SOIL HEALTH FOR IMPROVED FOOD SECURITIES:

AN EXTENSION PROFESSIONAL PERSPECTIVE

A Dissertation

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In Partial Fulfillment

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Doctor of Philosophy

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by

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The undersigned, appointed by the dean of the Graduate School,

have examined the dissertation entitled

SOIL HEALTH FOR IMPROVED FOOD SECURITIES:
AN EXTENSION PROFESSIONAL PERSPECTIVE

presented by Todd Elmer Lorenz,

a candidate for the degree of

Doctor of Philosophy,

and hereby certify that, in their opinion, it is worthy of acceptance.

Professor Brad Fresenburg (Chair)

Professor Robert Kremer

Professor Robert Kallenbach

Professor Marcia Carlson Shannon

Professor Kristen Veum Sloan

DEDICATION

This work is dedicated to my parents, Elmer and Pat Lorenz, who were children of the depression era and through hard work and sacrifice, were able to raise five boys through adulthood and are enjoying the rewards of grandchildren and great grandchildren. Additional praise goes to my children who had to endure the additional absence of their father through this non-traditional Doctorate process but may have learned something along the way as well.

My father taught me how to study things and fix them and my mother taught me, among other things, patience. My children have taught me that they are the toughest, smartest and most conscientious people to which this world needs more. I have learned that you can work hard to succeed in your dreams and aspirations and the road is much easier as long as you have the dedicated support of family. Their life model for me has been both inspirational and instrumental in my drive to achieve.

Deuteronomy 31:6 Be strong and of good courage, fear not, nor be afraid of them: for the Lord thy God, he it is that doth go with thee; he will not fail thee, nor forsake thee.

ACKNOWLEDGEMENTS

Outside of choosing an adequate descriptive vocabulary to describe the impact that others have contributed to your success, the acknowledgement section may very well be the easiest to salute those who took part in your advanced degree.

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Dr. J. R. Brown, who throughout my M.S. program, taught me the best of the pure scientific method. As a military veteran and consummate soil scientist, he provided me with the best academic and scientific foundation that anyone could deserve. Additionally, and without appointment, he was one of the preeminent resources for the Extension Educator and the taxpaying public while humbly moving his career forward in military style. It was his example that, in no small part, influenced my decision to enter an Extension career in order to provide producers with the scientific answers that resolve real world problems and offer immediate impact on their livelihood.

Don Day, Extension Agriculture Engineer, who provided me with the best Extension Specialist mentoring that anyone would envy. His complete dedication to the mission of Extension is instilled in me.

Dr. Kristen Veum Sloan for modeling her comprehensive soils knowledge and dedicated passion to the subject of soil health. She is also a big picture professional who understands that we can get more done together than as separate entities and understands the 1914 Extension delivery system of taking the research out to the public. Her willingness to work collaboratively is cherished greatly.

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Dr. Rob Kallenbach and Dr. Marcia Carlson Shannon who have a related connection with the Land Grant mission and have been involved with me at various levels throughout my career. Both provided the much-needed sounding board for clarifications and scientific advancement.

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This work was funded, in part, by the Mizzou Advantage grant which fosters interdisciplinary collaboration among faculty, staff, students and external partners to address and solve real-world needs and problems in four areas of strength identified at the University of Missouri, and a USDA NRCS Conservation Innovation Grant (CIG) USDA-NRCS-MO-CIG-15-02. Any opinions, findings, conclusions or references expressed in this dissertation are those of the author and do not necessarily reflect the view of the U.S. Department of Agriculture or NRCS. The purpose of CIG is to stimulate the development and adoption of innovative conservation approaches and technologies, while leveraging the Federal investment in environmental enhancement and protection in conjunction with agricultural

production. CIG projects are expected to lead to the transfer of conservation technologies, management systems, and innovative approaches (such as market-based systems) into NRCS technical manuals and guides or to the private sector. CIG is used to apply or demonstrate previously proven technology in order to increase adoption with an emphasis on opportunities to scale proven, emerging conservation strategies. CIG promotes sharing of skills, knowledge, technologies, and facilities among communities, governments, and other institutions to ensure that scientific and technological developments are accessible to a wider range of users. CIG funds projects targeting innovative on-the-ground conservation, including pilot projects and field demonstrations.

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CHAPTER ONE

Introduction

Historical human uses of soils have focused on food and fiber for sustaining life. Human agricultural and forestry practices often ignored important soil functions that sustained complex biological communities prior to the emergence of humans as a globe-changing species.

Human history is littered with the debris of failed societies, ravaged earth and polluted water. Douglas (1972), Egan (2005), Hillell (1992), Lowdermilk (1948), and Montgomery (2007) reviewed this human recklessness and described the cultural, economic, and agricultural shifts necessary for civilization to respectfully manage soil resources to ensure the survival of life on Earth.

EXTENSION ORIGINS

The practice of living off the land was well documented in early American history. Tisquantum, more commonly known as Squanto, was a Native North American of the Patuxet tribe that occupied the coastal area west of Cape Cod Bay in the late 16th early 17th century. To support their society, agricultural practices included clearing fields, breaking ground, and fertilizing the soil with fish and crustaceans and weeding was typically done with clam-shell hoes. This horticulture practice was necessary to accumulate surplus for winter needs and trade with the English settlers (Russel, 1980; Jennings, 1976). Legend has it that after a period of famine, Squanto was credited with giving the first "Extension" demonstration to the Pilgrims on proper planting and harvesting techniques followed by the first Thanksgiving feast (Bradford, 1952; Bradford and Winslow, 1588; Bay, 1961).

Some 200 years later the United States made formal attempts to continue this teaching and Extension through various Acts of Congress. The land-grant mission was established by the Morrill Act of 1862 to promote the liberal and practical education of various social classes, pursuits, and professions in life. It was followed by the Hatch Act of 1887 to ensure that the necessary basic and applied agricultural research would be conducted by state colleges of agriculture in cooperation with the federal government, which is now represented by the U.S. Department of Agriculture.

UNIVERSITY OF MISSOURI EXTENSION HISTORY

In 1899, Congressman Willard Vandiver conveyed, "I come from a state that raises corn and cotton, cockleburs and Democrats, and frothy eloquence neither convinces nor satisfies me. I'm from Missouri, and you have got to show me". The University of Missouri (MU) land-grant institution has a history of innovation and excellence in soil science research and Extension. Historic Sanborn Field, one of only three long-term studies of its kind in the world (University of Illinois Morrow Plots and Rothamsted in England are the others) has yielded important research findings since its establishment in 1888. (Albrecht, 1939; Mitchell, et al. 1991; Brown, 1991; Upchurch et al. 1985; Brown, 1994). Sanborn Field is the father of Missouri's research and Extension experiment station.

In 1913, ten University of Missouri "Farm Advisors" were charged with assisting farmers with an epidemic of hog cholera, which threatened to destroy swine herds throughout Missouri. With the passage of the 1914 Smith-Lever act, 27 years after the land grant establishment, the Extension Service was in full swing. "The Extension Service was established to provide a means of making research information readily available to those on the land and to assist farm people to use it in solving their individual problems" (Warburton et al., 1938). The Land Grant College was charged with the mission of taking unbiased research-based information to citizens at the local level. Since 1914, Extension educators have been responsible for adult education and improving the lives and economy of citizens at the local level. It is well known that this delivery model enables adults to have the ultimate determination in what action they take as a result of that education (Battel and Krueger, 2005).

