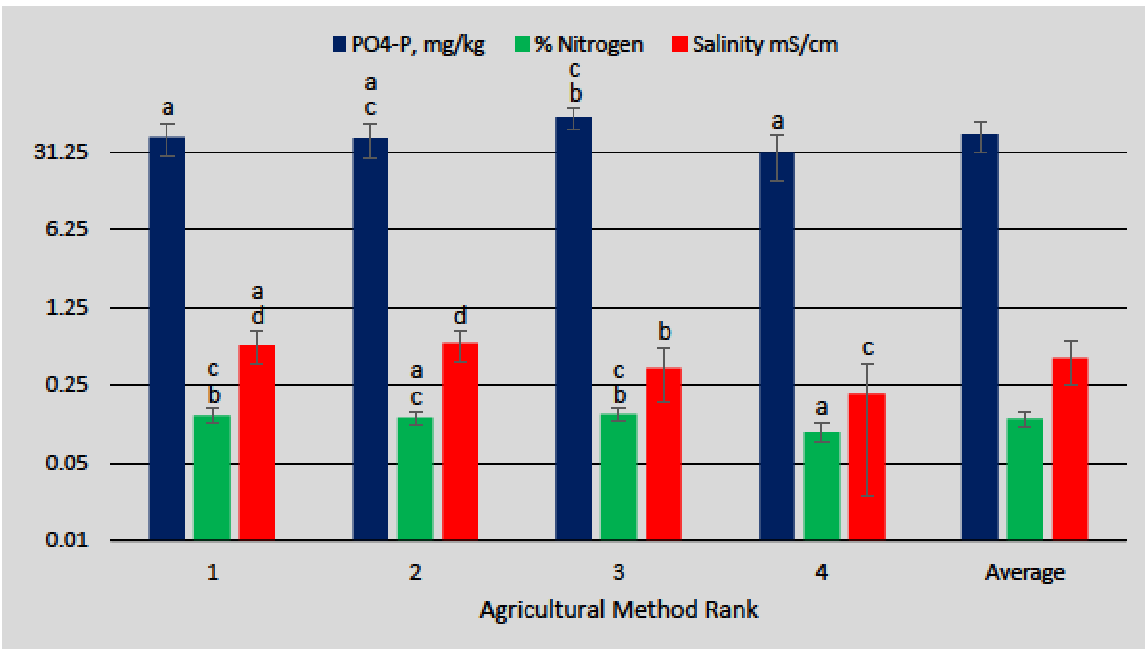

Figure 13 Average of Nutrients (P, N, Salinity) within agricultural method ranking for farms in Trumbull County, Ohio (LSD – mean comparisons) *Columns with different letters are sig different at < 0.1 significance

Figure 14 shows a comparison of physical characteristics between the ranked agricultural methods as well as the averages. The physical characteristics being compared within this graph consist of bulk density, soil organic material, and pH. The bulk density measurement ranged from 1.11 – 1.32 g/cm^3 and had an average of 1.22 g/cm^3. Percent soil organic material had a range of 3.18 – 3.91% and an average of 3.53%. pH was looked at in two different capacities of testing, consisting of water and calcium chloride. Calcium chloride is the more consistent and accurate representation of pH at the soil-plant interface and is what was chosen for this graph. The range of pH was from 4.82 – 4.89 and had an average of 4.73.

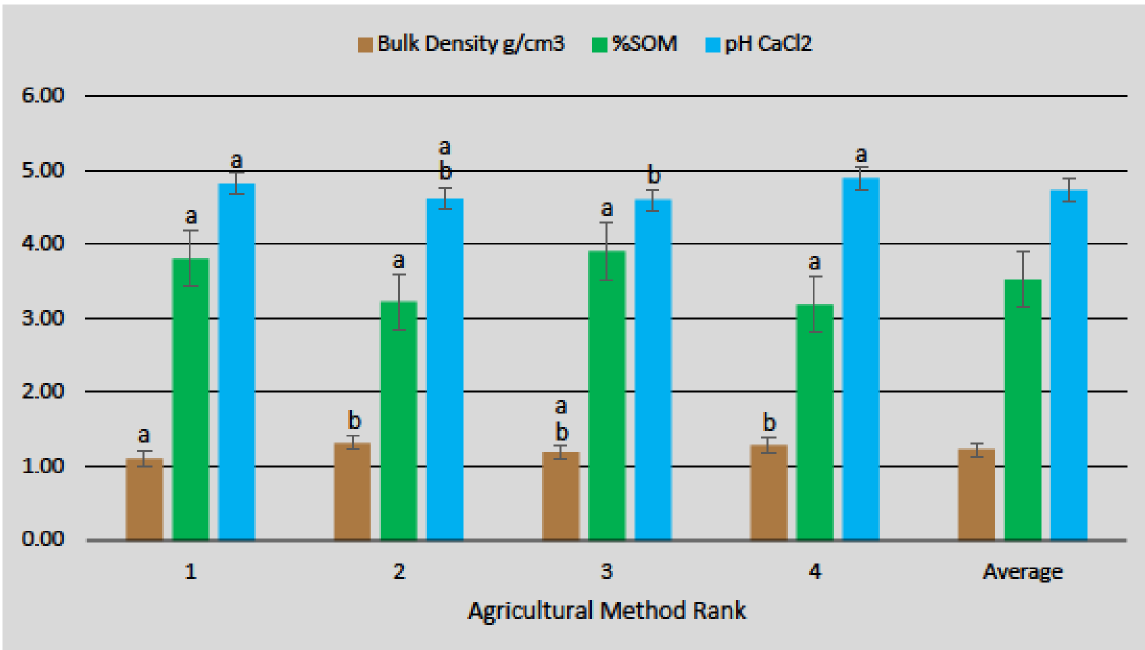

Figure 14 Average of physical characteristics (bulk density, %SOM, pH_{CaCl2}) with agricultural method rank for farms in Trumbull County, Ohio (LSD – mean comparisons) *Columns with different letters are sig different at < 0.1 significance

Figure 15 shows percentage porosity with the ranked agricultural methods as well as the average. The porosity was calculated using bulk density measurements using equation 1. The ranges of percent porosity for the data were from 50.17 – 58.17% and had an average of 53.67%.

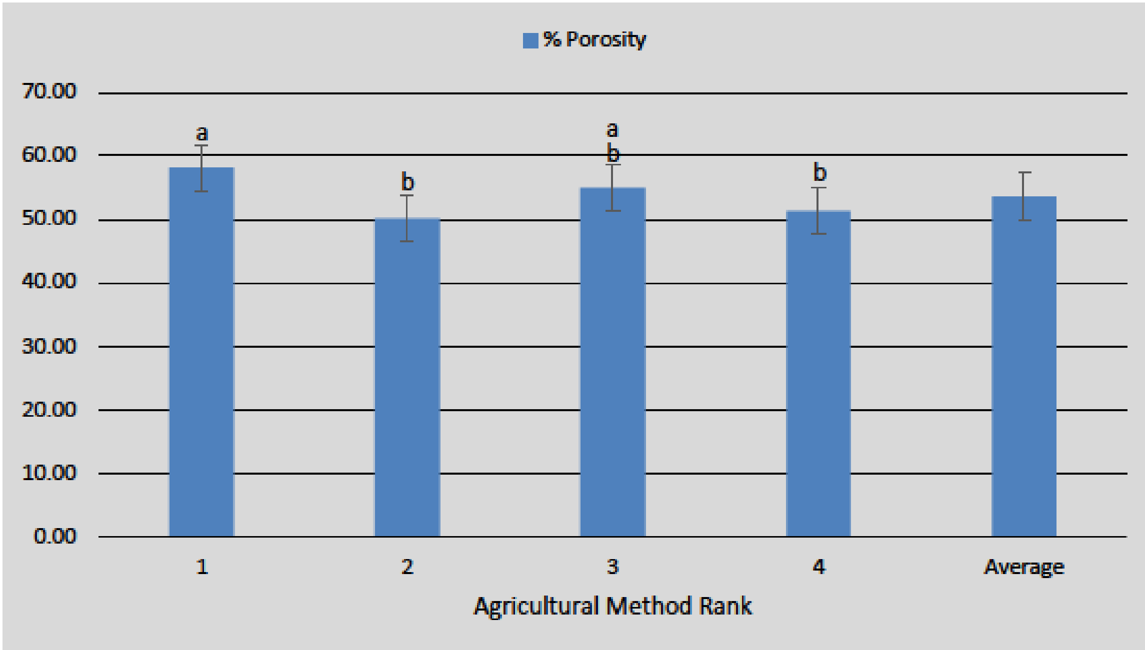

Figure 15 Average of percent porosity with agricultural method rank for farms in Trumbull County. (LSD – mean comparisons) *Columns with different letters are sig different at < 0.1 significance

Figure 16 shows a comparison of soil texture between the agricultural method rank as well as the averages. Soil texture consisted of percent sand, silt, and clay was determined using laser particle size analysis. Sand ranged from 20.71 – 46.05% with an average of 33.25%. Silt ranged from 50.05 – 74.17% with an average of 62.55%. Clay ranged from 3.81 – 5.12% with an average of 4.19%.

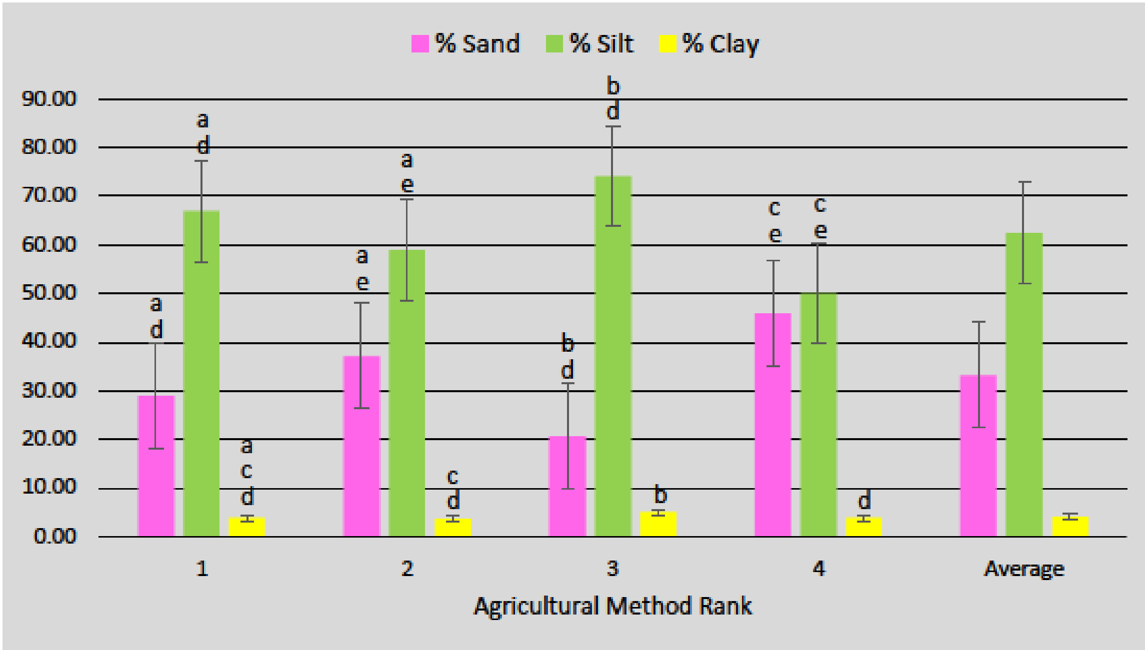

Figure 16 Average of soil texture (% Sand, % Silt, % Clay) within agricultural method rank for farms in Trumbull County. (LSD – mean comparisons) *Columns with different letters are sig different at < 0.1 significance

Top and bottom averages separated through Agricultural Rank:

Figure 17 showcases a comparison of phosphate -phosphorus between agricultural method ranks and separated through top and bottom samples. Within this graph PO_4-P in the top 15 cm ranged from 43.89 - 103.06 mg/kg, with an average of 63.20 mg/kg. The bottom 15 cm ranged from 6.90 – 54.04 mg/kg, with an average of 27.97 mg/kg.

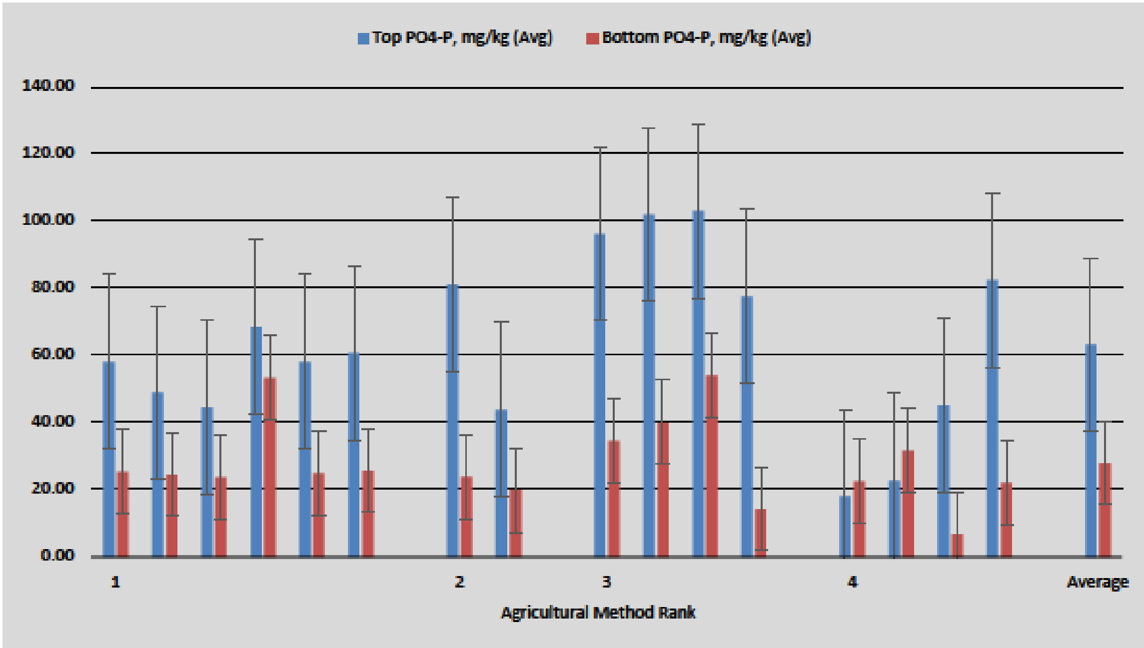

Figure 17 Phosphate-phosphorus concentration from soil cores indicating 15 cm top and bottom sections of core. Samples are from farms in Trumbull County and placed by agricultural method rank.

Figure 18 displays the salinity between agricultural method ranks and separated through top and bottom soil core samples. Within the top 15 cm salinity ranges from 0.209 – 0.860 mS/cm, with an average of 0.499 mS/cm. The bottom 15 cm had a range of 0.136 – 0.583 mS/cm, with an average of 0.371 mS/cm.

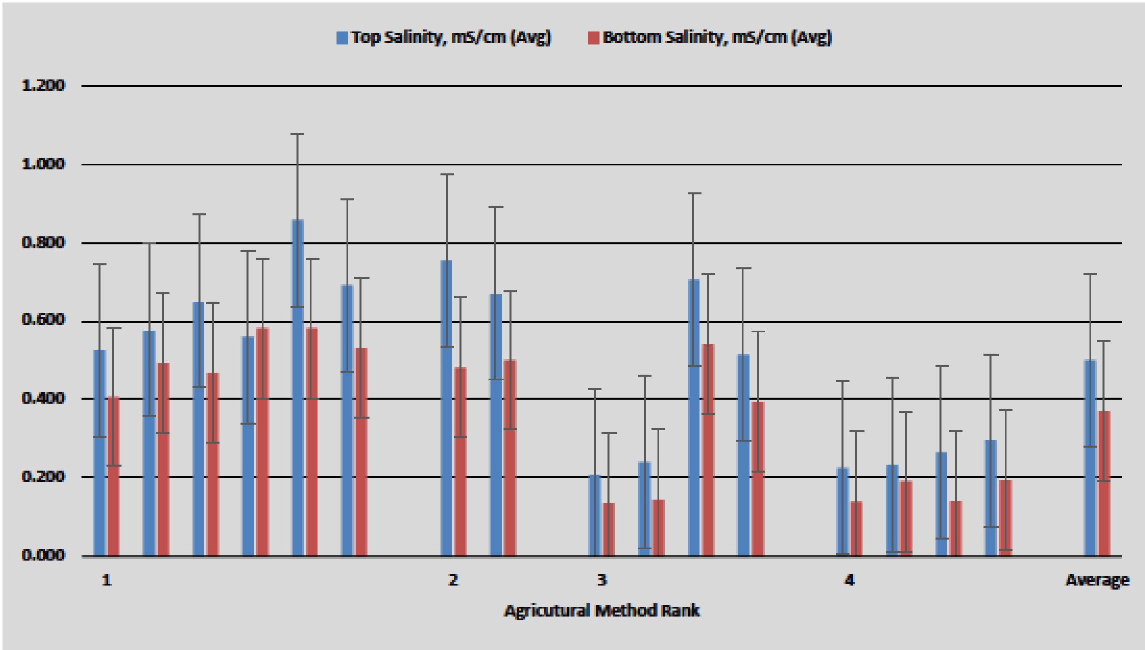

Figure 18 Salinity from soil cores indicating 15 cm top and bottom sections of core. Samples are from farms in Trumbull County and placed by agricultural method rank.