The University of Missouri has a rich history in soil science research. The Duley Miller erosion plots were the template for long-term soil erosion studies that led to creation of the Wischmeir Universal Soil Loss Equation. It has been regularly revised by the Natural Resource Conservation Service (NRCS) and, in its present form, the Revised Universal Soil Loss Equation (RUSLE 2) is one of the most important and frequently used erosion prediction tools (Woodruff, 1987). Curtis Fletcher Marbut, a Missouri native and former chair of the Soil Science Department at MU, is one of the best known and most admired soil scientists in history. He directed the American National Soil Survey for more than 20 years. Guy Smith received his M.S. in soil science at MU, and moved on to become the internationally known and respected "father of soil taxonomy," which is used in the U.S. and internationally. His work has been used to classify more than 25,000 identified American soils. When the Soil Science Society of America was formed in 1936, four of the six division chairs were MU faculty or alumni. Hans Jenny, the internationally known soil scientist who wrote the still frequently cited <u>The Factors of Soil Formation</u> (Jenny, 1941), began his career at MU, and published research findings from Tucker Prairie. Dr. William Albrecht, former chair of the MU department of Soil Science and president of the 1939 Soil Science Society of America, was internationally known. The linkages he established among soil quality, human health and human and animal nutrition are often cited as the beginning of the soil health concept. Over 170 Albrecht Papers are still being printed and cited today. C.M. Woodruff developed the "Woodruff buffer" for determining the lime requirement in soils and influenced thousands of Missourians during his 70+ year affiliation with MU (Woodruff, 1948). Clarence Scrivner developed the soil Productivity Index (PI) for Missouri soils based on soil attributes regulating root growth and water depletion with depth in the soil profile as a quantitative way to assess a soil's productivity potential (Kiniry et al. 1983). More recently, the Cooperative Soil Survey in Missouri between 1986 and 2002 was internationally known for its quality, the collaboration it encouraged among state and federal agencies and innovations it brought to the discipline. The statewide online digital soil survey was developed at MU. This leading technology was the first of its kind and served as the template for the NRCS "web soil survey" and several new techniques and standards were developed for soil survey quality assurance. All of those Missouri-developed techniques became national standards for NRCS (R. D. Hammer, personal communication, Jan 13, 2014).

SOIL HEALTH/QUALITY

In 2015, the phospholipid fatty acid (PLFA) method for characterizing microbial communities, implemented through Missouri's

Soil Health Assessment Center is the second public service lab of its kind in a Land Grant institution (https://cafnr.missouri.edu/soil-health). It is expected that this methodology will help in better understanding the impact that production management practices have on soil health overall and result in improved education on best management practices that will ultimately improve food securities.

For hundreds of years, many societies failed to consider soil as the foundation of a temporally and spatially complex system that included benefits of water storage and filtering, nutrient cycling, detritus decomposition, and energy flow as essential functions of the environmentally sound sustainable web of life. Ignoring the essential roles of millions of species of soil organisms (fungus, algae, bacteria, nematodes, earthworms, etc.) was another critical oversight in understanding soil as a living breathing organism (Loynachan, 2012). Soil quality is a term that has been utilized historically in an attempt to quantify this living organism. By 1949, Leopold introduced the value of land to embrace evolutionary biotic forces. He includes ethical and aesthetically right management with the collective economic understanding of land. Warkentin and Fletcher (1977) started developing the concept of soil quality as a result of needing to further differentiate various soil capability classifications or function of soil for land use (e.g. food and fiber, assimilation of wastes, recycling and recreation etc.). Soil Health can be broadly defined as the capacity of a soil to function collectively with environmental and agricultural sustainability (Doran and Parkin, 1994; Doran et al. 1994; Karlen et al. 2003, (Figure 1). This is a concept that includes spatial variability among soil series and within the same soil series. Predicting soil performance requires a better understanding of the relationship between various soil properties and the potential for improved management. The term soil quality and soil health are often use synonymously (Karlen et al., 2004). In 2016, Kremer distinguished the term soil health as relating to eco-agriculture and its potential use in developing management decisions.

Physical properties and chemical nutrients have been extensively studied with little consideration of the biological component until most recently. Soil health research and understanding has been enhanced over the last several decades through scientific interest and newer methodologies to quantify soil health. Work continues to develop a comprehensive understanding of soil health.

Figure 1.1. Comprehensive considerations for sustainability (Karlen et al. 2003).

Several issues have contributed to the reduction of soil health over the decades. After several wooden versions, by 1837 John Deere had developed and marketed the world's first steel plow. In just 100 years, American agriculture was fully engaged in the management practice of moldboard plowing of native prairies with this innovation. By the 1930s, America was in the heart of the "Dirty Thirties" or the "Dust Bowl" era which allowed for some of the most significant changes to the farmer's concepts and direction of production agriculture in the Midwest. The dust bowl tragedy was the catalyst that resulted in the 1935 Congressional Soil Conservation Act and the subsequent establishment of the Soil Conservation Service of the United States Department of Agriculture which ensured the implementation and diffusion of numerous soil conservation practices. The 1938 Yearbook of Agriculture - Soils and Men (USDA, 1938) addressed the nature and extent of soil health primarily from a chemical and physical perspective. With this edition, the series changed where each volume focused on a single topic of interest to the public. The scientific communities were beginning to address the underlying concerns of food and fiber globally. For farmers in the United States, this era, or sometimes perceived "error", initiated significant changes in production management practices and much of which were adopted and diffused as standard practice in a relatively short period of time. The resulting soil degradation that grew out of this management shift spurred interest in understanding and identifying soil health. For example, manure was shown to be of value in the improvement of soil chemical, physical, and biological characteristics and to subsequently supply nutrients needed for production (Salter and Schollenberger, 1938).

Prior to World War II, many of the less developed countries were net exporters of agricultural commodities but the change reversed rapidly after the war as U.S. munitions factories were converted into fertilizer factories (Brown, 2008). A rapid influx of commercial fertilizers coupled with improved mechanical power allowed for enhanced tillage methods for use with emerging chemical weed control to improve productivity. Concurrently, increases in population growth occurred as a result of high birth rates enhanced by the improved science and efficacy of disease controlling drugs, antibiotics and insecticide control of vectors of infection (Notestein, 1965). Thus, the race for higher yields to provide economic advantage became the desire of the agricultural community. The introduction of chemical fertilizers and the subsequent replacement of draft animals by mechanization followed by synthetic pesticides allowed producers to reevaluate management strategies. Eventually, crop diversity was replaced by monocultures or short term crop rotations for improved economic gain with considerable neglect to soil biological impact.

While these chemical and mechanically driven innovations were the next big diffusion in production agriculture, the resulting effect did lead to dramatic increases in crop production and economic successes. Little scientific consideration was given to the soils lessons learned just two decades earlier and the negative effects of the resulting lack of diversity from continuous tillage, including degradation of soil characteristics, losses of soil organic matter (Tiessen et al., 1982), and reincarnation of increased soil erosion. By the late 50's, the scientific community had a better understanding of soils as a living entity and a more thorough description of soil biological activities (USDA, 1957).

A NEW BEGINNING

In spite of the newest understandings from the scientific community, the diffusion of soil health in production agriculture has been left in the wake of the showier advances in technologies. In the past six decades, farms have increased in size and become specialized.

Small farms with diverse combinations of crop rotations, manure applications, green manure, and management of multiple animal species have been replaced by modern practices. Recent management practices include massive modern equipment to plant extensive monocultures or two crop monocultures maintained by chemical applications. The impact of this change in the United States resulted in approximately 25% reduction to grazing lands from 1945 to 2002 and an additional 6% from 2002-2012 (USDA-NASS, 204, 2014). The most recent change was likely due to a period of increased grain prices where many marginal grounds, better suited for perennial grass species, were cultivated for additional row crop production. Simultaneously, a 15% loss of grassland occurred with the timing of government contract renewal of Conservation Reserve Program, Wetland Reserve Program, and the Conservation Reserve Enhancement Program (Russell and Bisinger, 2015). Reduced biodiversity and disrupted ecological balance have impaired water quality, increased crop production expenses and destroyed wildlife habitat on local and global scales.

Today, the United Nations Department of Economic and Social Affairs estimates a nine billion world population by 2050 which is up from three billion in 1960 (United Nations, 2015). This dramatic increase in world population will require producers to improve food production capacities. Current estimates indicate that production levels will need to increase by 50 to 70% in order to meet this need (Ingram et al. 2010). While there have been efforts towards soil conservation in the past, recent environmental and ecological awareness has resulted in consideration of "healthy" soil as a key component of environmentally sound, sustainable ecological processes to produce adequate quantities of quality food to support a growing population.

These global realities coupled with environmental awareness have resulted, most recently, in long-term ecological considerations of soil beyond the concept of soils simply as a medium for root biological growth. It is now necessary for producers to assess and improve a soil's health, or the capacity of a soil to function within ecosystem boundaries in order to sustain biological productivity, maintain environmental health, and promote plant and animal health through the generations while meeting this growing population demand. The US continues to be a world leader in food production contributing to the reduction of world hunger. However, the increased demand will burden production agriculture in the balance of economically providing enough high quality and affordable food while preserving the natural resource on which they survive as stewards of the land. Production of animal and grain in sufficient quantities to provide food security will require adoption of ecologically based systems which influence the soil throughout the nation and improve output overall.

In order to meet the expected growing world population demand for consistent and accessible food production, producers are forced to reevaluate traditional management systems in order to maintain profitability coupled with ecological and social sustainability. After decades of overlooking the important role that soil microbiology contributes in this process, there has been recent increased focus on soil health and its effect on sustainability. Soil Health was identified as an agency "national initiative" by the U.S. Department of Agriculture (USDA) in November, 2012. USDA-Natural Resource Conservation Service (NRCS) is focusing funding efforts toward soil health management yet producers have been slow adopters due to the lack of research demonstrating the short term and long term implications of land use management and the economic viability of change. Whatever the short-term excuses for soil degradation or lack of soil health considerations, detrimental effects on land productivity and overall food securities are assuredly to occur. Fortunately, a few progressive farmers, many of whom are not in the "show-me" state of Missouri, have used cover cropping and conservation tillage management systems. These producers advertise soil attributes of increasing commodity crop yields and reducing the need for pesticides and fertilizers. The slow adoption and diffusion of soil health management in Missouri provides key opportunities for Extension educators to provide research based information. An integral component of soil health adoption by producers could include a better understanding of the biological functions within a soil. Current soil health assessment research is developing a comprehensive understanding of the impact of various management practices on the diverse soil microbial communities.

David White was one of the pioneers of utilizing the phospholipid fatty acid (PLFA) assay to characterize the structure and activities of microbial communities in natural environments (White, 1983). Phospholipids occur in many different lifeforms and the fatty acid chains are unique to each. The development of this new method to measure viable microbial biomass containing cellular PLFA markers which are characterized by functional groups (Zelles, 1999). Kremer (2014) discussed the benefits of understanding the microbial diversity and compared functional capabilities of soils in prairie and agriculture ecosystems. He further described the soil health concept as a balanced process of the given chemical, physical, and biological activities within a natural setting. Soil health parameters in agricultural lands could be compared to adjacent undisturbed areas such as native prairies or even boundaries such as fence rows. Thus began the PLFA analysis as a means of identifying microbial biomarkers and describing the specific community arrangement of biological activities and effects within a given ecosystem (Kremer and Veum, 2015).

Describing the soil microbial community from PLFA analysis includes saprophytic fungi, mycorrhizae fungi, Gram negative (G-) and positive (G+) bacteria, actinobacteria, anaerobic bacteria and protists. Each of these members of the microbiota community plays a different role for a given ecosystem. The level of each of these groups were lower in cultivated fields when compared to prairie soils (Veum et al., 2014).

The saprophytic fungi are responsible for decomposition of lignin, cellulose, and pectin from organic matter residue accumulation from roots and plant material. Fungi can feed on both living and dead plant material by absorption through the hyphal filaments. Thus the plant community plays a critical role in determining fungi composition (Taylor and Sinsabaugh, 2015). Mycorrhizae metabolize plant host carbohydrates by associating symbiotically with root systems and mobilize nutrients from organic matter for translocation through hyphal filaments into the living roots for plant uptake. Early conservative estimates indicate that there are between 660,000 to 1.5 million fungi that are known to colonise, multiply and survive in diverse habitats (Hawksworth, 1991). Mora et al. (2011) indicated that these estimates are incomplete when considering the total number of species on Earth.

Bacteria that colonize on root surfaces are beneficial for synthesizing plant growth regulators for cell growth and root development and produce substances to help ward off pathogenic microorganisms. The G- bacterial community are essential for all nitrogen transformations and are crucial to any nitrogen fixing associations with roots. While the bacteria group is known for assisting with decomposition of cellulose, more recent interest involves their utilization in the bioremediation of contaminated environments. (Crawford and Crawford, 1996). The actinobacteria are filamentous bacteria critical in the process of breaking down insect exoskeletons and cell walls. They are known as agents for both diseases and antibiotic production. The protozoa group are crucial to maintenance of the microbial community balance, release of available N, P, and S, and thrive in well-drained soils or also exist in anoxic conditions. Several animal and human diseases such as malaria and gastrointestinal infections can be traced to protozoan communities.