Figure 19 presents percent soil organic matter between agricultural method ranks and separated by top and bottom soil core samples. The top 15 cm within this parameter ranged from 3.36 – 5.56% and had an average of 4.19%. Within the bottom 15 cm percent soil organic matter ranged from 2.45 – 4.05%, with an average of 2.96%.

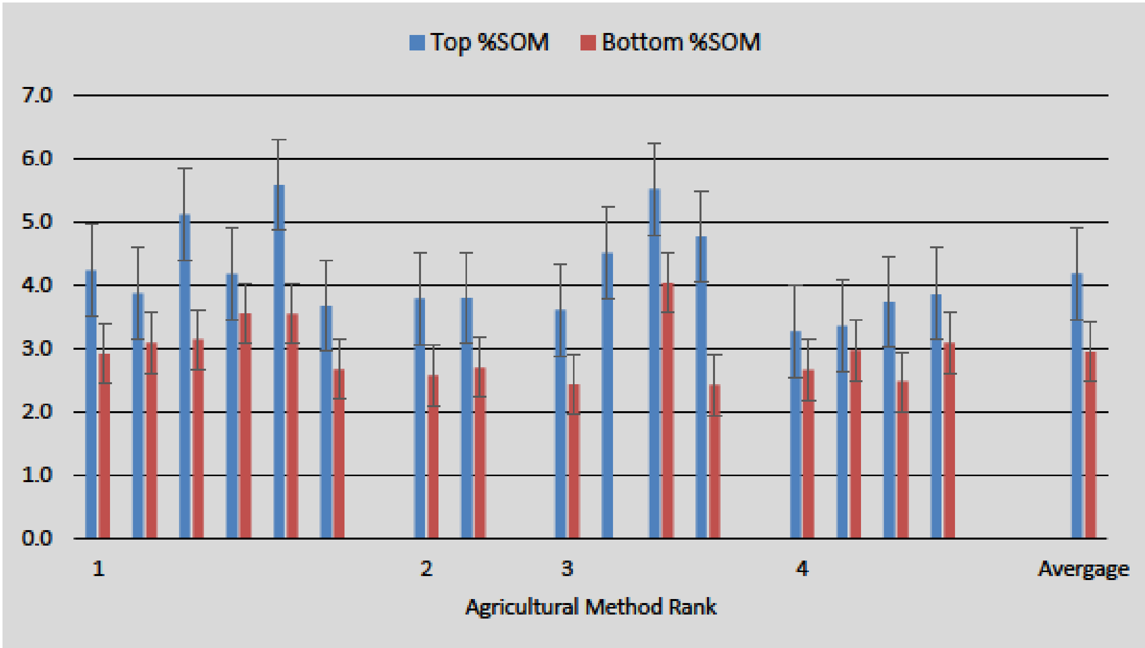

Figure 19 %SOM from soil cores indicating 15 cm top and bottom sections of core. Samples are from farms in Trumbull County and placed by agricultural method rank.

Figure 20 showcases the percent total nitrogen between agricultural method ranks and separated by top and bottom soil core samples. The range for the top 15 cm of percent nitrogen consisted of 0.093 – 0.247% with an average of 0.155%. The bottom 15 cm had a range of 0.063 – 0.166% and had an average of 0.095%.

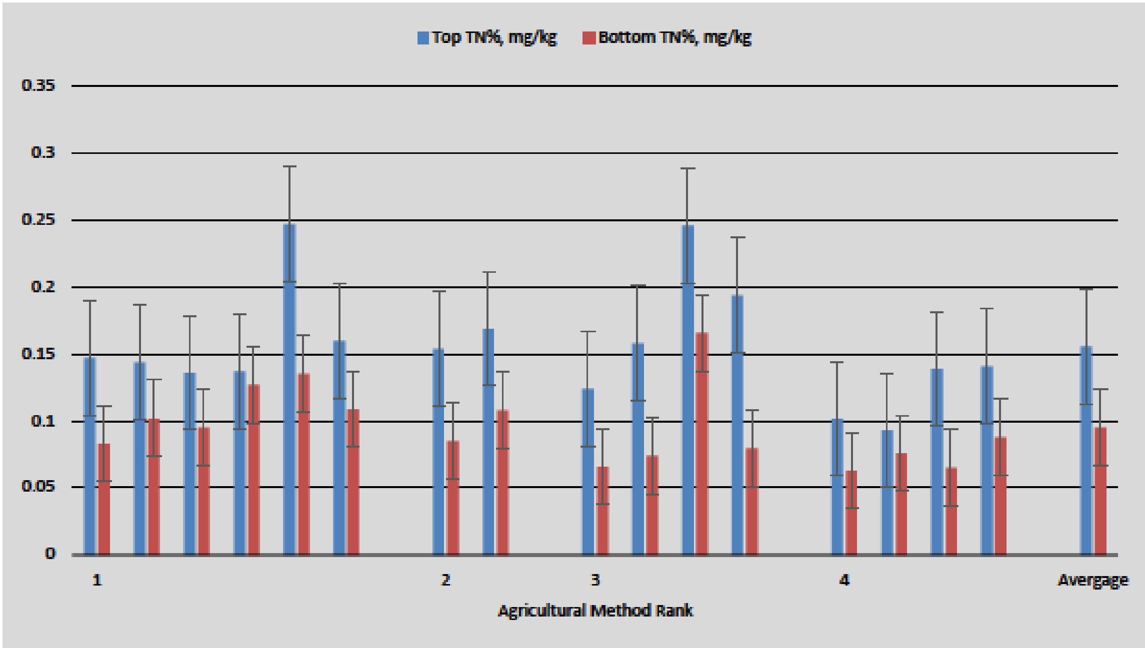

Figure 20 % Nitrogen from soil cores indicating 15 cm top and bottom sections of core. Samples are from farms in Trumbull County and placed by agricultural method rank.

Figure 21 showcases a comparison of pH (C_aCl^2) between agricultural method ranks and separated by top and bottom soil core samples. The top 15 cm had a range of 4.32 – 5.28 with an average of 4.82. The bottom 15 cm's range was from 4.24 – 5.14 and had an average of 4.69.

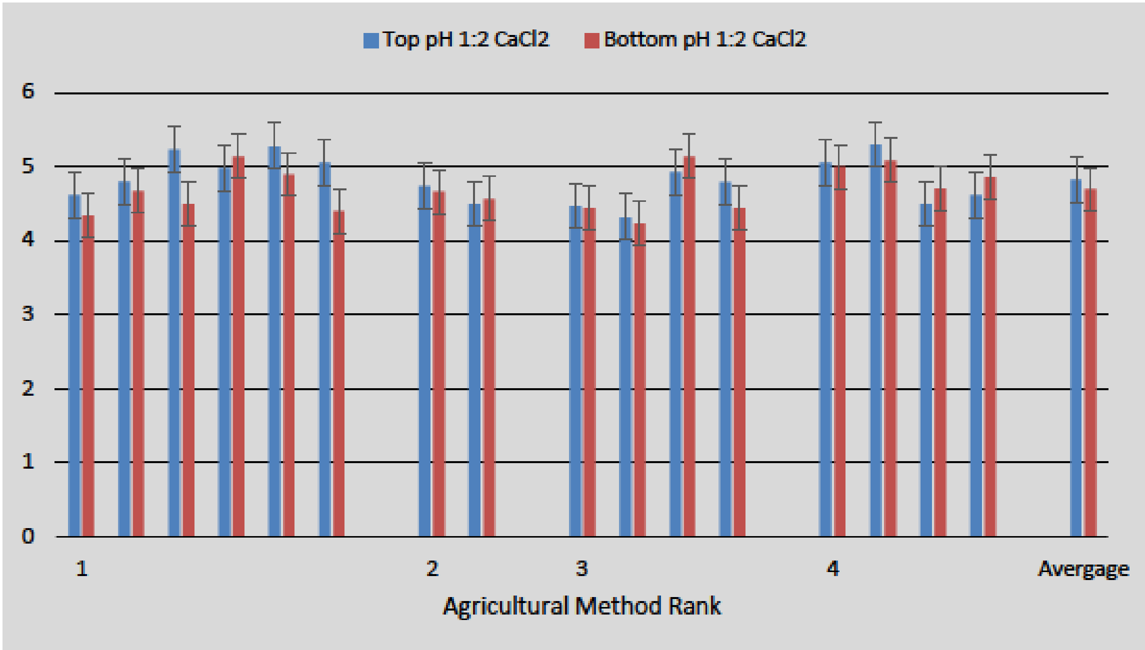

Figure 21 pH C_aCl^2 from soil cores indicating 15 cm top and bottom sections of core. Samples are from farms in Trumbull County and placed by agricultural method rank.

Figure 22 and 23 present soil texture between agricultural methods rankings and separated between top and bottom soil core samples. For space purposes the content was split in-between two graphs. Within the top 15 cm graph, the range of data for percent sand was from 14.15 – 64.23%, and an average of 28.19%. Percent silt had a range of 34.20 – 81.42%, and an average of 67.30%. Finally, percent clay had a range of 1.57 – 7.08%, and an average of 4.51%. Within the bottom 15 cm percent sand had a range of 14.24 – 76.91%, and an average of 37.49%. Percent silt within the bottom 15 cm had a range of 21.51 – 80.65% and an average of 58.79%. Lastly percent clay in the bottom 15 cm had a range of 1.58 – 6.69%, and an average 3.72%.

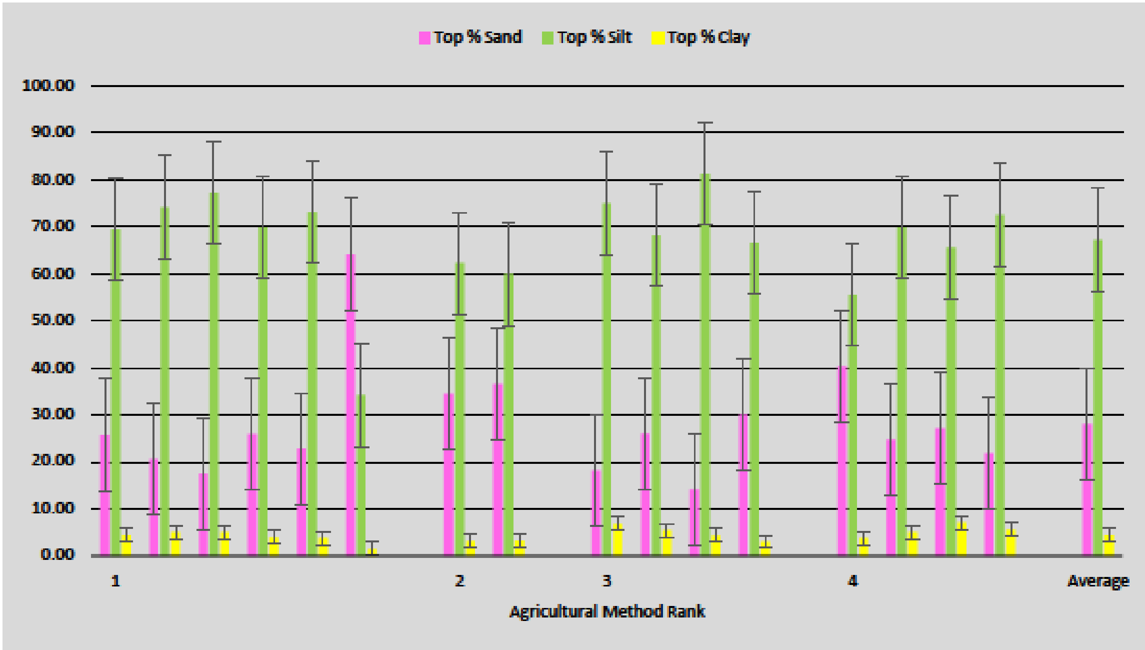

Figure 22 Soil texture from soil cores indicating 15 cm top sections of core. Samples are from farms in Trumbull County and placed by agricultural method rank.

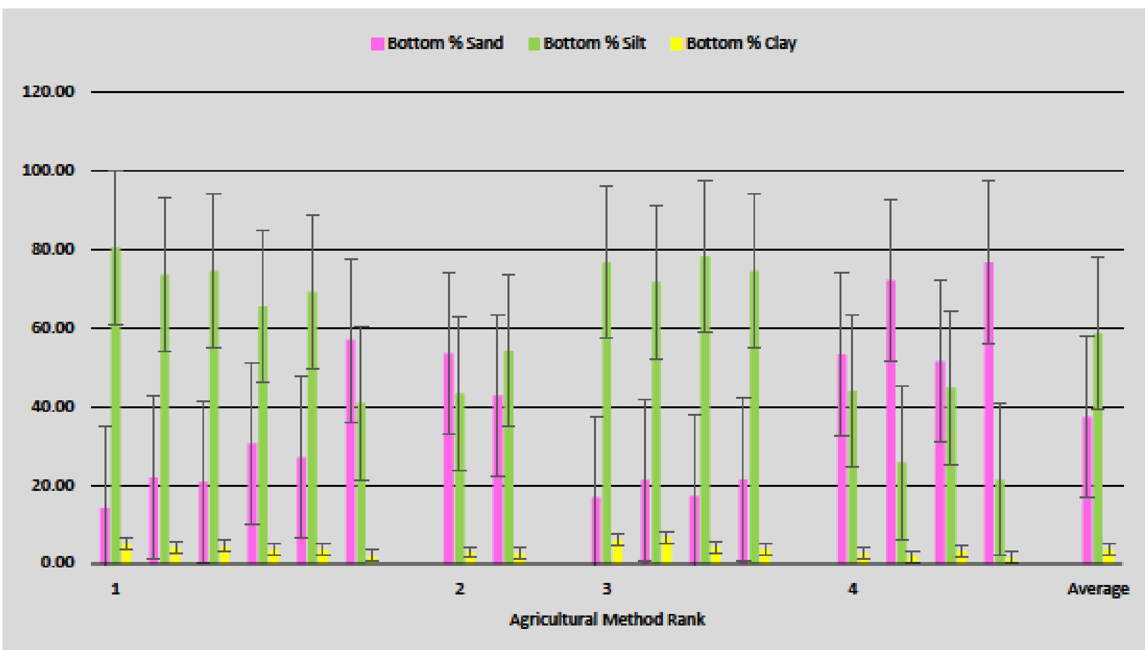

Figure 23 Soil texture from soil cores indicating 15 cm bottom sections of core. Samples are from farms in Trumbull County and placed by agricultural method rank.

Chapter 5: Discussion

Agricultural Method Ranking Average:

When looking at the averages amongst agricultural rankings the parameters that stand out the most include salinity, and available phosphorus. The results from this comparison show a trend of salinity becoming lower within higher ranked samples. The small difference in salinity can be an offset, and moderately affect the yield produced by certain crops. Productivity may be reduced from 25-50% within these plant species, such as flax, clovers, carrots, onions, bell peppers, lettuce, and sweet potatoes (Sanchez, 2015). Salinity levels of less that 0.4ms/cm have mostly negligible effects, outside the crops beans and carrots (Sanchez, 2015). Scientist have agreed that there is no agronomic reason or need for soil test phosphorus to be greater than 50ppm or mg/kg (Sharpley, 2010). The results from this research show an increase in phosphorus within higher ranked agricultural methods, but the highest amount was not in the highest ranked method. This could be influenced by type of crop that was being grown in the field and the time of the year the samples were collected. Plants or crops that reproduce and die in one year require large amounts of phosphorus, as well as plants that have limited roots and rapid top growth such as lettuce, legumes also require plentiful amount of nutrients (California Fertilizer Foundation, 2009). The availability of soil phosphate and phosphorus concentration is typically greater within the spring season, than compared to the autumn and winter (Saunders et. al, 1971). According to Penn State University the optimum range of phosphorus in soils is in-between 30-50ppm (Beegle, 2021). The phosphorus examined in this research stays within the previously mentioned range of 30-50ppm, except for one ranking category (Figure 13). Higher amounts of soil phosphorus could lead to higher phosphorus surface runoff depending on other factors such as soil texture and permeability (Sharpley, 2010). The availability of phosphorus is very dependent on microbial life, as well as pH in the optimum range of 6.0 – 7.0 (Beegle, 2021). Although there were no significant differences between rank and pH, the trend showed increases in pH as rank increased. The ideal soil porosity for any type of soil is in-between 40-60%. Most of the soils are within the average range, but some lower ranked soils have a slightly higher % porosity. In comparison to data from bulk density results, the difference between rankings was minimal but does show the highest bulk density recorded within a lower ranking (2), see Figures 14 and 15. Higher bulk densities tend to lower available water holding capacity of soils (USDA-NRCS, 1998). Soil water holding capacity is the amount of water a soil can hold for use by a crop. Further investigation in the water holding capacity could be beneficial in determining the influence of conservation methods.