The diversity of this microbiological community can be disrupted dramatically within a given agriculture ecosystem (Buyanovsky and Wagner, 1998). One indicator of soil health is soil organic matter which is typically measured as soil organic carbon (SOC). Tillage increases SOC losses due to oxidation or mineralization, leaching and translocation, and the possibility of accelerated erosion (Lal, 2002). The increasing rate of microbial breakdown of SOC provides energy for the microorganisms which in turn release nutrients through mineralization for utilization by plant growth (Doran, 1987). Increases in SOC are closely associated with the activity and diversity of the microbial community which affects soil health over all (Kremer, 2014). Significant levels of soil respiration releases carbon dioxide back to the atmosphere. Thus, dramatic changes to this pool of SOC can result in corresponding changes to global carbon dioxide levels (Wolf and Wagner, 2005). Therefore, mineralized SOC for plant growth reduces additional energy for the community of microbial activity and presumed overall soil health. It is well known that no-till management practices often increase SOC. Blanco-Canqui, et al., (2015) indicated SOC could increase dramatically, as much as 20%, with the addition of cover crops and other technologies which can improve accumulation at deeper depths than no-till alone. A long term study from Sanborn Field demonstrated that manure application coupled with residue retention could increase the overall SOC 50% above conventional tillage (Buyanovsky and Wagner, 1998).

Studies by Veum et.al (2014, 2015) (Figure 2), indicated that soil health improves with perennial vegetation including grasses and legumes; a reduced tillage/soil disturbance; incorporation of livestock grazing and manure into the system; increased rotation diversity including cash crops and forages; and cover crops for increased soil cover and diversity of the microbial population. Utilizing all of these options for improving soil health may not be practical in every management scenario. However, implementing some of these considerations in an integrated and diversified systems-management approach will likely improve soil health and benefit production agricultural overall.

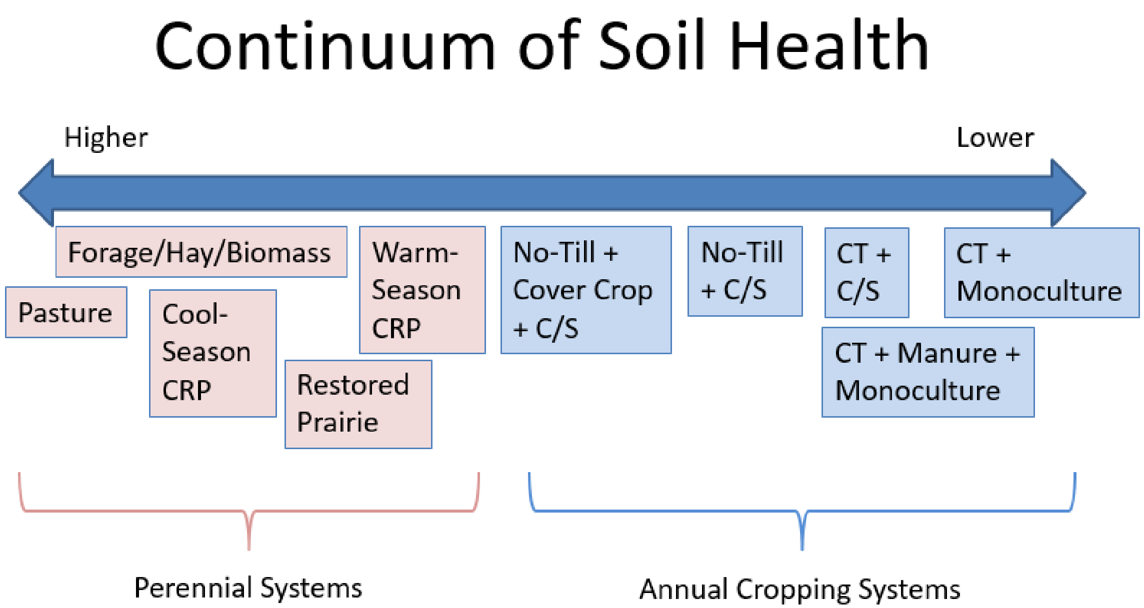

Figure 1.2. Continuum of soil health in various systems (Veum et al. 2014). {Conservation Reserve Program (CRP), Corn (C), Soybean (S), Continuous Tillage (CT)}

After a cover crop cost-share initiative was established through the local Soil and Water Conservation District, a noticeable improved diffusion of this practice occurred. It is difficult to provide an accurate acreage estimate of cover crops now in production. Some producers misinterpreted soil health only as the implementation of cover crop practices and not more precisely as cover crops being just one of many tools in soil health management. The direct and indirect benefits of cover crops to soil health include improving the water cycle, integrated pest management, helping to build soil organic matter, nutrient cycling, enhancing pollinators, adjusting carbon to nitrogen ratios, wildlife winter food and shelter, lasting residue, weed suppression, breaking compaction and the potential integration of livestock grazing.

To further understand cover crop perceptions, a producer survey, conducted by a team of Extension agronomists from the 12 north central region Land Grant Universities (Figure 1.3), indicated that soil health was the overwhelming number one reason to consider this new management tool followed by soil erosion control and nutrient management. The results suggest that producers are starting to consider soil health management as a viable production tool (Kammler et.al., 2016).

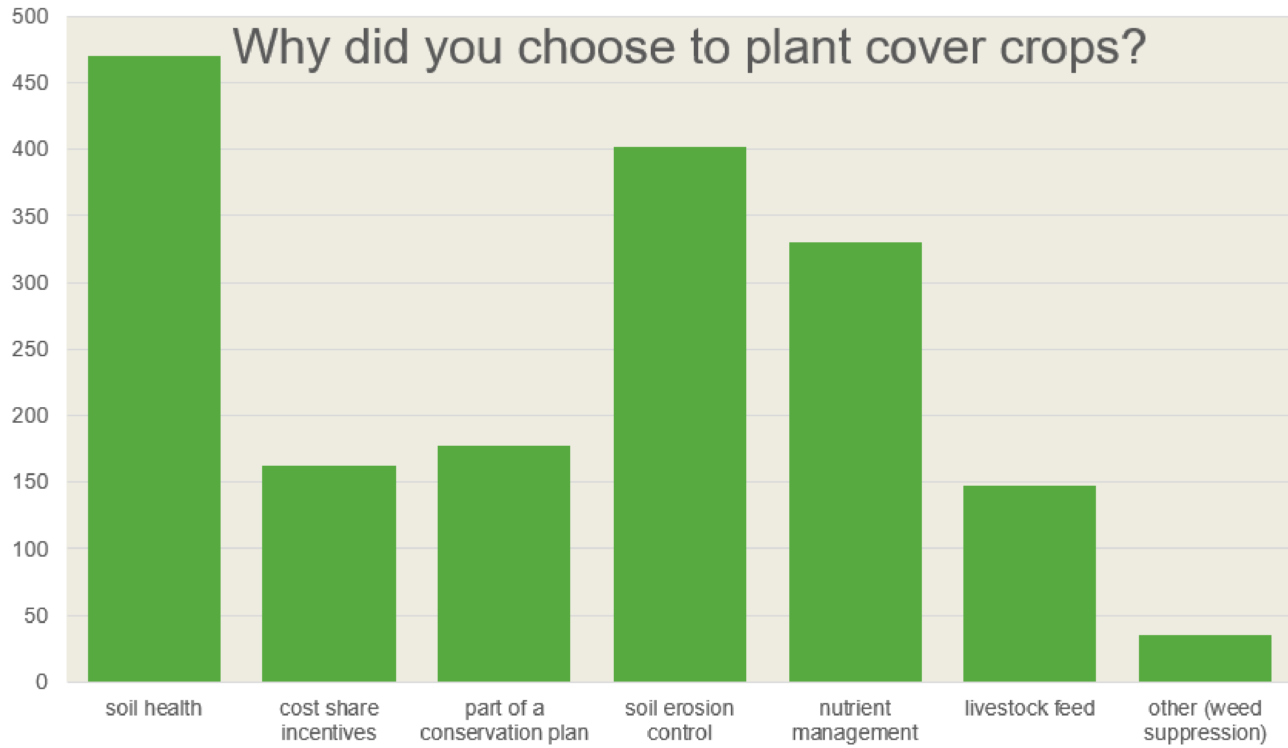

Figure 1.3: NC-ANR Academy Cover Crop Production Survey (Kammler, et al. 2016)

Other components of the survey were resoundingly similar in the understanding of soil health from a physical standpoint. The main challenges or adoption of this innovation from producers in the north central region were time of planting, costs of additional seeds, increased management costs, expenses, and rotational consideration. When asked what additional information they would like to have available to make management decisions, the top two responses were economics and research.

Farmers and managers are bombarded by often conflicting or confusing "testimonial" and anecdotal information at workshops, seminars, in popular press, and in local coffee shops. Much of the information presented bears what Stone (1975) ruefully called ". . . the burden of supposition imposed by lack of rigor." It is expected that following the new Soil Health initiative will result in increased rigorous research that will guide producers in best management practices to improve food security while increasing environmentally sustainable agriculture production. While new cropping systems show promise, the supporting scientific research based evidence is currently lacking.

In contrast to the Dust Bowl era adoption of the plow, the rush to adoption of Soil Health practices seems to be limited to a group of early adopters at this time. The role of a Regional Extension Agronomy Specialist is to help educate the farming community about the comprehensive benefits of managing our living, breathing soils.

In order to meet the expected growing world population demand for consistent and accessible food production, producers are reevaluating traditional management systems to maintain profitability as well as ecological and social sustainability. Ecosystems that maximize soil organic matter and good soil structure are known to maintain high soil biological function, soil health, and plant growth. Soil microbial diversity may be the most valuable biological component of any ecosystem. Natural ecosystems, such as prairies, are known to exhibit high microbial diversity, providing a greater range of pathways for primary production and ecological processes (e.g., nutrient cycling). These natural ecosystems also serve as valuable references for developing sustainable crop and soil management practices. In addition, reconstruction of native prairie ecosystems is often targeted on sites that have been subjected to long-term intensive cultivation with degraded soil conditions. Soil health assessment tools provide a basis for monitoring changes in soil health during establishment of perennial ecosystems in degraded landscapes, and aid in developing environmentally sustainable management systems. Therefore, assessment of soil health in prairie ecosystems can serve as a guide to restoration of soil biological function, plant productivity, and environmental quality in row crop and animal production systems.

The impact of animals in our global food securities cannot be understated. In Missouri, livestock production alone accounts for over 67,000 jobs (Milhollin, et al. 2016). Consumption of animal-sourced food provides dietary adequacy, prevents under nutrition and nutritional deficiencies while providing improvement in growth, cognitive function, and improved immune systems (Keusch and Farthing, 1986; Neumann et al., 2002. The other indirect effect of livestock on food security comes by cash income from animal sales which provide income for the purchase of other staple foods.

On a global scale, milk, meat, and eggs currently provide 13% of the energy and 28% of the protein consumed whereas, in developing countries, the numbers rise to 20 and 48% respectively (FAO, 2009). Livestock producers and landowners read about basic forage plants, soil fertility, soil health and animal management techniques that can improve pasture eco-systems, carrying capacity, and ultimately farm profitability. However, many are not responsive to combining soil health practices with forage management techniques which highlights areas of needed applied research and education. Many producers have not had access to research plots that demonstrate the short-term and long-term plant responses to management changes when adopting soil health practices.

Soil fertility, soil health, and forages are very integral to ruminant livestock operations. Without sufficient soil fertility, forages cannot grow to their full capability which greatly diminishes pasture stocking rates and animal productivity. When producers increase forage quality and quantity, then stocking rates and health potential can be increased which improves the economic viability of their operation.

The use of livestock manures in cropping systems has many advantages. Animal manures can reduce the cost of fertilizer inputs. Manure can help build or maintain soil fertility, increase water holding capacity, improve soil tilth and provide energy for the microbiome. In addition to the major plant nutrients of nitrogen, phosphorus, and potassium, manure also contains calcium, sulfur, magnesium and many micronutrients such as iron, zinc, boron, copper and manganese. However, application of manure in excess of needs can reduce the following crop yield, create surface and groundwater pollution and reduce the economic returns that are desired. A study by Randall (2003) listed the benefits of livestock being integrated into cropping systems: (i) crops produced on site can be utilized as feed stuff reducing import needs; (ii) livestock manure can be utilized as a crop nutrient source thus cycling nutrients within the system; (iii) livestock can be the sink for agricultural by-products; and (iv) due to consumption needs, livestock encourages grass and legume forage production systems. Sulc and Tracy (2007) indicated that an efficiently managed integrated crop-livestock system could improve soil function, profitability, and natural resources.

Land application of manure should follow proper rates based upon laboratory analysis and suitable soil conditions to eliminate or reduce erosion and runoff possibilities. The longer that manure is on the soil prior to crop uptake, the more possibilities exist for nutrient losses through mineralization, volatilization, denitrification, leaching, and erosion. Uniform application or spread should also consider application timing, for the most efficient plant uptake of nutrients, thereby reducing any negative environmental impact. Kleinman et al. (2011) discussed prudent tempering of agronomic practices for sustainable management of phosphorus (P). He went further to discuss the, often over looked, vertical movement of P through the profile and potential impact to ground water sources. USDA Natural Resources Conservation Service agronomy standards and US Environmental Protection Agency have updated manure application rules (USEPA, 2003). Manure is to be applied based upon the crop removal rate of phosphorous (P). No manure may be applied on fields when P and nitrogen (N) soil assessments are rated very high based on routine soil tests.

Fall manure applications are often necessary. This management practice allows for increased storage capacity for manure accumulations during the cold wet winter months. The least desirable application is during the winter when the soil is frozen and nutrients are not able to infiltrate and bind with the soil. Manure lying on the surface of frozen ground is more apt to be lost from the system. Surface application of fertilizers and manures can increase the amount of nutrients in any surface water runoff. Excess P reaching streams are known for their negative stimulation of eutrophication. This negative effect include reduced water clarity, excessive algal growth, low oxygen content, altered fisheries, increased filtration costs and different water tastes (Lory et al., 2004).

While recent warmer winters have stretched the application window, producers should consider potential negative environmental impacts of winter applications. It is always recommended that a manure sample be submitted for analysis prior to application so that the producer is applying adequate quantities for crop needs but not in excess for environmental interferences. This should be matched with an appropriate soil testing program. Both soil and manure testing is available through the MU Soil Testing and Plant Diagnostic Service.