Soil texture is near the same when consolidating all fields into the four categories or rankings observed. This similarity eliminates variability such as parent material, geographic location, etc. This places more emphasis on the agricultural management system or method as the main factor in the physiochemical soil parameters and soil quality. Trumbull County is within the Mahoning-Canfield-Rittman-Chili soil region (Natural Resources Conservation Service Ohio, n.d.). The soil of Ohio is based primarily on parent material and glacial history of the state (Ohio State University Extension, n.d.). Trumbull County is covered by a soil region that has a large concentration of calcium carbonate which increases from east to west and consists mainly of sandstone or shale fragments (Ohio State University Extension, n.d.). Of the investigated area the main soil order is “Alfisols” (NRCS). The most recent glacier to cover the state of Ohio and Trumbull County was the Wisconsinan, which left behind mixtures of clay, sand, gravel and boulders in two different fashions either directly by the ice or by meltwater from the glacier (Ohio Division of Geologic Survey, 2005). This vast area covered by the Wisconsinan glacier, and the geologic factors, contribute to the similarities between soil texture amongst agricultural method rankings.

Percent soil organic matter was expected to vary between agricultural methods or rank, but results indicate relatively similar concentrations, suggesting more investigations should be made on these and other fields to confirm trends. The time of year that these samples were collected may have influenced the %SOM of each sample. Research has shown that time of year and tillage methods influence the amount of organic carbon in soil (Wuest, 2014). No-till fields have greater seasonal variability in soil organic carbon as compared to tilled fields. In addition, samples were retrieved in the middle to late fall, and post-harvest scenarios. Total percentage nitrogen stands out within agricultural method rank 3 being the highest % per category but is not conclusive. The indication in rank 3, gives insight to question the plant uptake of nitrogen as well as the addition of nitrogen-based fertilizers within conventional agricultural management styles.

Overall, when looking at the averages between ranking methods the differences are not huge but there are slight differences in areas that play a larger role in soil quality health. These factors include salinity, phosphorus, and % porosity. The comparison of the effects of agricultural method and soil parameters does not give many significant differences (Figure 39 in the Appendix). These slight differences within the ranking averages alone, suggest more testing and investigation should be done, in order to tell the story or properly describe the impacts or benefits different agricultural methods provide.

Another look into the results can be done when comparing the top 15 cm and bottom 15 cm of each sample. When comparing top layer to bottom layers there are slight differences within soil characteristics such as phosphorus, salinity, and % nitrogen. Bulk density, and % porosity cannot be compared within this comparison, due to the fact that bulk density was gathered from the top 15 cm only. The importance to evaluate tops from bottoms is to examine the amount of leaching of nutrients, humus and other material from the surface.

Phosphorus comparison of top layer concentration vs. bottom layer concentration indicate some trends with higher available phosphate in lower levels of the agricultural methods in rank 3 vs. rank 1. Using a larger data set (more sampling) or examining total phosphorus may give a clearer understanding of the movement of phosphorus from these different agricultural methods. The average difference when subtracting bottom concentration from top concentration between the higher ranked methods (rank 3 and 4) was 40.13 mg/kg, and 30.34 mg/kg between lower ranked methods (rank 1 and 2). Salinity had a much clearer trend of lower salinity in higher ranked soils, in both the top and bottom layers. Soil organic matter exhibits very little variance between the tops and bottoms of higher vs lower ranked categories. Multi-seasonal sampling may improve the understanding of SOM in all soil and layers. The total % of nitrogen had a higher % of nitrogen in the conventional managed soils, but there is not that much of variation. The higher % of nitrogen in the conventional fields could be a result of nitrogen-based fertilizers being implemented.

The next few figures illustrate a Principal Component Analysis (PCA) that was used to examine any trends, clustering, or outliers in the data set. Figure 24 shows the direction of influence for each variable used in the PCA for the samples from the top 15 cm layer. Figure 25 is a scatter plot of the PCA, which has the data points labeled for their agricultural method ranking and organized in size based on their available phosphorus concentration a prominent nutrient in defining soil health. Principle component analysis is an adaptive data analysis technique, that is used for reducing dimensionality of datasets, increasing interpretability and at the same time minimizing information loss (Joliffe, et. al, 2016). The variability is described through PCA by component matrices. In this case the 2nd and 3rd component were chosen as the axis for the scatter plot. The variance these two components explain shows a clearer picture for the data within this research. A cluster of higher ranked agricultural methods can be seen in the bottom left-hand corner. This cluster indicates that samples in the top 15 cm, had higher phosphorus concentrations, higher nitrogen concentration, as well as lower salinity. This result was already anticipated from looking at the numbers earlier through bar graphs, but this scatter plot gives a better visualization to the relatedness of the samples that were tested. Finally, Figure 27 describes the total variance explained within the components.

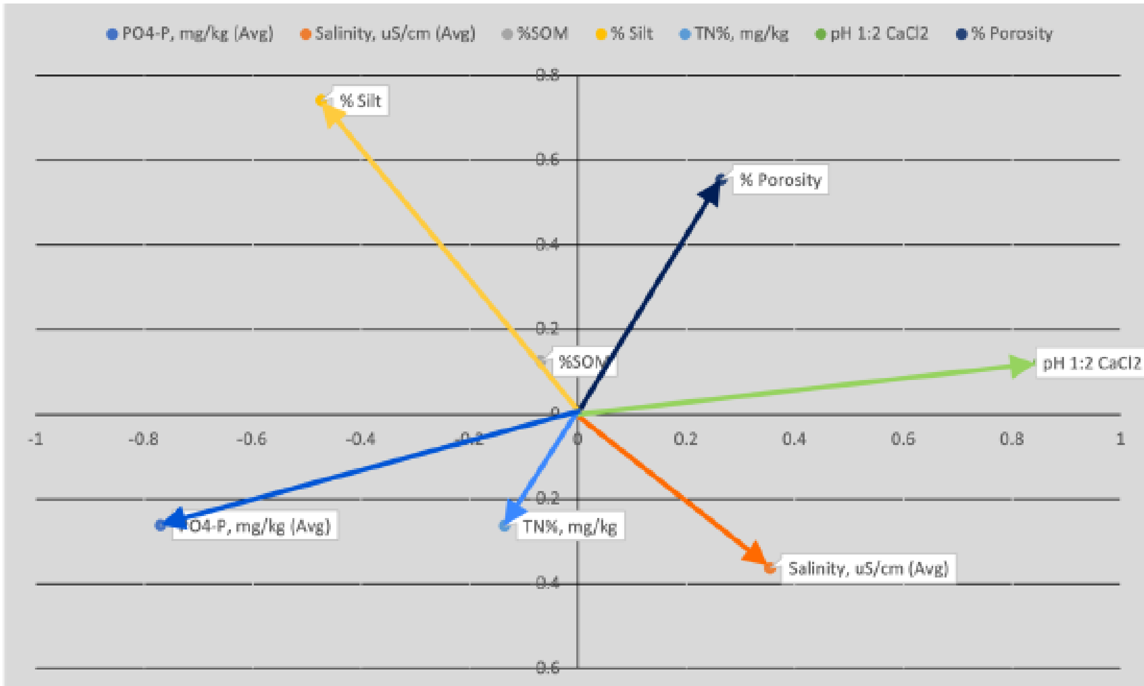

Figure 24 Graph Guide of Components 2 & 3 displaying direction of variance of each soil characteristic for PCA Top 15 cm Scatter Plot for farms in Trumbull County, Ohio

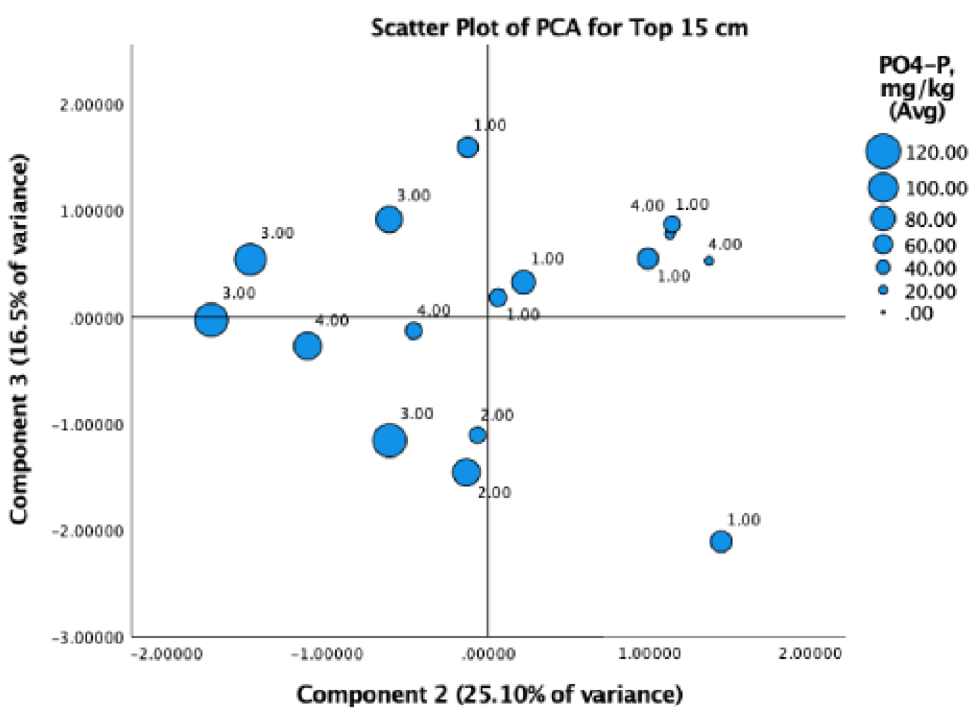

Figure 25 Scatter Plot of PCA analysis Component 2 & 3 for Top 15 cm for farms in Trumbull County, Ohio

Component Matrix[a]

	Component 1	Component 2	Component 3
PO4-P, mg/kg (Avg)	.420	-.770	-.262
Salinity, uS/cm (Avg)	.753	.354	-.363
%SOM	.940	-.069	.126
% Silt	.236	-.473	.741
TN%, mg/kg	.902	-.135	-.263
pH 1:2 CaCl2	.251	.850	.123
% Porosity	.534	.264	.555

Extraction Method: Principal Component Analysis.
a. 3 components extracted.

Figure 26 Component Matrix for PCA Top 15 cm for farms in Trumbull County, Ohio

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.845	40.643	40.643	2.845	40.643	40.643
2	1.757	25.101	65.744	1.757	25.101	65.744
3	1.158	16.540	82.283	1.158	16.540	82.283
4	.582	8.320	90.604			
5	.357	5.102	95.706			
6	.213	3.046	98.751			
7	.087	1.249	100.000			

Extraction Method: Principal Component Analysis.

Figure 27 Total Variance Explained for PCA Top 15 cm for farms in Trumbull County, Ohio

Below is another PCA analysis. This time the analysis consisted of both the top and bottom 15cm of the samples. Figure 29, the PCA scatter plot is set up the same with rankings identifying data points, and the size being dictated by the sample's phosphorus concentration, the only difference is the addition of color dictated by the layer that the sample is a part of. Similar to the first set of figures Figure 28 illustrates the direction of the higher concentration between variables. In this particular comparison, all the variables are moving toward the right-hand side of the quadrated graph. When comparing the top and the bottom less clustering is apparent, and it is difficult to identify a trend with the limited amount of samples. Nonetheless a trend can be identified through the placement of the top samples. This result was already anticipated as it has been noted the top 15 cm samples have had higher concentrations within most characteristic categories.

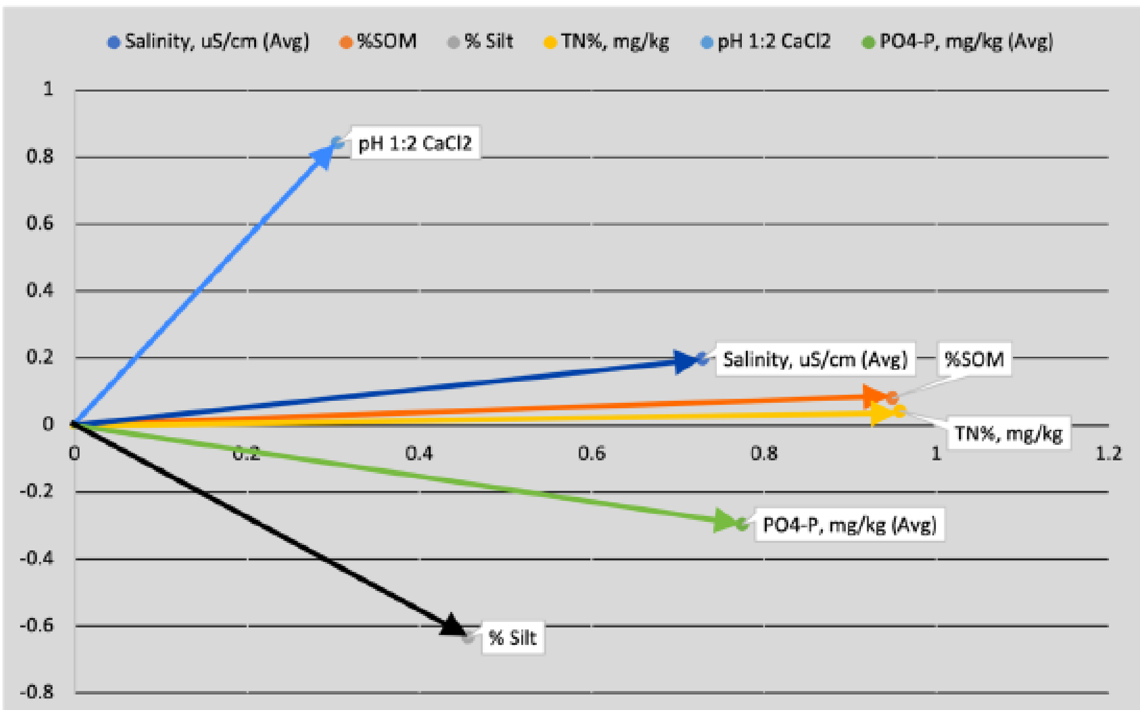

Figure 28 Graph Guide of Components 1 & 2 displaying direction of variance of each soil characteristic for PCA Top and Bottom 15 cm Scatter Plot for farms in Trumbull County, Ohio

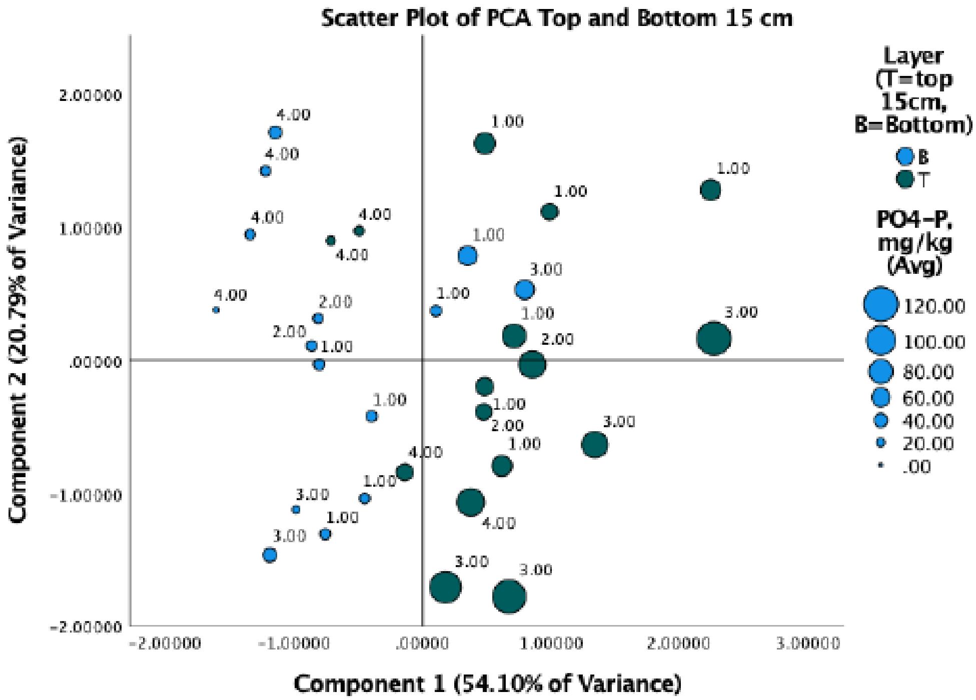

Figure 29 Scatter Plot of PCA analysis Components 1 & 2 including Top and Bottom 15 cm for farms in Trumbull County, Ohio

Component Matrix[a]

	Component 1	Component 2
PO4-P, mg/kg (Avg)	.774	-.296
Salinity, uS/cm (Avg)	.728	.197
%SOM	.949	.081
% Silt	.456	-.634
TN%, mg/kg	.957	.042
pH 1:2 CaCl2	.305	.843

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Figure 30 Component Matrix for PCA analysis Top and Bottom 15 cm for farms in Trumbull County, Ohio

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.246	54.102	54.102	3.246	54.102	54.102
2	1.248	20.792	74.894	1.248	20.792	74.894
3	.698	11.627	86.521			
4	.597	9.948	96.469			
5	.154	2.569	99.038			
6	.058	.962	100.000			

Extraction Method: Principal Component Analysis.