While large scale, confined livestock feeding systems allow for the collection of animal waste to be applied to crop, hay, and pasture land to replace or supplement inorganic fertilizer, the implications of manure application on PLFA soil health parameters have not been studied in central Missouri. A four state study from Karlen et al. (2014) included samples from northeast Missouri Mark Twain reservoir watershed and included samples from soils receiving manure application. In this soil quality study, utilizing the Soil Management Assessment Framework (SMAF), a decrease in soil microbial activity (as β-glucosidase activity) occurred under manure application. However, only three of eleven indicators measured showed a difference due to manure.

There is currently a gap in the research knowledge base determining basic scientific implications of soil health data from the impact of field applications of livestock manure. Additionally, data is lacking on the impact of cover crops being utilized in a grazing system where livestock will simultaneously add manures back to the field. Current soil fertility and forage research combined with soil health indicators will provide a better understanding of the implications of livestock components and assist in the development of best management practices.

The objectives of the studies in this dissertation are to 1) determine background information on the current perceptions of the farming community and to determine the driving factors of change in agriculture management diffusion on this new subject of soil health; 2) compare soil health sampling and handling procedures for superior soil health data; 3) assess the variability of microbial communities in reference Missouri prairie soils; 4) assess the variability of microbial communities in select Missouri soil classes; and 5) quantify the impact of livestock on soil health indicators in a permanent pasture system and a conventional row crop system.

An accumulation of personal Extension Specialist communications and production observations will provide background for this research.   A pilot study with qualitative interviews with early adopters of agricultural innovation was utilized to justify the approach.

Due to inherent biological sensitivities, potential human errors in soil health sample handling can impede scientific understanding. The validity of precise sampling and handling processes is important in any research experiment. Three experiments will address soil health sample collection and storage procedures, sample size and depth, and potential impacts of fecal depositions.

Microbial community variability can also exist in various soil types and past management systems. The remaining experiments will quantify some this management variability in soil types throughout Missouri and in both livestock and production agriculture.

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CHAPTER TWO

SOIL HEALTH DIFFUSION OF INNOVATION: A CENTRAL MISSOURI TRIAL STUDY

Abstract

This trial study examines barriers to the diffusion and adoption of an agricultural concept surrounding soil health as an improved management tool which has most recently been introduced into production agriculture. For this study, a small sample set of perceived early adopters of soil health management practices were interviewed for their perspective on the subject of diffusion of innovation in soil health. Rogers' (1995) diffusion of innovation serves as the theoretical underpinning for this study. Where "an idea, practice or object that is perceived as new by an individual or other unit of adoption". H. F. Lionberger from the Department of Rural Sociology at University of Missouri was one of the contributing authors and had previous publications (Lionberger, 1957, 1960; Lionberger and Gwin, 1991). While diffusion of innovation has provided an overview of how information is diffused and adopted for Extension professionals, academia, and students, its use in discerning the adoption of soil health management practices has not been examined previously. There were both differences and similarities in what experiences, attitudes, and beliefs shaped the early adoption of Soil Health practices and how each interviewee perceived the most limiting factor

of adoption from other producers. Similarities included 1) family farm lived in diffusion of innovations. 2) economic concerns and 3) education is key while differences included perception of older folks as slow adopters. Even though the number sampled was small, N=2 for this study, the differences between the young and older age groups were characterized as "Blinding Energy" and "Earned Wisdom" respectively.

Introduction

This qualitative research approach is through a broad lens of several interpretive frameworks which make an inquiry of this agricultural community most challenging. In the postpositive lens where all cause and effect is a probability, Creswell (2013) indicates that the inquiry belief is in multiple perspectives from participants. In this case, progressive leaders in production agriculture were utilized for the interview. A broad lens of social constructivism includes participant's views from a social and historical perspective which include cultural norms in postpositivsm which is the idea that empiricist observations of the natural sciences can be applied to the social sciences. Empiricism emphasizes evidence based experiments which is a fundamental part of scientific methods tested against the natural world.

There has been a historical and somewhat unfair stereotype, where the producers have been characterized by, "that is the way that Dad did it and that is the way that I will do it". While there are farmers that still personify that historical methodology, a producer who operated by that philosophy is likely less successful in today's current agriculture business production models.

Personal interviews will peer through a pragmatic lens to determine what worked for the selected perceived innovative and early adopting producers and how they arrived at the solutions to a problem. The role of an Extension Educator provides a close proximity to producer customs due to the nature of the job and as Creswell (2013) indicated this may provide "dangerous knowledge" where there is potential for political and risky insider biased approaches. The basic Extension professional philosophy and directives are to provide non-biased research based perspective with courteous tolerance towards the views of others.

This trial study is grounded in diffusion of innovation theories which is the process by which an innovation, in this case, Soil Health practices, is communicated through certain channels over time and the potential adoption of this practice through a social system.

Diffusion theories and the study of adoption originated in agriculture with the introduction of hybrid seed corn in Iowa in 1928. (Ryan & Gross, 1943). In that study, it took nearly 12 years before most Iowa corn growers adopted the practice. Early work in agriculture involved the study of farmers independently and didn't take into account the socioeconomics. Often, production agriculture perceives success through short-term cash flows dependent upon the stability of current markets and average weather patterns. When soil health practices are part of the yearly management operation, considerations should include the comprehensive benefits of reduced input and improved water infiltrations for generational advantages. The understanding of soil health can be a modern consideration or solution to improved production capacities for feeding a growing world population. Further research and Extension education could enhance the diffusion process and adoption much more quickly than previous examples.

The first North Central Regional Extension Publication (1955) attempted to characterize that lag in adoption process by four stages of adoption through situational group influences and characteristics of farm people. As a side note, H. F. Lionberger from the Department of Rural Sociology at University of Missouri was one of the contributing authors. By 1961, a second North Central Extension Publication had emerged to better qualify the distribution of adopter categories into five categories of innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%) and late adopters or laggards (16%), (Figure 2.1). By 1995, Rogers gave five attributes that affect the rate of adoption as well: 1) relative advantage- of innovation being better, 2) compatibility- consistent with values, past experience and needs, 3) complexity- the degree to which the innovation is understood, 4) trialability- the degree an innovation can be experimented with on a short term basis, and 5) observability- results of innovation are observable to others. (Rogers,1958). Rogers' Diffusion of Innovation serves as the theoretical underpinning for this initial study.

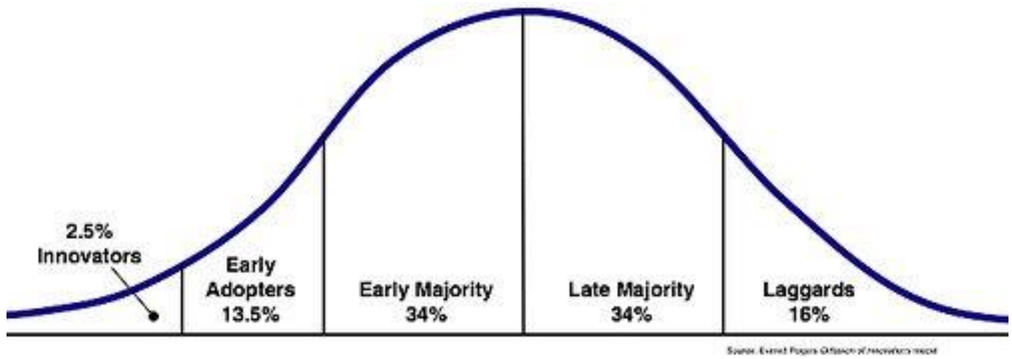

Figure 2.1: Classic adoption curve illustrating the scheme of innovation adoption (Rogers, 1958).

By 1992, Nowak attempted to oversimplify descriptors into two categories of being unable to adopt, unwilling to adopt or both. In this example, he is clearly biased towards an unconditional need for adoption of his described management technique. Later he acknowledged that adopting changes in management practices can also be rooted in economy of scales where a higher proportion of time commitment is spent in expanding acreage production (Nowak et al. 1996).

With the passing of the 1914 Smith-Lever act, the Land Grant College has assigned Extension educators with taking unbiased research based information to citizens to improve their lives at the local level. It is well known in this delivery model that adults have the ultimate determination in what action they take as a result of that education (Battel and Krueger, 2005).

Stephenson (2003) indicated that the innovation diffusion theory is the foundation of Extension agriculture outreach methods in the United States but had flaws when applied to international developments. Criticisms to the diffusion of innovations as compiled by Rogers (1995) included 1) Innovation bias in that the innovation should be diffused 2) Individual farmer blamed for not adopting the innovation 3) Socioeconomic gaps that do not look at the negative impacts of the innovation change 4) Potential biases in favor of larger wealthier farmers where agencies provide assistance to the most innovative, wealthy, educated and information seeking clients.

Hightower (1972) was quick to blame the land grant institution for mechanical innovations in the horticulture industry that led jobs to retreat from rural America to Mexico. He further explained that the vertical integration model forced independent farmers to "adapt or die" as machines exist to replace farm labor.

Harder (2012) indicated that a needs assessment of factors affecting the diffusion of innovation was needed prior to program development. She further indicated that doing the assessment will assist in a solution for the identified need and not promote it for the sake of the innovation itself.

After a cover crop cost share initiative was established through local Soil and Water Conservation District, producers sometimes misinterpreted soil health only as the implementation of cover crop practices and not more precisely as cover crops being just one of many tools in soil health management. The direct and indirect benefits of cover crops to soil health include improving the water cycle, integrated pest management, helping to build soil organic matter, nutrient cycling, enhancing pollinators, adjusting carbon to nitrogen ratios, wildlife winter food and shelter, lasting residue, weed suppression, breaking compaction and the potential integration of livestock grazing.

To further understand cover crop perceptions, a producer survey was conducted by a team of Extension agronomists from the 12 North Central Region Land Grant Universities (Figure 2.2). The results indicated that soil health was the overwhelming number one reason to consider this new management tool followed by soil erosion control and nutrient management indicating that producers are starting to consider soil health management as a viable production tool (Kammler et.al., 2016). Other components of the survey were resoundingly similar in the understanding of soil health from a physical standpoint. The main challenges indicated from producers in the north central region were time of planting, costs of additional seeds, increased management costs, expenses, and rotational consideration. When asked what additional information they would like to have available to make management decisions, the top two responses were economics and research.

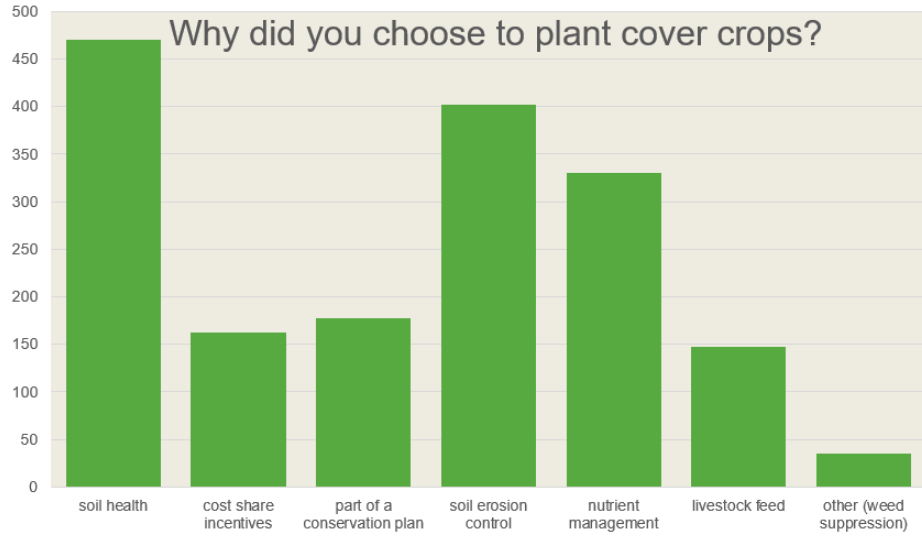

Figure 2.2: NC-ANR Academy Cover Crop Production Survey (Kammler et al., 2016).

Purpose/Central question

Creswell (2013) indicated that inquiry focus could either be (p. 150) first order where the individual is speaking about them or second order where the research focuses on a collective story that represents the lives of many. The sample participants represent a single agriculture-sharing group of progressive farmers. The purpose of this research is to qualify the current diffusion of innovation practice of including Soil Health as a key management practice in order to provide more food security. My central question is, "What experiences, attitudes, beliefs have shaped your early adoption of Soil Health practices and how do you perceive the most limiting factor of adoption from other producers?" As this was a trial study, two producers were selected from both ends of the prospective age group which might possibly highlight generational variations in perspective. The study sought to understand (a) what conditions caused the farmer to adopt soil health practices, (b) what were the greatest challenges to the new practice, (c) what were some of the perceived challenges to those not adopting soil health practices, and (d) how early adopters perceived late adopters. Supporting questions during the course of the interview included the following:

-Tell me about your farming operation from a historical perspective…when it was established, basic farming philosophy, when you started and where you are now?

-What do you perceive as some of the innovations that have happened in production agriculture in your lifetime that would demonstrate differing adoption or acceptance of that innovation?

-What experiences, attitudes, beliefs have shaped your early adoption of Soil Health practices and how do you perceive the most limiting factor of adoption from other producers?

-How do you define Soil Health?

-Biological/Physical/Chemical

-Soil as a living breathing entity/biodiversity

-Above ground below ground

-What is your overall goal/approach to Soil Health in your operation?

-What are the benefits of a healthy soil and why does it matter to you or others?

-How do you define Soil Health in your crop management “toolbox”

-What is your perception of the current state of Soil Health adoption?

-How are you determining the cost/benefit ratio to adoption?

-How long ago do you believe that you started Soil Health practices?

-What are the greatest challenges in Soil Health?

-What is the greatest challenge to adoption by other producers?

-What separates early adopters from later adopters?

-How do you describe sustainability?

-Current estimates indicate that we will need to be feeding 9 billion people by 2050 and if so, our current production levels will need to increase by 70%. How do you perceive that occurring?

-As we move into Soil Health management practices, cover crop (CC) sometimes is intermixed with the term soil health while others define cover crops as a management tool to help improve soil health. How do you define CC?