Figure 31 Total Variance Explained for PCA analysis Top and Bottom 15 cm for farms in Trumbull County, Ohio

This research was a great probe into the current situation within the agricultural environment and food production in the United States and the world. We often forget how impactful food production is on various levels within society. What was seen from the results and data is that there is some variation between soil quality and health within different agricultural processes. Although the variations seen were not definitive results to declare that what was set out to be discovered is 100% true, what was discovered implies that there is some truth to the argument. From the results gathered it is not definite now that implementing more conservational processes, that cutback on fuel, fertilizers, and various other costs are a major benefit to the soil as well as a cost saving practice, but what was found shows that there is promise from implementing these practices. This starting point is something that can be investigated or evaluated further. Clear results within lower salinity, and minor trends within other characteristics are leaning towards conservational practices to be beneficial to soil quality health, as well as a cost saving option for agricultural mangers.

The results may have been impacted by the conditions in the season, previous cultivated crops from the plots, as well as the years conservational practices have been implemented. Each sample was retrieved in the fall season, and some were retrieved post-harvest. These unaccounted-for variables lead to unknowns in the results. Such unknowns are how much nutrients were absorbed by the cultivated crops, and also if the soil quality would be better or optimal to test within the spring season, near the time crops would be planted. The other unaccounted-for variable that may have an impact to the results is the time that the conservational practices have been implemented. The longer these practices have been implemented the better the soil quality is expected to be. Within this research only a few fields have been implementing no-till practices for a continuation of years. No field exceeded being within conservational practices for over 10 years.

Table 4: Summary Table of the Economic Valuation of Ecosystem Services in Ohio.

	Annual Value Per Acre ($/acre/year)	Acres	Total Annual Value ($/year)
Agriculture	$112	12,274,572	$1,379,397,391
Timber	$62	6,843,076	$423,792,303
Carbon Storage	$404	7,733,533	$3,126,488,897
Public Forest Recreation	$309	890,457	$274,784,889
Private Forest Recreation	$71	6,843,076	$487,120,029
All Ecosystem Services	$287	20,008,105	$5,746,729,566
Breakout of Forest Based Ecosystem Services (these are included above)			
All Forest Recreation	$99	7,733,533	$761,904,918
All Forest Ecosystem Services	$565	7,733,533	$4,367,332,175

Retrieved from: (Gioglio, et. al, 2019)

Ecosystem	ESService	ESSubservice	Valuation Method	Value Type	Value	Unit	Currency	Year Of Publication
Croplands	Erosion	Erosion prevention	Replacement Cost	Annual	106.25	USD/ha/yr	US Dollar	1995
Croplands	Soil fertility	Maintenance of soil structure	Replacement Cost	Annual	168.75	USD/ha/yr	US Dollar	1995
Croplands	Erosion	Erosion prevention	Mitigation and Restoration Cost	Annual	40	USD/ha/yr	US Dollar	1995

Retrieved from: (Pimentel, et. al, 1995) – The Economics of Ecosystems and Biodiversity (TEEB)

Figure 32 Estimated Ecosystem Valuations of annual agricultural acreage, carbon storage, and replacement cost of soil ecosystem services.

Item	Trumbull
Farms .... number	1,036
Land in farms .... acres	123,654
Average size of farm .... acres	119
Median size of farm .... acres	47
Estimated market value of land and buildings:	
Average per farm .... dollars	516,981
Average per acre .... dollars	4,331
Estimated market value of all machinery and equipment $1,000	112,195
Average per farm .... dollars	108,297

Figure 33 2017 Census of Agriculture - County Data USDA, National Agricultural Statistics Service

The original thought behind this research contained the element of investigating the ecosystem services of soil and the economics behind them. Figures 32 and 33 are presented to showcase monetary values and add perspective to the entirety of the research its importance as well as the overall societal influence of soil's ecosystem services. The first chart in Figure 32 consists of estimates for the state of Ohio from The Ohio State University in fall 2019. Three factors of interest within this chart consist of agriculture, carbon storage, and all ecosystem services. The second chart within Figure 32 shows an excerpt from the TEEB database, and a study done by (Pimentel, et. al, 1995). This study was done in 1995 for the replacement cost of erosion prevention and soil fertility and the mitigation and restoration cost of erosion prevention. This costs for these values would be inflated within this time period, but it puts some perspective on the cost associated with detrimental effects to soil, as we know poor agricultural management can leave some fields vulnerable to erosion. Figure 33 is not an estimate and consists of real reported data. This figure showcases how costly agricultural operations are, we often do not realize that all farms, small or large cost a considerable amount of money and invest over $100,000 into equipment to be fully operational. These two figures were included to provide insight to the overall costs of ecosystem services, restoring ecosystem services, and the general costs of running a farm.

Fertilizer Calculations:

In terms of monetary and economic connections to address questions in the thesis, fertilizer costs based on found nutrient concentrations in the samples within their respective agricultural rank were calculated. Figures 34 - 35 below showcase the statistical difference between categories. In Figure 34 containing phosphorus it can be seen that the rank of 3 is significantly different from rankings 1, and 4, but not 2. Rankings 1, 2, and 4 are significantly the same statistically. Looking at Figure 35 containing percent nitrogen it can be observed that rank 4 is significantly different from ranks 1 and 3, but not 2. Rankings 1, 2, and 3 are significantly the same statistically.

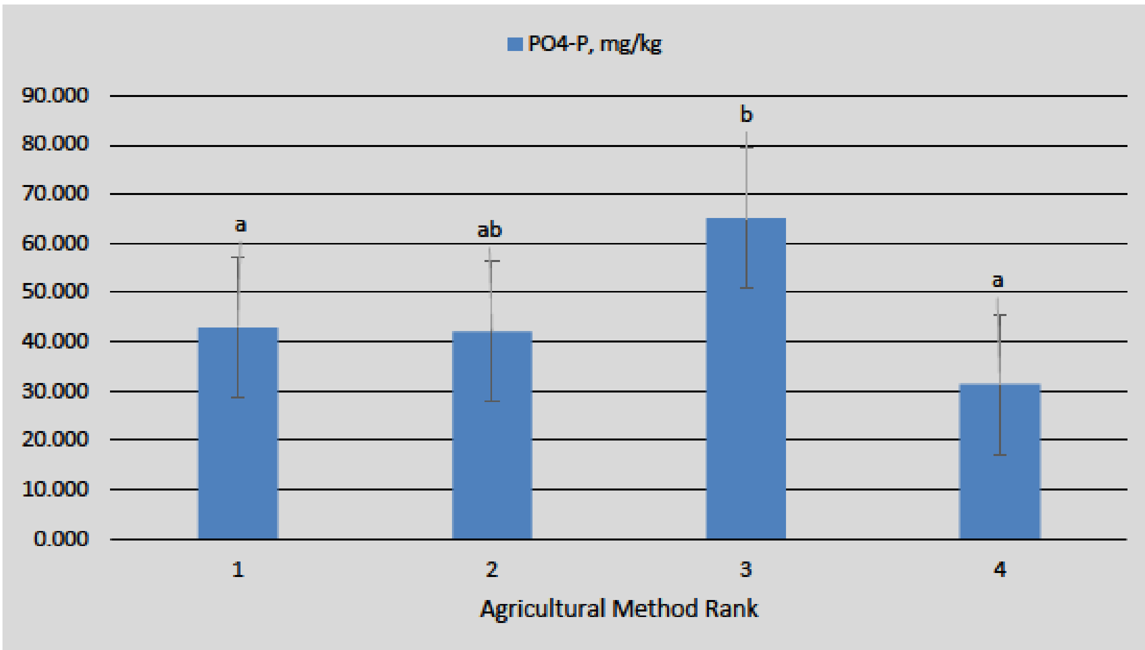

Figure 34 Phosphorus concentration significance comparison. Samples are from farms in Trumbull County and placed by agricultural method rank. . (LSD – mean comparisons)
*Columns with different letters are sig different at < 0.1 significance

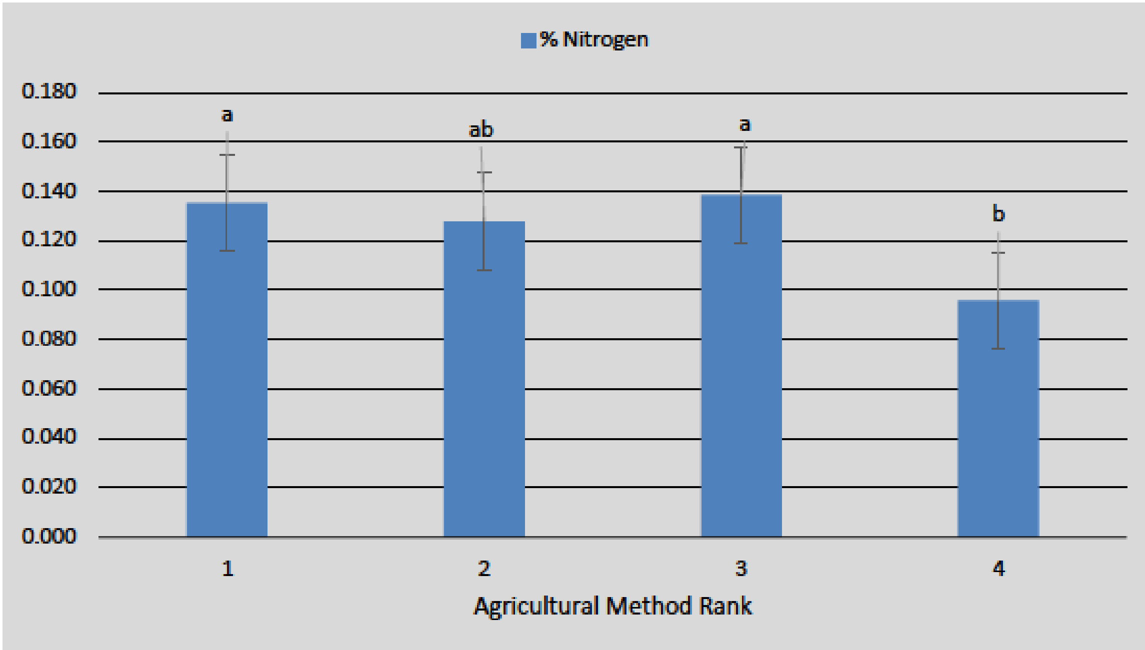

Figure 35 % Nitrogen concentration significance comparison. Samples are from farms in Trumbull County and placed by agricultural method rank. . (LSD – mean comparisons) *Columns with different letters are sig different at < 0.1 significance

To create Figure 36 below a series of calculations were made. The amount of observed total phosphorus was converted into ppm, and then multiplied by 2 to acquire the pounds of phosphorus per acre (Liu, et. al, 2013). According to NRCS and USDA, the amount of organic naturally occurring phosphorus is 13.38 pounds per acre (Sharpley, 1995). The amount of estimated naturally occurring phosphorus was then subtracted from the calculated pounds of phosphorus per acre. This new number is an estimate of the amount of phosphorus per fertilizer each agricultural manager would have needed to apply. That number was then multiplied by 2.913 for a conversion of the pounds of fertilizer per acre for that amount of phosphorus (Liu, et. al, 2013). The total pounds per acre of fertilizer were then multiplied by the cost of phosphorus in a common fertilizer used as an example called "Superphosphate" (Flynn, 2014). This gave the dollar amount shown in the graph below for how much Superphosphate per pound would have needed to be purchased in order to produce the extracted phosphorus levels.

The results from the calculations show similar results to Figure 34 and 35, above. When looking at the higher ranked categories specifically rank 3, the amount of phosphorus extracted from these samples equaled around $100.00 more of fertilizer compared to the lower 2 rankings. This higher amount could be a result of the fields producing enough phosphorus within the conservation method naturally, but fertilizer was still added due to the normal process or particular crop being grown and understood trusted practices. This higher amount can be an indication that there is an opportunity to save money by using less fertilizer. Rank 3 had the highest phosphorus levels and could cut out around 100 pounds of phosphorus-based fertilizer and still be in the optimum phosphorus range, as well as lowering the potential for surface runoff. Figure 36 also shows the minimum cost for the optimum range of phosphorus with rank 4. The range of phosphorus is crop dependent and fertilizer is applied based on need. Within this category two fields were in a cover crop phase and were intentionally grown to increase soil health and quality. These were not going to be cultivated and sold crops; therefore, it would be understood why there could be a lower implementation of fertilizer and lower phosphorus levels. Even with this observation the rank is still in the optimum range of phosphorus concertation which is 30 – 50mg/kg (Beegle, 2021).

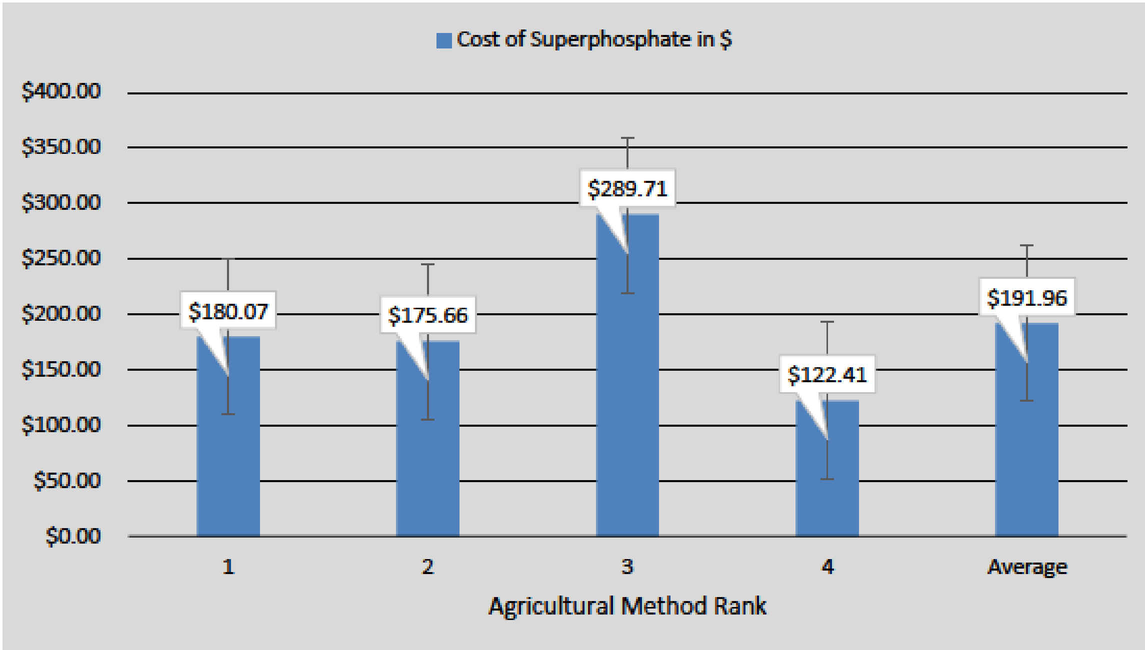

Figure 36 Cost of superphosphate a phosphorus concentration increasing fertilizer. Samples are from farms in Trumbull County and placed by agricultural method rank.

Figure 37 showcases the costs of a popular nitrogen enhancing fertilizer named anhydrous ammonia. The cost was determined by using a few conversions and calculations. The first conversion made was converting % nitrogen to ppm. 98% of nitrogen found in soil is in organic forms and cannot be taken up by plants, only 2% of nitrogen is actually plant available (Carson & Phillips, n.d.). To calculate for the nitrogen that is plant available the concentration in ppm was multiplied by 0.02 to find the 2% of nitrogen that is plant available. Next ppm of plant available nitrogen had to be converted to pounds per acre. To calculate pound per acre the equation (depth in inches divided by 3 and multiplied by test results in ppm) was used (Camberto, et al, 2017). To find the average amount of fertilizer used within the method an average amount of plant available nitrogen per acre was subtracted from the result of that equation. The average amount of nitrogen per acre used was 2,800 pounds, although this estimate was determined for

Pennsylvania, due to the regional geographic area, and exploration of this research this estimate is adequate. (Beegle, 2005). Using the same logic in the previous conversion, the average amount of naturally occurring nitrogen (2,800lbs) was multiplied by 0.02 in order to calculate for the plant available nitrogen of the natural occurring nitrogen in pounds per acre (Carson & Phillips, n.d.). The new calculated amount pounds of nitrogen per acre, was then multiplied by the concentration of nitrogen per anhydrous ammonia which is 82%. Finally, anhydrous ammonia is priced at $691 a ton, or $0.35 a pound, this price was multiplied with the pounds per acre needed to achieve the nitrogen concentrations (Schnitkey, et. al, 2021).

The results from the calculations and Figure 37 show the estimated costs of fertilizer each agricultural method would have had to apply in order to reach the nitrogen % concentrations recorded. The average total nitrogen % for soil in Pennsylvania is around 0.14% (Beegle, 2005). For this exploratory research and the similarity of geologic location to Ohio, using an average for Pennsylvania is adequate. All soil samples fell below this average. From the previous results Figure 13 and the calculations it can be observed that the closest to that average is agricultural rank 3. Nitrogen can make its way into soil in various ways. In this explorational exercise we are assuming a lot. It can be seen in Figure 37 that around $34.76 can bring a soil to an adequate average amount of nitrogen, but what was not measured is how much nitrogen in the soil was attributed organically or naturally. In this scenario we can only assume and make a judgment call. The increase of nitrogen concentration in rank 3 could attribute to the increase in conservation methods as well as the implementation of previous agricultural methods and applications, such as utilizing fertilizers. The combination may be to blame for the increase of around 200 pounds of nitrogen between rank 1 and rank 3. The other item to address is the lower amount and correlated cost within rank 4. This could be attributed to the avoidance of fertilizer and intention to build soil quality instead of producing a crop to monetize as mentioned previously. Considering all other soil quality characteristics, rank 4 still produced fairly good soil, when calculating nitrogen fertilizer use, the cost is almost half of the lower ranked samples without being half of the concentration, this is another area that should be investigated further.

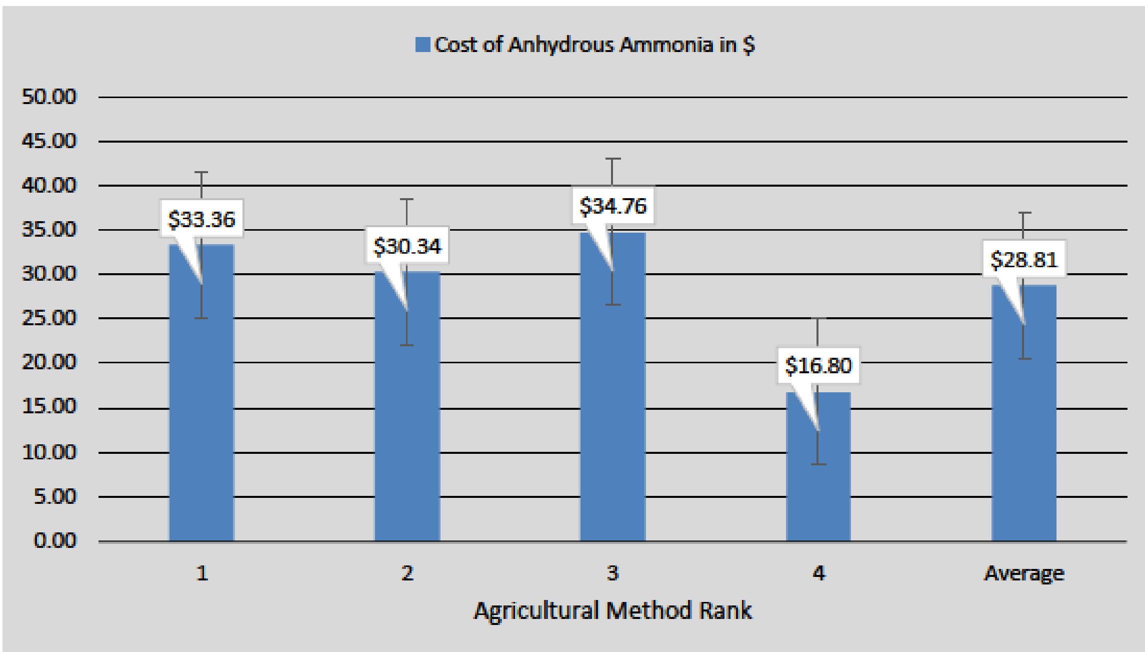

Figure 37 Cost of anhydrous ammonia a nitrogen concentration increasing fertilizer. Samples are from farms in Trumbull County and placed by agricultural method rank.

Expectations for this research were met in a sense that this research was purposefully exploratory. The idea behind this research was to see if it could logically be done, repeated, and if the data gathered would be useful going forward. In that sense the expectations were exceeded. The expectation for the results and the overall hypothesis were partial met. There are some characteristics that are set apart between agricultural methods as stated previously, but more data would be needed to confidently declare the results totally confirm the hypothesis: "Different agricultural processes can impact soil's overall quality and sustainability. Agricultural practices that can influence soil health include conventional tillage vs. no-till methods and use of other conservation methods such as plant residue, cover crops, and crop rotation. Utilization of conservation practices will improve the soil quality as measured by select soil parameters." Overall, this research is a great starting point for understanding how to move forward, learning what works, what can be improved and what can be avoided.

One thing to mention when discussing this research is the complexity. Studies similar to this are more intense, spread out over more time, and done with more hands, and input. This a very complex topic or item to evaluate and understand. There are many factors that can be evaluated, and some variables can be naturally the same due to the geographic area and parent material of the soil. Adding an evaluation of ecosystem services, as well as economic impacts or costs, adds another complex element to the already complex investigation. Although all these items build upon each other and are the foundation for how we already live-in society, putting a measurement to all of this will take time and a much longer study with multiple people evaluating the situation through different angles.

Lastly, it is important to discuss the economic importance of this whole experiment, planning for the research, and obtaining clear figures from agricultural organizations. The importance for simply emphasizing the economic impact of soil quality is a major factor for society moving forward. In the current time period we are in, we are experiencing the effects of climate change, and the result of increased global production, industrialized agriculture, and commercialization at a global level. Now is a great time to bring to the forefront the continuous tradeoffs we make in society, especially in the food production environment. Everything in the natural environment has some type of economic value. The way we use items especially ecosystem services contradicts this statement. The more awareness brought to this fact will help evolve our current situation and environment to make the challenges we will face in the future more manageable. As for planning, this research developed as exploratory, and a thought-out plan for execution was made in increments to meeting goals for time, due dates, and complexity. A more thorough plan would have resulted in a better executable research. The problem with developing a thorough plan, was the research behind all characteristics and parameters, their importance and how to evaluate them. With the leg work of that process in the past a new updated, plan of action can be created. Lastly gathering concrete numbers for fuel and spending from agricultural organizations was the original plan but created another leg of research that could not have been done within the time frame that was allocated. The numbers gathered were just rough estimates and more of categorical statements that were not recorded just observed. Gathering concrete figures for costs and expenses per each method would have created another variable within the research that could have allowed for much better comparisons within spending ranges and result of soil quality.

Recommendations

Recommendations for this research mainly include expanding the samples size, repeating repetitions, as well as continuing the investigation over time. As mentioned previously more data, and repetitions will continue to develop the narrative of the research, tell the story of the situation more clearly and help to differentiate the benefits of each agricultural method category. As observed the most adverse result from the research was salinity. It would be important moving forward to identify the main characteristics that will help to differentiate the agricultural methods and narrow the in-lab testing for these characteristics. Another recommendation would be to carefully plan and implement a repeatable process to include and evaluate economics or costs associated with each agricultural method. As discussed previously this would allow for a more definable comparison within the data sets. For example, if a conventional process develops more soil organic material, but the cost is two times that of a conservational process and the benefit is between 1-2 percentage points it would be much easier to make a claim regarding what process is more beneficial. When looking at the data statistically all the characteristics were split between top 15 cm, and bottom 15cm of a soil probe, except bulk density and porosity where only the top 15cm was measured. It is possible to perform bulk density and measure porosity at the top and bottom levels. It would be recommended to do the measurements for both levels to get a better picture of the soil and develop better comparisons, for overall data comparisons as well as running statistical analyses. Additionally, recommendations can be made for other and more characteristics or variables to be evaluated. One characteristic that can be evaluated is the field itself, through identifying topsoil depth, the soil profile as well as other various checks within the field. Another characteristic that was found in a study when researching is an evaluation of earthworm presence, this would be a great addition to this research. Finally, other nutrients can be evaluated, such as potassium, and also total organic carbon, as well as a physical characteristics such as infiltration rate can be investigated.

Recommendations for agricultural managers attempting to improve their processes to become more environmentally friendly or improve soil quality and heath are as followed. The first recommendation would be to seek knowledge or self-education on conservation-based methods. A second recommendation would be to seek assistance or guidance from different organizations that may be of service. Thirdly, it would be wise to evaluate current processes and methods. Ask questions to the proven process to see what items can be recycled if they are not, where cover crops can be implemented into the process to avoid fuel cost of tilling that field, identifying a crop that can be planted in a no-till process such as wheat, barley, rye, or other cereals, clovers, peas, lupins, and vetch, as well as taking note of the most expensive or costly parts of the organization. The first step of gaining knowledge of conservational agriculture may open the door for implementation as holes, and gaps in the process are identified. As technology increases, so does farming or agriculture equipment, most likely on the horizon, is electric powered machinery. A recommendation would be to lease instead of buy as much equipment as possible, as these newer technologies can be brought to the forefront and be more efficient and cost effective as time progresses. Instead of committing to a machine it may be best within this transition period of operating power to have available funds for better decisions in the future. A fourth recommendation would be to experiment. Everyone will have different success with different methods and processes. From the agricultural managers that were met within this research it was found that each individual had a varying experience when implementing conservational processes. Short term success may derail and has derailed many organizations that attempted switching over to more conservational processes, but long-term success that requires commitment has proven to be as efficient or more efficient as conventional agriculture while also investing in soil health and protecting ecosystem services.

Chapter 6: Conclusion

As this research continues to develop, the main factor for an improvement of quality of life, as well as the conservation of soil for economic, and environmental sustainability, will ultimately rely on law makers or governments. The people will continue to speak and discuss, the issues at hand and its importance, but true change or implementation will need to be guided by newly generated laws or policies, that take into account all aspects of soil's benefits or ecosystem services provided to society. It is understood that human life will continue to advance, with computer technologies, conveniences, science, and a larger population. Before upcoming challenges arise, it would be wise as a society to focus, examine, analyze, and understand our main lifelines, which consist of soil and water. While searching on the internet it may be rare to find instances where this conversation is being projected through legislation within bills or acts, in this current era. Much has changed since previous laws were enacted, and there is more information, research, and understanding than ever before. Historically U.S. laws revolving around soil conservation began with the Soil Conservation Act of 1935 and have had advancements throughout the 1970s with the development of the EPA (Environmental Protection Agency), and other acts such as the Resource Conservation and Recovery Act (RCRA). More recently the mention of investing into sustainable farming and land use practices to increase soil health have been mentioned and appeared within legislation pushing for a "Green New Deal". There is no telling if this legislation will move forward in the near future, but it is hopeful and a good start for the transition of the perception of soil, its uses, and how it impacts society, to be more widely understood. Every five years congress reviews the "Farm Bill", the current Agricultural Act of 2018 provides for the modification and continuation of programs through the end of Fiscal Year 2023 (The Wildlife Society, 2020). The Farm Bill was established during the great depression with the Agricultural Adjustment Act of 1933 (The Wildlife Society, 2020). This act encouraged conservation and raised farm incomes by paying farmers to reduce crop production, thus correcting commodity surpluses (The Wildlife Society, 2020). Title II of the Farm Bill focuses on conservation, and usually accounts for 6-8% of mandatory Farm Bill spending, that represents the largest single source of federal funding for private lands conservation (The Wildlife Society, 2020). The conservation programs developed by Title II, helps build public-private partnerships, by providing technical assistance and cost-sharing options for landowners wishing to voluntarily improve habitats for fish and wildlife, reduce erosion, or address other natural resource concerns on their working land (The Wildlife Society, 2020). These programs include the Conservation Reserve Program (CRP) ran by the FSA and NRCS, the Agricultural Conservation Easement Program (ACEP) ran by the NRCS, the Conservation Stewardship Program (CSP) for working lands ran by the NRCS, as well as the Environmental Quality Incentives Program (EQIP) for working lands ran by the NRCS (The Wildlife Society, 2020). Cumulative enrollment in these programs reached 466 million acres in 2018, roughly equivalent to the land area managed by the National Park Service, U.S. Fish and Wildlife Service, and Bureau of Land Management (The Wildlife Society, 2020). It is estimated by the Congressional

Budget Office that the conservation spending within the Farm Bill from 2018 to 2028 will increase to $59.8 billion (The Wildlife Society, 2020).

In conclusion the hypothesis for this research is tentatively rejected, additional sampling and analysis is needed. In comparison to larger studies no research definitively concludes that conservational agricultural benefits increase soil quality health, cuts costs, and contributes to improved environmental economics for the community. These studies usually suggest optimistic insights into what the impacts and the benefits are from various agricultural operations. This type of investigation is relatively new with all things considered. The industrial revolution and the commercialization of agriculture and the food production industry is relatively new in itself also. Within the past 25-30 years more people and scientist have questioned the reality of things within this realm, and their impacts to society as well as economics. This research specifically provides insight to what can possibly be discovered when investigating different agricultural methods and the parameters of the soil they impact. Unfortunately, in this research, time is a huge factor as well as level of investigation. This research is a beginner level probe into the situation itself. It is also unfortunate that this research did not collect samples from a full regenerative farming agricultural organization. Regenerative farming would be the peak of conservational management methods and would be a better comparison to what was collected through this research. On the other hand of the spectrum, it would of been great to have gathered samples from a real commercial agricultural organization, or an area or field known to have a very low quality soil. Overall, a case can be made for the hypothesis to be partially accepted. Slight improvements in soil quality health were seen in the various agricultural methods tested. The best indicator of change within methods was salinity which showed a clear separation between conservational versus conventional methods. Although we did not receive definitive results that point to accepting the hypothesis, it is believed that with more research gathered, and years of collecting samples a better argument can be made and more definitive results can be presented that showcase improvement of soil quality heath, ecosystem services, and reduced costs to the agricultural manager through implementation of agricultural management processes.

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Appendix

Summary of all data collected

Farm/Field Name	Sample Location	Crop	Conservation Methods	Agricultural Method Ranking	Layer (T=top 15cm, B=Bottom)	Rep	Bulk Density, g/cm3	% Porosity	pH 1:1 Water (Avg)	pH 1:2 CaCl2	PO4-P, mg/kg (Avg)	Salinity, uS/cm (Avg)	%SOM	Texture	% Sand	% Silt	% Clay	TN%, mg/kg
Miller Farm Roadside	Miller Farm	Corn	C	1	T	1	0.943	64.42	5.24	4.62	58.14	0.527	4.242	Silt Loam	17.58	77.34	5.08	0.147
Miller Farm Middle Field	Miller Farm	Corn	C	1	T	1	1.264	52.30	5.33	4.8	48.92	0.577	3.876	Silt Loam	20.68	74.28	5.04	0.144
Miller Farm Field Far Right	Miller Farm	Corn	C	1	T	1	1.099	58.52	5.76	5.23	44.67	0.65	5.119	Silt Loam	25.83	69.65	4.52	0.136
Miller Farm S-SW Field	Miller Farm	Corn	C	1	T	1	1.164	56.07	5.35	4.98	68.51	0.5595	4.182	Silt Loam	25.90	70.05	4.05	0.137
Shady Maple Field 3	Shady Maple	Soy Bean	CR, C (Fall Chisel)	1	T	1	1.002	62.19	5.35	5.28	58.17	0.8595	5.598	Silt Loam	22.88	73.24	3.88	0.247
Shady Maple Field 3	Shady Maple	Soy Bean	CR, C (Fall Chisel)	1	T	2	1.178	55.54	5.21	5.06	60.77	0.69	3.683	Sandy Loam	64.23	34.2	1.57	0.16
Miller Farm Roadside	Miller Farm	Corn	C	1	B	1			4.95	4.34	25.36	0.407	2.925	Silt Loam	20.91	74.55	4.54	0.083
Miller Farm Middle Field	Miller Farm	Corn	C	1	B	1			5.26	4.67	24.60	0.4935	3.096	Silt Loam	22.06	73.7	4.24	0.102
Miller Farm Field Far Right	Miller Farm	Corn	C	1	B	1			5.31	4.5	23.65	0.469	3.150	Silt	14.24	80.65	5.11	0.095
Miller Farm S-SW Field	Miller Farm	Corn	C	1	B	1			5.41	5.14	53.30	0.5825	3.569	Silt Loam	30.74	65.57	3.69	0.127
Shady Maple Field 3	Shady Maple	Soy Bean	CR, C (Fall Chisel)	1	B	1			5.36	4.9	25.02	0.583	3.555	Silt Loam	27.13	69.28	3.59	0.135
Shady Maple Field 3	Shady Maple	Soy Bean	CR, C (Fall Chisel)	1	B	2			4.88	4.4	25.78	0.5325	2.678	Sandy Loam	56.92	41.03	2.05	0.109
Shady Maple Field 2	Shady Maple	Corn	CR, RT	2	T	1	1.312	50.49	5.24	4.74	81.10	0.7565	3.799	Silt Loam	36.65	60.07	3.28	0.154
Shady Maple Field 2 Back	Shady Maple	Corn	CR, RT	2	T	2	1.330	49.84	4.92	4.5	43.89	0.67	3.805	Silt Loam	34.51	62.3	3.19	0.169
Shady Maple Field 2	Shady Maple	Corn	CR, RT	2	B	1			5.08	4.66	23.80	0.4825	2.581	Silt Loam	42.96	54.33	2.71	0.085
Shady Maple Field 2 Back	Shady Maple	Corn	CR, RT	2	B	2			5.03	4.57	19.94	0.5	2.706	Sandy Loam	53.59	43.42	2.99	0.108
First Year	Farmer Jeff	Radishes	CR, CC, RT	3	T	1	1.200	54.70	5	4.47	96.23	0.2085	3.617	Silt Loam	18.11	75.02	6.87	0.124
First Year	Farmer Jeff	Radishes	CR, CC, RT	3	T	2	1.196	54.85	4.83	4.32	102.00	0.2405	4.516	Silt Loam	26.14	68.33	5.53	0.158
Shady Maple Field 1 Rye	Shady Maple	Rye	CR, CC, NT	3	T	1	1.263	52.35	5.24	4.93	103.06	0.707	5.521	Silt Loam	30.16	66.74	3.1	0.246
Shady Maple Field 1 Rye	Shady Maple	Rye	CR, CC, NT	3	T	2	1.109	58.17	5.01	4.79	77.60	0.5155	4.779	Silt	14.15	81.42	4.43	0.194
First Year	Farmer Jeff	Radishes	CR, CC, RT	3	B	1			5	4.45	34.478	0.13615	2.446	Silt Loam	16.81	76.94	6.25	0.066
First Year	Farmer Jeff	Radishes	CR, CC, RT	3	B	2			4.78	4.24	40.104	0.14565	N/A	Silt Loam	21.44	71.87	6.69	0.074
Shady Maple Field 1 Rye	Shady Maple	Rye	CR, CC, NT	3	B	1			5.29	5.14	54.04	0.542	4.053	Silt Loam	21.59	74.65	3.76	0.166
Shady Maple Field 1 Rye	Shady Maple	Rye	CR, CC, NT	3	B	2			4.71	4.45	14.30	0.396	2.428	Silt Loam	17.30	78.36	4.34	0.08
Corn Field	Farmer Jeff	Corn	CC, NT	4	T	1	1.153	56.47	5.33	5.06	18.048	0.2255	3.278	Silt Loam	40.47	55.74	3.79	0.102
Corn Field	Farmer Jeff	Corn	CC, NT	4	T	2	1.324	50.04	5.46	5.3	22.672	0.2335	3.361	Silt Loam	24.90	70.01	5.09	0.093
Old Field	Farmer Jeff	Grass (wheatgrass)	CC, NT	4	T	1	1.313	50.45	4.7	4.5	45.10	0.2665	3.746	Silt Loam	27.13	65.79	7.08	0.139
Old Field	Farmer Jeff	Grass (wheatgrass)	CC, NT	4	T	2	1.369	48.33	4.94	4.62	82.41	0.297	3.872	Silt Loam	21.79	72.58	5.63	0.141
Corn Field	Farmer Jeff	Corn	CC, NT	4	B	1			5.5	5	22.509	0.13885	2.667	Sandy Loam	53.33	44.0	2.605	0.063
Corn Field	Farmer Jeff	Corn	CC, NT	4	B	2			5.41	5.09	31.683	0.19105	2.976	Loamy Sand	72.21	25.82	1.97	0.076
Old Field	Farmer Jeff	Grass (wheatgrass)	CC, NT	4	B	1			5.16	4.71	6.904	0.1409	2.482	Sandy Loam	51.66	44.89	3.45	0.065
Old Field	Farmer Jeff	Grass (wheatgrass)	CC, NT	4	B	2			5.28	4.86	22.067	0.19405	3.096	Loamy Sand	76.91	21.51	1.58	0.088

Table: Summary of all collected data for farms in Trumbull County, Ohio

Correlation matrix of all soil quality characteristics from SPSS

Correlations

		RANKNUMBERS	Bulk Density, g/cm3	% Porosity	pH 1:1 Water (Avg)	pH 1:2 CaCl2	PO4–P, mg/kg (Avg)	Salinity, uS/cm (Avg)	%SOM	% Sand	% Silt	% Clay	TNK, mg/kg
RANKNUMBERS	Pearson Correlation	1	.536*	-.536*	-.207	.003	-.038	-.738**	-.211	.240	-.268	.117	-.268
	Sig. (2-tailed)		.032	.032	.256	.989	.836	<.001	.255	.185	.138	.521	.138
	N	32	16	16	32	32	32	32	31	32	32	32	32
Bulk Density, g/cm3	Pearson Correlation	.536*	1	-1.000**	-.367	-.274	.042	-.279	-.472	.176	-.205	.109	-.256
	Sig. (2-tailed)	.032		<.001	.162	.304	.879	.295	.065	.515	.446	.687	.339
	N	16	16	16	16	16	16	16	16	16	16	16	16
% Porosity	Pearson Correlation	-.536*	-1.000**	1	.366	.274	-.041	.280	.472	-.176	.206	-.110	.257
	Sig. (2-tailed)	.032	<.001		.163	.305	.879	.294	.065	.514	.445	.686	.338
	N	16	16	16	16	16	16	16	16	16	16	16	16
pH 1:1 Water (Avg)	Pearson Correlation	-.207	-.367	.366	1	.834**	-.108	.255	.251	.173	-.152	-.366*	.073
	Sig. (2-tailed)	.256	.162	.163		<.001	.558	.158	.174	.344	.407	.040	.692
	N	32	16	16	32	32	32	32	31	32	32	32	32
pH 1:2 CaCl2	Pearson Correlation	.003	-.274	.274	.834**	1	-.006	.306	.382*	.222	-.200	-.415*	.294
	Sig. (2-tailed)	.989	.304	.305	<.001		.972	.089	.034	.222	.273	.018	.102
	N	32	16	16	32	32	32	32	31	32	32	32	32
PO4–P, mg/kg (Avg)	Pearson Correlation	-.038	.042	-.041	-.108	-.006	1	.301	.725**	-.321	.319	.271	.712**
	Sig. (2-tailed)	.836	.879	.879	.558	.972		.095	<.001	.073	.076	.131	<.001
	N	32	16	16	32	32	32	32	31	32	32	32	32
Salinity, uS/cm (Avg)	Pearson Correlation	-.738**	-.279	.280	.255	.306	.301	1	.573**	-.157	.197	-.319	.722**
	Sig. (2-tailed)	<.001	.295	.294	.158	.089	.095		<.001	.391	.280	.075	<.001
	N	32	16	16	32	32	32	32	31	32	32	32	32
%SOM	Pearson Correlation	-.211	-.472	.472	.251	.382*	.725**	.573**	1	-.366*	.375*	.172	.904**
	Sig. (2-tailed)	.255	.065	.065	.174	.034	<.001	<.001		.043	.037	.356	<.001
	N	31	16	16	31	31	31	31	31	31	31	31	31
% Sand	Pearson Correlation	.240	.176	-.176	.173	.222	-.321	-.157	-.366*	1	-.998**	-.785**	-.267
	Sig. (2-tailed)	.185	.515	.514	.344	.222	.073	.391	.043		<.001	<.001	.139
	N	32	16	16	32	32	32	32	31	32	32	32	32
% Silt	Pearson Correlation	-.268	-.205	.206	-.152	-.200	.319	.197	.375*	-.998**	1	.749**	.288
	Sig. (2-tailed)	.138	.446	.445	.407	.273	.076	.280	.037	<.001		<.001	.110
	N	32	16	16	32	32	32	32	31	32	32	32	32
% Clay	Pearson Correlation	.117	.109	-.110	-.366*	-.415*	.271	-.319	.172	-.785**	.749**	1	-.025
	Sig. (2-tailed)	.521	.687	.686	.040	.018	.131	.075	.356	<.001	<.001		.893
	N	32	16	16	32	32	32	32	31	32	32	32	32
TNK, mg/kg	Pearson Correlation	-.268	-.256	.257	.073	.294	.712**	.722**	.904**	-.267	.288	-.025	1
	Sig. (2-tailed)	.138	.339	.338	.692	.102	<.001	<.001	<.001	.139	.110	.893	
	N	32	16	16	32	32	32	32	31	32	32	32	32

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table: Correlation matrix for all soil characteristics investigated for farms in Trumbull County, Ohio

Mean Comparison (LSD & Tukey HSD) for all soil characteristics from SPSS

Dependent Variable	Post Hoc Test	(I) RANKNUMBERS	(J) RANKNUMBERS	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
							Lower Bound	Upper Bound
Bulk Density, g/cm3	Tukey HSD	1	2	-0.212667	0.078063	0.076	-0.44443	0.0191
			3	-0.08387	0.061715	0.546	-0.26709	0.09935
			4	-0.181601	0.061715	0.052	-0.36483	0.00162
		2	1	0.212667	0.078063	0.076	-0.0191	0.44443
			3	0.128797	0.082799	0.438	-0.11702	0.37462
			4	0.031065	0.082799	0.981	-0.21476	0.27689
		3	1	0.08387	0.061715	0.546	-0.09935	0.26709
			2	-0.128797	0.082799	0.438	-0.37462	0.11702
			4	-0.097731	0.067605	0.497	-0.29844	0.10298
		4	1	0.181601	0.061715	0.052	-0.00162	0.36483
			2	-0.031065	0.082799	0.981	-0.27689	0.21476
			3	0.097731	0.067605	0.497	-0.10298	0.29844
	LSD	1	2	-.212667*	0.078063	0.018	-0.38275	-0.04258
			3	-0.08387	0.061715	0.199	-0.21833	0.05059
			4	-.181601*	0.061715	0.012	-0.31607	-0.04714
		2	1	.212667*	0.078063	0.018	0.04258	0.38275
			3	0.128797	0.082799	0.146	-0.05161	0.3092
			4	0.031065	0.082799	0.714	-0.14934	0.21147
		3	1	0.08387	0.061715	0.199	-0.05059	0.21833
			2	-0.128797	0.082799	0.146	-0.3092	0.05161
			4	-0.097731	0.067605	0.174	-0.24503	0.04957
		4	1	.181601*	0.061715	0.012	0.04714	0.31607

			2	-0.031065	0.082799	0.714	-0.21147	0.14934
			3	0.097731	0.067605	0.174	-0.04957	0.24503
% Porosity	Tukey HSD	1	2	8.008333	2.94762	0.077	-0.74286	16.75952
			3	3.15477	2.330298	0.549	-3.76365	10.07319
			4	6.850109	2.330298	0.053	-0.06831	13.76853
		2	1	-8.008333	2.94762	0.077	-16.75952	0.74286
			3	-4.853563	3.126423	0.439	-14.1356	4.42848
			4	-1.158224	3.126423	0.982	-10.44026	8.12382
		3	1	-3.15477	2.330298	0.549	-10.07319	3.76365
			2	4.853563	3.126423	0.439	-4.42848	14.1356
			4	3.695339	2.552713	0.496	-3.88341	11.27409
		4	1	-6.850109	2.330298	0.053	-13.76853	0.06831
			2	1.158224	3.126423	0.982	-8.12382	10.44026
			3	-3.695339	2.552713	0.496	-11.27409	3.88341
	LSD	1	2	8.008333*	2.94762	0.019	1.58602	14.43064
			3	3.15477	2.330298	0.201	-1.92251	8.23205
			4	6.850109*	2.330298	0.012	1.77283	11.92739
		2	1	-8.008333*	2.94762	0.019	-14.43064	-1.58602
			3	-4.853563	3.126423	0.147	-11.66545	1.95833
			4	-1.158224	3.126423	0.717	-7.97011	5.65367
		3	1	-3.15477	2.330298	0.201	-8.23205	1.92251
			2	4.853563	3.126423	0.147	-1.95833	11.66545
			4	3.695339	2.552713	0.173	-1.86655	9.25722
		4	1	-6.850109*	2.330298	0.012	-11.92739	-1.77283
			2	1.158224	3.126423	0.717	-5.65367	7.97011
			3	-3.695339	2.552713	0.173	-9.25722	1.86655
pH 1:1 Water (Avg)	Tukey HSD	1	2	0.21667	0.13077	0.365	-0.1404	0.5737
			3	.30167*	0.10338	0.033	0.0194	0.5839
			4	0.06167	0.10338	0.932	-0.2206	0.3439
		2	1	-0.21667	0.13077	0.365	-0.5737	0.1404
			3	0.085	0.1387	0.927	-0.2937	0.4637
			4	-0.155	0.1387	0.682	-0.5337	0.2237
		3	1	-.30167*	0.10338	0.033	-0.5839	-0.0194
			2	-0.085	0.1387	0.927	-0.4637	0.2937
			4	-0.24	0.11325	0.172	-0.5492	0.0692
		4	1	-0.06167	0.10338	0.932	-0.3439	0.2206
			2	0.155	0.1387	0.682	-0.2237	0.5337
			3	0.24	0.11325	0.172	-0.0692	0.5492
	LSD	1	2	0.21667	0.13077	0.109	-0.0512	0.4845
			3	.30167*	0.10338	0.007	0.0899	0.5134
			4	0.06167	0.10338	0.556	-0.1501	0.2734
		2	1	-0.21667	0.13077	0.109	-0.4845	0.0512
			3	0.085	0.1387	0.545	-0.1991	0.3691
			4	-0.155	0.1387	0.273	-0.4391	0.1291
		3	1	-.30167*	0.10338	0.007	-0.5134	-0.0899
			2	-0.085	0.1387	0.545	-0.3691	0.1991
			4	-.24000*	0.11325	0.043	-0.472	-0.008
		4	1	-0.06167	0.10338	0.556	-0.2734	0.1501
			2	0.155	0.1387	0.273	-0.1291	0.4391
			3	.24000*	0.11325	0.043	0.008	0.472
PO4-P, mg/kg (Avg)	Tukey HSD	1	2	0.89167	14.46158	1	-38.5929	40.3763
			3	-22.15233	11.43288	0.236	-53.3677	9.063
			4	11.65004	11.43288	0.74	-19.5653	42.8654
		2	1	-0.89167	14.46158	1	-40.3763	38.5929
			3	-23.044	15.33882	0.45	-64.9238	18.8358
			4	10.75837	15.33882	0.896	-31.1214	52.6381
		3	1	22.15233	11.43288	0.236	-9.063	53.3677
			2	23.044	15.33882	0.45	-18.8358	64.9238
			4	33.80238	12.52409	0.054	-0.3923	67.997
		4	1	-11.65004	11.43288	0.74	-42.8654	19.5653
			2	-10.75837	15.33882	0.896	-52.6381	31.1214
			3	-33.80237	12.52409	0.054	-67.997	0.3923
	LSD	1	2	0.89167	14.46158	0.951	-28.7315	30.5149
			3	-22.15233	11.43288	0.063	-45.5715	1.2669
			4	11.65004	11.43288	0.317	-11.7692	35.0692
		2	1	-0.89167	14.46158	0.951	-30.5149	28.7315
			3	-23.044	15.33882	0.144	-54.4641	8.3761
			4	10.75837	15.33882	0.489	-20.6618	42.1785
		3	1	22.15233	11.43288	0.063	-1.2669	45.5715

			2	23.044	15.33882	0.144	-8.3761	54.4641
			4	33.80238*	12.52409	0.012	8.1479	59.4568
		4	1	-11.65004	11.43288	0.317	-35.0692	11.7692
			2	-10.75837	15.33882	0.489	-42.1785	20.6618
			3	-33.80237*	12.52409	0.012	-59.4568	-8.1479
Salinity, uS/cm (Avg)	Tukey HSD	1	2	-0.02470833	0.08001087	0.99	-0.2431629	0.1937463
			3	.21612917*	0.06325415	0.01	0.0434256	0.3888327
			4	.36662292*	0.06325415	<.001	0.1939194	0.5393265
		2	1	0.02470833	0.08001087	0.99	-0.1937463	0.2431629
			3	.24083750*	0.08486435	0.039	0.0091314	0.4725436
			4	.39133125*	0.08486435	<.001	0.1596251	0.6230374
		3	1	-.21612917*	0.06325415	0.01	-0.3888327	-0.0434256
			2	-.24083750*	0.08486435	0.039	-0.4725436	-0.0091314
			4	0.15049375	0.06929145	0.156	-0.0386935	0.339681
		4	1	-.36662292*	0.06325415	<.001	-0.5393265	-0.1939194
			2	-.39133125*	0.08486435	<.001	-0.6230374	-0.1596251
			3	-0.15049375	0.06929145	0.156	-0.339681	0.0386935
	LSD	1	2	-0.02470833	0.08001087	0.76	-0.1886032	0.1391865
			3	.21612917*	0.06325415	0.002	0.0865589	0.3456994
			4	.36662292*	0.06325415	<.001	0.2370527	0.4961932
		2	1	0.02470833	0.08001087	0.76	-0.1391865	0.1886032
			3	.24083750*	0.08486435	0.008	0.0670008	0.4146742
			4	.39133125*	0.08486435	<.001	0.2174945	0.565168
		3	1	-.21612917*	0.06325415	0.002	-0.3456994	-0.0865589
			2	-.24083750*	0.08486435	0.008	-0.4146742	-0.0670008
			4	.15049375*	0.06929145	0.038	0.0085567	0.2924308
		4	1	-.36662292*	0.06325415	<.001	-0.4961932	-0.2370527
			2	-.39133125*	0.08486435	<.001	-0.565168	-0.2174945
			3	-.15049375*	0.06929145	0.038	-0.2924308	-0.0085567
%SOM	Tukey HSD	1	2	0.5835	0.49114	0.639	-0.7605	1.9275
			3	-0.10239	0.40458	0.994	-1.2096	1.0048
			4	0.62125	0.38828	0.395	-0.4413	1.6838
		2	1	-0.5835	0.49114	0.639	-1.9275	0.7605
			3	-0.68589	0.53319	0.579	-2.145	0.7732
			4	0.03775	0.52093	1	-1.3878	1.4633
		3	1	0.10239	0.40458	0.994	-1.0048	1.2096
			2	0.68589	0.53319	0.579	-0.7732	2.145
			4	0.72364	0.44027	0.372	-0.4812	1.9285
		4	1	-0.62125	0.38828	0.395	-1.6838	0.4413
			2	-0.03775	0.52093	1	-1.4633	1.3878
			3	-0.72364	0.44027	0.372	-1.9285	0.4812
	LSD	1	2	0.5835	0.49114	0.245	-0.4242	1.5912
			3	-0.10239	0.40458	0.802	-0.9325	0.7277
			4	0.62125	0.38828	0.121	-0.1754	1.4179
		2	1	-0.5835	0.49114	0.245	-1.5912	0.4242
			3	-0.68589	0.53319	0.209	-1.7799	0.4081
			4	0.03775	0.52093	0.943	-1.0311	1.1066
		3	1	0.10239	0.40458	0.802	-0.7277	0.9325
			2	0.68589	0.53319	0.209	-0.4081	1.7799
			4	0.72364	0.44027	0.112	-0.1797	1.627
		4	1	-0.62125	0.38828	0.121	-1.4179	0.1754
			2	-0.03775	0.52093	0.943	-1.1066	1.0311
			3	-0.72364	0.44027	0.112	-1.627	0.1797
% Sand	Tukey HSD	1	2	-12.83583	8.57608	0.453	-36.2512	10.5795
			3	8.37917	6.77999	0.61	-10.1323	26.8906
			4	-16.95833	6.77999	0.082	-35.4698	1.5531
		2	1	12.83583	8.57608	0.453	-10.5795	36.2512
			3	21.215	9.09631	0.115	-3.6208	46.0508
			4	-4.1225	9.09631	0.968	-28.9583	20.7133
		3	1	-8.37917	6.77999	0.61	-26.8906	10.1323
			2	-21.215	9.09631	0.115	-46.0508	3.6208
			4	-25.33750*	7.4271	0.01	-45.6158	-5.0592
		4	1	16.95833	6.77999	0.082	-1.5531	35.4698
			2	4.1225	9.09631	0.968	-20.7133	28.9583
			3	25.33750*	7.4271	0.01	5.0592	45.6158
	LSD	1	2	-12.83583	8.57608	0.146	-30.4031	4.7315
			3	8.37917	6.77999	0.227	-5.509	22.2673
			4	-16.95833*	6.77999	0.018	-30.8465	-3.0702
		2	1	12.83583	8.57608	0.146	-4.7315	30.4031
			3	21.21500*	9.09631	0.027	2.5821	39.8479

			4	-4.1225	9.09631	0.654	-22.7554	14.5104
		3	1	-8.37917	6.77999	0.227	-22.2673	5.509
			2	-21.21500*	9.09631	0.027	-39.8479	-2.5821
			4	-25.33750*	7.4271	0.002	-40.5512	-10.1238
		4	1	16.95833*	6.77999	0.018	3.0702	30.8465
			2	4.1225	9.09631	0.654	-14.5104	22.7554
			3	25.33750*	7.4271	0.002	10.1238	40.5512
% Silt	Tukey HSD	1	2	11.930833	7.941543	0.45	-9.75205	33.61372
			3	-7.204167	6.278341	0.664	-24.34599	9.93766
			4	16.911458	6.278341	0.054	-0.23037	34.05329
		2	1	-11.930833	7.941543	0.45	-33.61372	9.75205
			3	-19.135	8.423279	0.129	-42.13318	3.86318
			4	4.980625	8.423279	0.934	-18.01755	27.9788
		3	1	7.204167	6.278341	0.664	-9.93766	24.34599
			2	19.135	8.423279	0.129	-3.86318	42.13318
			4	24.115625*	6.877578	0.008	5.33769	42.89356
		4	1	-16.911458	6.278341	0.054	-34.05329	0.23037
			2	-4.980625	8.423279	0.934	-27.9788	18.01755
			3	-24.115625*	6.877578	0.008	-42.89356	-5.33769
	LSD	1	2	11.930833	7.941543	0.144	-4.33668	28.19835
			3	-7.204167	6.278341	0.261	-20.06477	5.65643
			4	16.911458*	6.278341	0.012	4.05086	29.77206
		2	1	-11.930833	7.941543	0.144	-28.19835	4.33668
			3	-19.135000*	8.423279	0.031	-36.3893	-1.8807
			4	4.980625	8.423279	0.559	-12.27368	22.23493
		3	1	7.204167	6.278341	0.261	-5.65643	20.06477
			2	19.135000*	8.423279	0.031	1.8807	36.3893
			4	24.115625*	6.877578	0.002	10.02754	38.20371
		4	1	-16.911458*	6.278341	0.012	-29.77206	-4.05086
			2	-4.980625	8.423279	0.559	-22.23493	12.27368
			3	-24.115625*	6.877578	0.002	-38.20371	-10.02754
% Clay	Tukey HSD	1	2	0.904167	0.799946	0.674	-1.27994	3.08827
			3	-1.174583	0.632413	0.269	-2.90127	0.5521
			4	0.047292	0.632413	1	-1.67939	1.77398
		2	1	-0.904167	0.799946	0.674	-3.08827	1.27994
			3	-2.07875	0.848471	0.091	-4.39534	0.23784
			4	-0.856875	0.848471	0.745	-3.17346	1.45971
		3	1	1.174583	0.632413	0.269	-0.5521	2.90127
			2	2.07875	0.848471	0.091	-0.23784	4.39534
			4	1.221875	0.692774	0.311	-0.66961	3.11336
		4	1	-0.047292	0.632413	1	-1.77398	1.67939
			2	0.856875	0.848471	0.745	-1.45971	3.17346
			3	-1.221875	0.692774	0.311	-3.11336	0.66961
	LSD	1	2	0.904167	0.799946	0.268	-0.73445	2.54278
			3	-1.174583	0.632413	0.074	-2.47002	0.12086
			4	0.047292	0.632413	0.941	-1.24815	1.34273
		2	1	-0.904167	0.799946	0.268	-2.54278	0.73445
			3	-2.078750*	0.848471	0.021	-3.81676	-0.34074
			4	-0.856875	0.848471	0.321	-2.59489	0.88114
		3	1	1.174583	0.632413	0.074	-0.12086	2.47002
			2	2.078750*	0.848471	0.021	0.34074	3.81676
			4	1.221875	0.692774	0.089	-0.19721	2.64096
		4	1	-0.047292	0.632413	0.941	-1.34273	1.24815
			2	0.856875	0.848471	0.321	-0.88114	2.59489
			3	-1.221875	0.692774	0.089	-2.64096	0.19721
TN%, mg/kg	Tukey HSD	1	2	0.006167	0.02659	0.996	-0.06643	0.07876
			3	-0.003333	0.021021	0.999	-0.06073	0.05406
			4	0.039292	0.021021	0.264	-0.0181	0.09669
		2	1	-0.006167	0.02659	0.996	-0.07876	0.06643
			3	-0.0095	0.028203	0.987	-0.0865	0.0675
			4	0.033125	0.028203	0.647	-0.04388	0.11013
		3	1	0.003333	0.021021	0.999	-0.05406	0.06073
			2	0.0095	0.028203	0.987	-0.0675	0.0865
			4	0.042625	0.023027	0.272	-0.02025	0.1055
		4	1	-0.039292	0.021021	0.264	-0.09669	0.0181
			2	-0.033125	0.028203	0.647	-0.11013	0.04388
			3	-0.042625	0.023027	0.272	-0.1055	0.02025
	LSD	1	2	0.006167	0.02659	0.818	-0.0483	0.06063
			3	-0.003333	0.021021	0.875	-0.04639	0.03973
			4	0.039292	0.021021	0.072	-0.00377	0.08235
		2	1	-0.006167	0.02659	0.818	-0.06063	0.0483

			3	-0.0095	0.028203	0.739	-0.06727	0.04827
			4	0.033125	0.028203	0.25	-0.02465	0.0909
		3	1	0.003333	0.021021	0.875	-0.03973	0.04639
			2	0.0095	0.028203	0.739	-0.04827	0.06727
			4	0.042625	0.023027	0.075	-0.00454	0.08979
		4	1	-0.039292	0.021021	0.072	-0.08235	0.00377
			2	-0.033125	0.028203	0.25	-0.0909	0.02465
			3	-0.042625	0.023027	0.075	-0.08979	0.00454
pH 1:2 CaCl2	Tukey HSD	1	2	0.20917	0.16868	0.607	-0.2514	0.6697
			3	0.22792	0.13335	0.338	-0.1362	0.592
			4	-0.06583	0.13335	0.96	-0.4299	0.2983
		2	1	-0.20917	0.16868	0.607	-0.6697	0.2514
			3	0.01875	0.17891	1	-0.4697	0.5072
			4	-0.275	0.17891	0.43	-0.7635	0.2135
		3	1	-0.22792	0.13335	0.338	-0.592	0.1362
			2	-0.01875	0.17891	1	-0.5072	0.4697
			4	-0.29375	0.14608	0.208	-0.6926	0.1051
		4	1	0.06583	0.13335	0.96	-0.2983	0.4299
			2	0.275	0.17891	0.43	-0.2135	0.7635
			3	0.29375	0.14608	0.208	-0.1051	0.6926
	LSD	1	2	0.20917	0.16868	0.225	-0.1364	0.5547
			3	0.22792	0.13335	0.098	-0.0452	0.5011
			4	-0.06583	0.13335	0.625	-0.339	0.2073
		2	1	-0.20917	0.16868	0.225	-0.5547	0.1364
			3	0.01875	0.17891	0.917	-0.3477	0.3852
			4	-0.275	0.17891	0.135	-0.6415	0.0915
		3	1	-0.22792	0.13335	0.098	-0.5011	0.0452
			2	-0.01875	0.17891	0.917	-0.3852	0.3477
			4	-0.29375	0.14608	0.054	-0.593	0.0055
		4	1	0.06583	0.13335	0.625	-0.2073	0.339
			2	0.275	0.17891	0.135	-0.0915	0.6415
			3	0.29375	0.14608	0.054	-0.0055	0.593
* The mean difference is significant at the 0.05 level.								

Table: Mean comparison for all soil characteristics investigated for farms in Trumbull County, Ohio

Excluded Variables for Linear Regression of % Nitrogen

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
2	% Clay	.015[b]	.113	.911	.023	.172
3	% Clay	-.022[c]	-.299	.767	-.060	.538
	% Silt	-.028[c]	-.442	.662	-.088	.687

a. Dependent Variable: TN%, mg/kg

b. Predictors in the Model: (Constant), Salinity, uS/cm (Avg), % Silt, pH 1:2 CaCl2, %SOM, RANKNUMBERS

c. Predictors in the Model: (Constant), Salinity, uS/cm (Avg), pH 1:2 CaCl2, % SOM, RANKNUMBERS

Table: Excluded variables for linear regression of % nitrogen for farms in Trumbull County, Ohio

Excluded Variables for Linear Regression of Total Phosphorus

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
2	Salinity, uS/cm (Avg)	.073[b]	.241	.811	.049	.154
3	Salinity, uS/cm (Avg)	-.016[c]	-.067	.947	-.013	.247
	% Clay	.096[c]	.428	.672	.085	.275
4	Salinity, uS/cm (Avg)	-.001[d]	-.005	.996	-.001	.255
	% Clay	.000[d]	-.001	.999	.000	.732
	% Silt	-.046[d]	-.339	.738	-.066	.712
5	Salinity, uS/cm (Avg)	-.156[e]	-1.113	.275	-.209	.671
	% Clay	.040[e]	.299	.767	.057	.768
	% Silt	-.080[e]	-.591	.559	-.113	.738
	RANKNUMBERS	.167[e]	1.431	.164	.266	.940

a. Dependent Variable: PO4-P, mg/kg (Avg)

b. Predictors in the Model: (Constant), % Silt, pH 1:2 CaCl2, %SOM, RANKNUMBERS, % Clay

c. Predictors in the Model: (Constant), % Silt, pH 1:2 CaCl2, %SOM, RANKNUMBERS

d. Predictors in the Model: (Constant), pH 1:2 CaCl2, %SOM, RANKNUMBERS

e. Predictors in the Model: (Constant), pH 1:2 CaCl2, %SOM

Table: Excluded variables for linear regression of total phosphorus for farms in Trumbull County, Ohio

Independent Samples t-test for all characteristics investigated and the top and bottom layers

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
pH 1:1 Water (Avg)	Equal variances assumed	.030	.863	.348	30	.365	.730	.03125	.08967	-.15189	.21439
	Equal variances not assumed			.348	29.658	.365	.730	.03125	.08967	-.15198	.21448
pH 1:2 CaCl2	Equal variances assumed	.044	.836	1.217	30	.117	.231	.13000	.10681	-.08813	.34813
	Equal variances not assumed			1.217	29.945	.117	.231	.13000	.10681	-.08814	.34814
PO4-P, mg/kg (Avg)	Equal variances assumed	8.426	.007	4.892	30	<.001	<.001	35.23469	7.20190	20.52645	49.94293
	Equal variances not assumed			4.892	21.629	<.001	<.001	35.23469	7.20190	20.28401	50.18536
Salinity, uS/cm (Avg)	Equal variances assumed	1.015	.322	1.805	30	.041	.081	.12805312	.07092523	-.01679552	.27290177
	Equal variances not assumed			1.805	28.737	.041	.081	.12805312	.07092523	-.01706304	.27316929
%SOM	Equal variances assumed	2.837	.103	5.537	29	<.001	<.001	1.22650	.22150	.77347	1.67953
	Equal variances not assumed			5.612	26.005	<.001	<.001	1.22650	.21856	.77724	1.67575
% Sand	Equal variances assumed	10.782	.003	-1.556	30	.065	.130	-9.29312	5.97174	-21.48905	2.90280
	Equal variances not assumed			-1.556	23.951	.066	.131	-9.29312	5.97174	-21.61951	3.03326
% Silt	Equal variances assumed	11.406	.002	1.522	30	.069	.138	8.508438	5.590119	-2.908109	19.924984
	Equal variances not assumed			1.522	23.624	.071	.141	8.508438	5.590119	-3.038715	20.055590
% Clay	Equal variances assumed	.001	.970	1.542	30	.067	.134	.785312	.509216	-.254646	1.825271
	Equal variances not assumed			1.542	29.985	.067	.134	.785312	.509216	-.254667	1.825292
TN%, mg/kg	Equal variances assumed	.871	.358	4.715	30	<.001	<.001	.060563	.012843	.034333	.086792
	Equal variances not assumed			4.715	26.118	<.001	<.001	.060563	.012843	.034168	.086957

Table: Independent t-test for all characteristics investigated separated by top and bottom layer for farms in Trumbull County, Ohio

Excluded Variables for Backwards Linear Regression for % Nitrogen and top and bottom layers

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
2	% Silt	-.014[b]	-.087	.931	-.018	.187
3	% Silt	-.047[c]	-.335	.741	-.067	.220
	RankLayer	-.067[c]	-.662	.514	-.131	.428
4	% Silt	-.091[d]	-1.198	.242	-.229	.737
	RankLayer	-.037[d]	-.374	.711	-.073	.450
	% Clay	-.102[d]	-1.208	.238	-.231	.590

a. Dependent Variable: TN%, mg/kg

b. Predictors in the Model: (Constant), RankLayer, pH 1:2 CaCl2, Salinity, uS/cm (Avg), %SOM, % Clay

c. Predictors in the Model: (Constant), pH 1:2 CaCl2, Salinity, uS/cm (Avg), %SOM, % Clay

d. Predictors in the Model: (Constant), pH 1:2 CaCl2, Salinity, uS/cm (Avg), %SOM

Table: Excluded variables for backwards linear regression for % nitrogen and top and bottom layers for farms in Trumbull County, Ohio

Excluded Variables for Backwards Linear Regression for total phosphorus and top and bottom layers

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
2	% Silt	-.031[b]	-.112	.911	-.023	.187
3	% Silt	-.072[c]	-.535	.597	-.106	.737
	% Clay	-.085[c]	-.553	.585	-.110	.561
4	% Silt	-.075[d]	-.565	.577	-.110	.738
	% Clay	-.019[d]	-.139	.891	-.027	.699
	Salinity, uS/cm (Avg)	-.116[d]	-.813	.424	-.157	.637
5	% Silt	-.080[e]	-.591	.559	-.113	.738
	% Clay	.040[e]	.299	.767	.057	.768
	Salinity, uS/cm (Avg)	-.156[e]	-1.113	.275	-.209	.671
	RankLayer	-.245[e]	-1.495	.146	-.277	.474

a. Dependent Variable: PO4-P, mg/kg (Avg)

b. Predictors in the Model: (Constant), RankLayer, pH 1:2 CaCl2, Salinity, uS/cm (Avg), % SOM, % Clay

c. Predictors in the Model: (Constant), RankLayer, pH 1:2 CaCl2, Salinity, uS/cm (Avg), % SOM

d. Predictors in the Model: (Constant), RankLayer, pH 1:2 CaCl2, %SOM

e. Predictors in the Model: (Constant), pH 1:2 CaCl2, %SOM

Table: Excluded variables for backwards linear regression for total phosphorus and top and bottom for farms in Trumbull County, Ohio.

PCA Top 15 cm Scatter Plot (Component 1 & 2) for farms in Trumbull County, Ohio

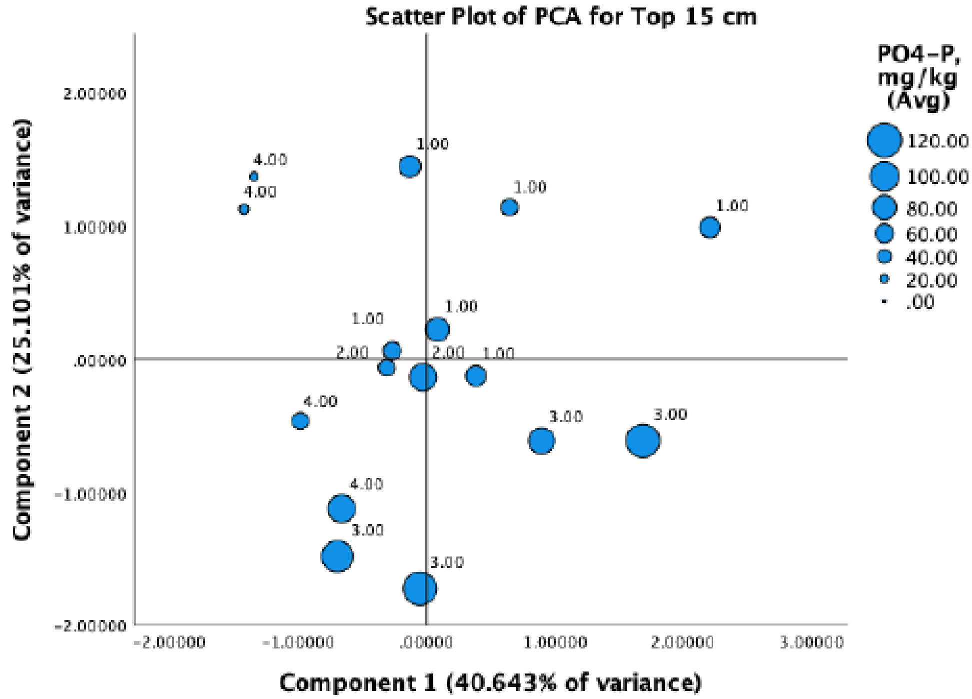

Figure: Scatter Plot of PCA analysis Components 1 & 2 for Top 15 cm for farms in Trumbull County, Ohio

Sample Averages Separated through two categories: Conventional and Conservational

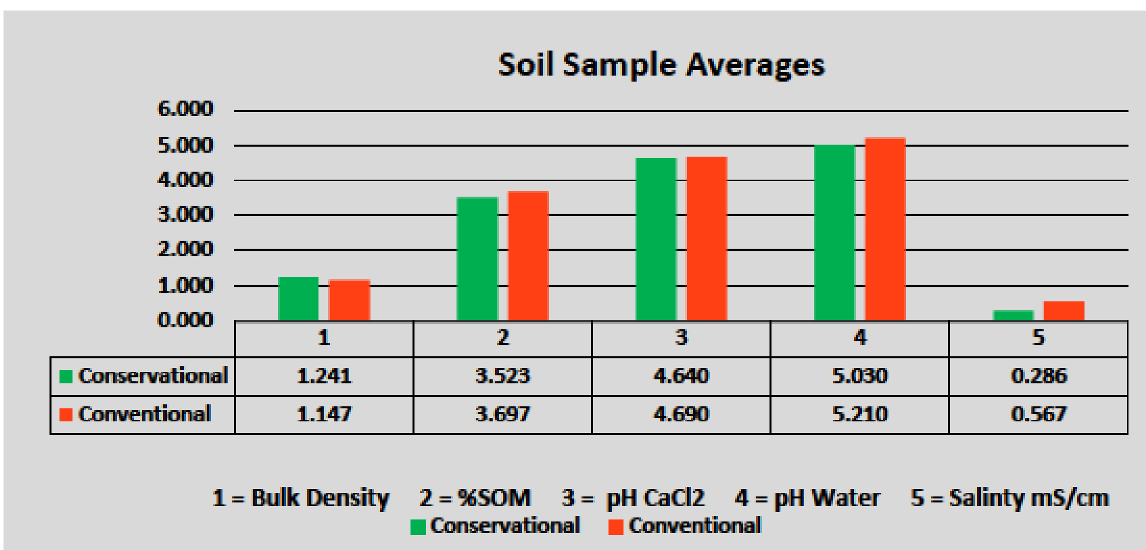

Figure: Sample averages for bulk density, %SOM, pH, and salinity, separated in categories conventional and conservational for farms in Trumbull County, Ohio.

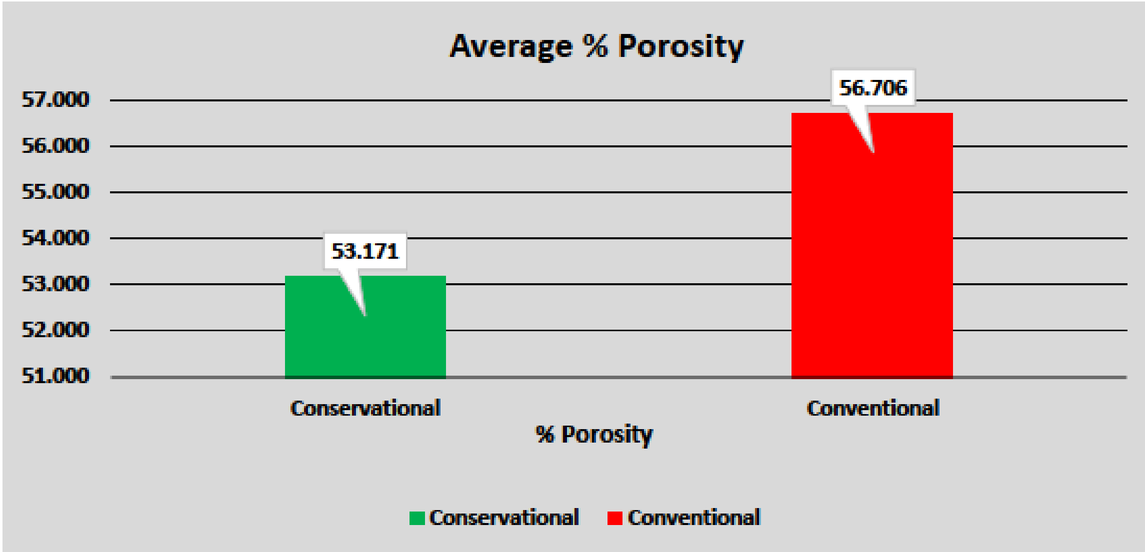

Figure: Sample averages for % porosity, separated in categories conventional and conservational for farms in Trumbull County, Ohio.

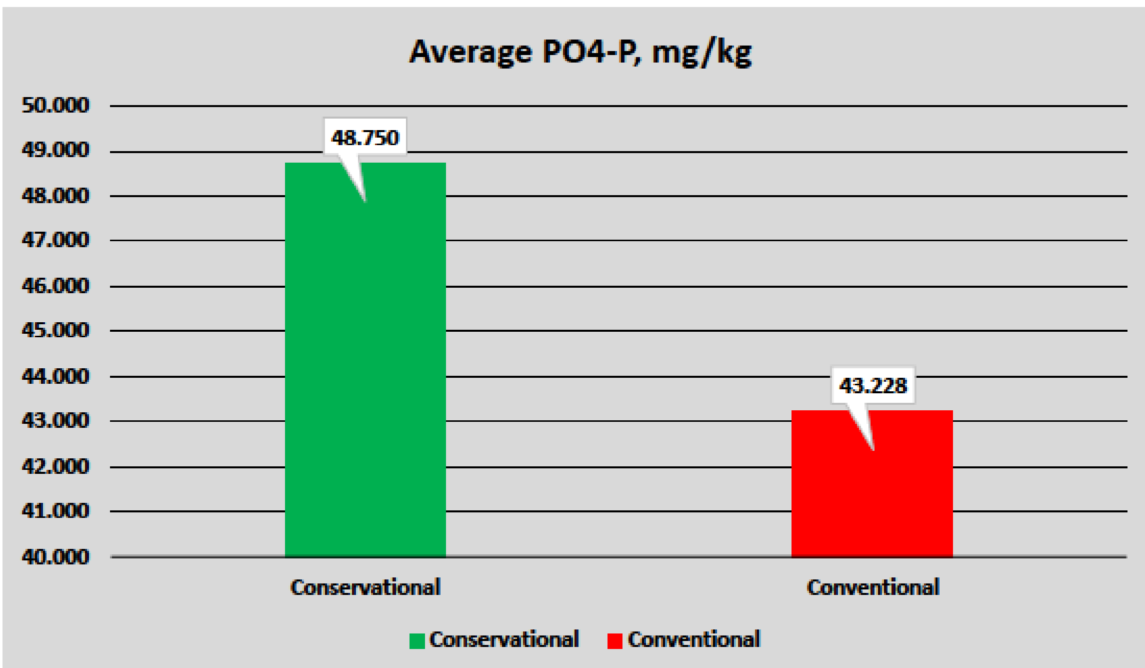

Figure: Sample averages for total phosphorus, separated in categories conventional and conservational for farms in Trumbull County, Ohio.

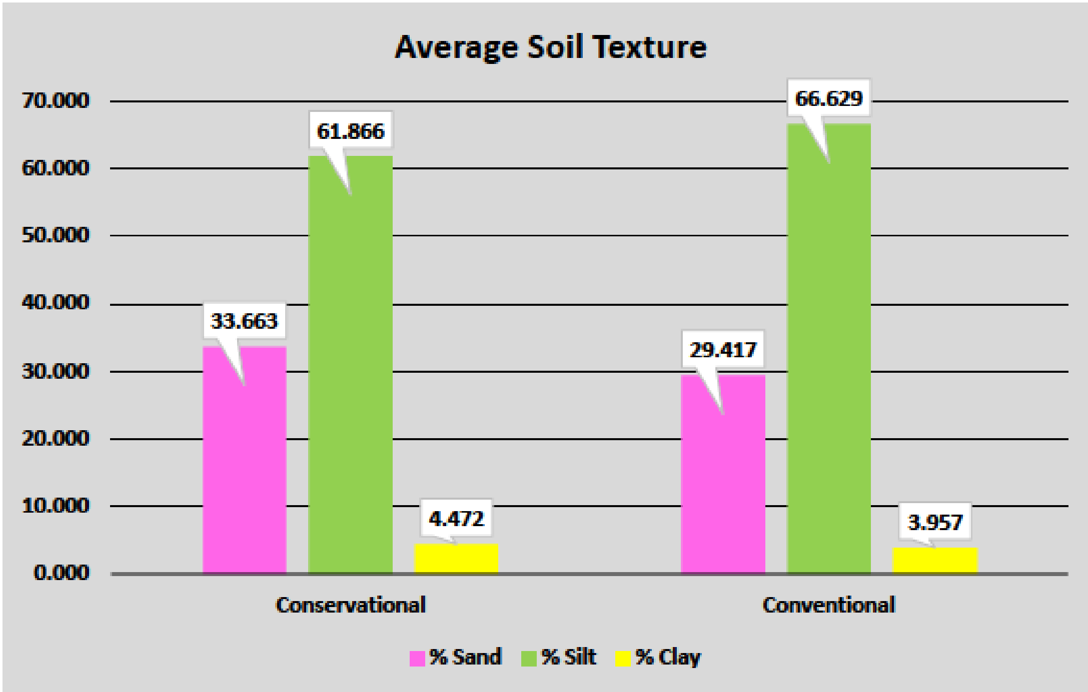

Figure: Sample averages for soil texture: (sand, silt, clay), separated in categories conventional and conservational for farms in Trumbull County, Ohio.

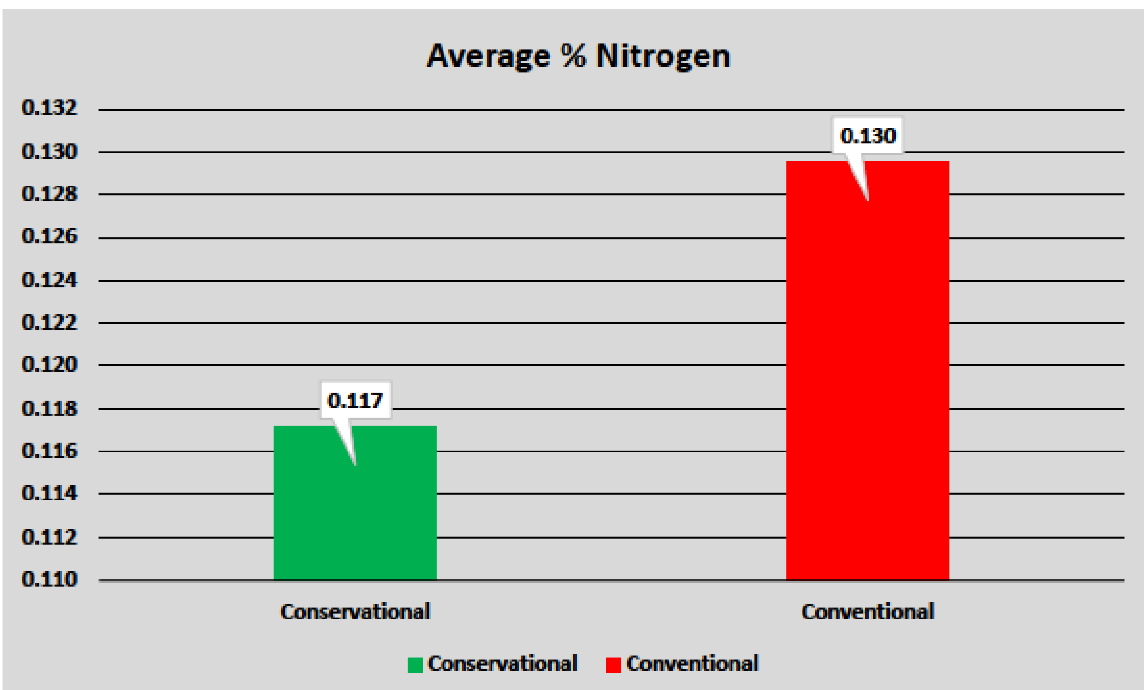

Figure: Sample averages for % nitrogen, separated in categories conventional and conservational for farms in Trumbull County, Ohio.