Do you have CC in your operation?

Why did you choose to plant CC?

What were the criteria you used to select which CC to plant?

Seeding date; cost of seed, equipment, timing of cash crop, growth habit, lasting residue, source of N, soil builder, loosen sub/top soil, erosion control, grazing, nitrogen scavenger, water quality.

Are the current crop insurance regulations a concern?

What are the most important benefits of CC for your farm?

What challenges have you had in planting CCs?

What is the greatest challenge to adoption by other producers?

Research Method and Procedures

While the grounded theory approach (Strauss & Corbin, 1998) involving construction of theory through analysis of data might be appropriate in an extensive research proposal, this will represent a pilot study. A case study approach was utilized where personal interviews were conducted with those producers perceived as early adopters. Each interview was recorded and transcribed and then coded separately line by line. Based upon the limitations of this pilot project, two categories were broken out by the nature of the topic as either perceived early adopter or late adopter. They were asked by recollection about their time of adoption, the decision making process, educational process and perceptions of others within their industry.

A chronological approach provided pragmatic narrative descriptions of letting people tell their ontological beliefs in the story of what is useful, practical, and works for them. The epistemological beliefs were expressed both objectively and subjectively in the interview process of personal beliefs and personal education.

My position with University of Missouri Extension includes extensive exposure to soil health concepts and practices from field days, individual consultations, group educational settings, workshops, conferences, consortiums, and multimedia resources such as publications in professional journal, Extension, industry, and federal agency. Creswell (2013) states, "How we write is a reflection of our own interpretation based on the cultural, social, gender class and personal politics that we bring to research and all writing is positioned within that stand." The biases in my writing come from an Extension educator perspective who delivers university research based information to the public. In contrast to a quantitative study where everything is written, stated, or presented in absolutes indiscriminately, this approach will be qualitative in nature.

Perceptions of soil health will vary tremendously depending on the observers' lens, organizational objectives, or cultural background. Typically, producers are looking at soil health through a filter of return on their investment. Retailers' normal approach relates strictly to a sales opportunity. Agency folks can have directives from above and, in some cases, with little scientific guidance. Federal directives typically do not provide clear objectives but more of an overview and each state/regions define how they interpret the directive. That leaves the land grant universities with the process of research, demonstration, dissemination, and education of the scientifically sound methods and approaches to help farmer in understanding best management practices and ultimately options for management change.

Numerous invited presentations from "leading authorities" have provided ample opportunities for speakers to scientifically contradict themselves throughout the course of the presentation. What causes the greatest issue for an Extension educator is when the farmer follows a "leading authority recipe" and does not have success. This lack of success is often attributed to inflated producer expectations after the grossly overstated rapid outcomes coupled with a lack of basic scientific truths. Other issues occur from the combination of effect, both positive and negative, that are a result of introducing a new management practice. For whatever reason, farmers can be turned off from the experience and likely to completely abandon the innovation practice. This leaves Land Grant Institutions with additional and sometimes challenging research and educational opportunities to correct misinformation.

The new direction facing our bread basket nation is improved food production capacities for feeding the future estimated 9 billion people. This improved production capacity can be aided with a healthy soil. If current estimates of 70% increased global food production is necessary, then a more ecologically sound practice of soil health management will need further consideration. Soil health has been broadly defined as the capacity of a soil to function collectively with environmental and agricultural sustainability (Doran and Parken, 1994). The diffusion of innovation on the topic of soil health must occur faster than previous generations in the agricultural community.

There were 2 (n=2) perceived adopters of this diffusion of innovation practice in this trial study. The producers were purposefully selected with a biased age category for enhancing any generational differences and maximum variation (Creswell, 2013, pg. 158). A semi-structured interview guide was used for data collection. The first adopter was a 28-year-old farmer with a BS in Agriculture Business. The second was a 76-year-old farmer with a high school education who had been working on the farm "since he was old enough to do his share of chores". In both cases, the interview was initiated after a comfort period w.as established so that they both felt relaxed during the actual process. The interviews are listed in Appendix A. While this trial study was conducted with a limited population and with time constraints, it is perceived that the results are not much different than a larger more diverse population.

Findings and Limitations of the Study

While the average age of the Missouri farmer is 58 (USDA NASS, 2014), individuals from both ends of the proverbial bell curve were selected to make certain that generational perspectives were included. Given a few outliers, both generations are observing information similarly but the descriptors used are sometimes different.

Both subjects were inviting and receptive to the interview. The elder made the comment that "I never thought anyone ever thought of me as an innovative farmer". This was an obvious indication of his humble nature. While he had been farming much of his 76 years in some capacity, he later reinforced that humble style by saying in jest "I am just a 'spare time' farmer". This reference is to the fact that he had an off-farm career for many years. However, the majority of farmers have supplemental off farm jobs. While he never really thought of himself as an innovator, he was insightful, respectful, and humorous in his storytelling style which reinforced my opinion of him as an innovator. Near the end, his answers seemed to be at saturation level. However, the longer he talked, the more addicting the process of prospecting for golden nuggets became.

The 28 year old farmer, who also had an off-farm career, seemed to have a better understanding of the overall science behind soil health stated, "I have seen agriculture shift to technology pretty hard core…the increased amount of grid sampling and precision farming and I think that innovation is a stepping stone to a lot of things to come down the road". He went further to state, "In our production, in our operation, we understand that everything starts with the soil and we have to maintain a healthy soil in order to maintain our livelihood". He also concluded that, "a person is not going to farm for just 5 years so you might as well take care of what you have". This statement is directed at the connection between the farmer and the land.

This trial study was not only enlightening but could be expanded and tailored to variations that exist in the farm population by type, size of farm, financial scale and age differences. A deeper study could help in directing educational programs to a more specifically defined audience.

The codes were broken into categories and ultimately two themes stand out. The first was the farmers' perspectives on what makes an early adopter or a late adopter with perceived barriers and secondly, how education impacts that process. From the 28 year old perspective, "Slow adopters are not managing soil health, they are the ones that don't spend money on fertilizer…and they are not maximizing their opportunities economically". He went further to suggest that the older generation was dominant in the late adopter's category because, "they have done the same thing for the same way over the years". While the perceived early adopter 76 year old farmer indicated that, "I am just getting too old to start on this new idea". Later in the discussion, the younger farmer conceded that their operation has been adopting soil health practices, "I guess we have been adopting these practices the entire time we have been farming this land (45 years)" which was before he was born.

Much of the perspective of the younger farmer surrounded economic return on investment as he had a B.S. major in Agribusiness and is currently employed in this field. He indicated that early adopters, "Are risk takers that are willing to put money out front to try to see a return on investment", and that, "late adopters just float along". He believed that, "Getting them to believe in soil health and that they are going to see a return on their investment will require research", but also recognized that, "there hasn't been enough research done on cover crops either", which is one of the soil health management practice tools. His economic evaluation of soil health included "we are always investing in things, so why don't we invest our money in the soil….getting people to understand that you have to invest in order to get the payback". The different perspectives between who was considered early adopters and late adopters seem to develop during the interview with the younger farmer. When asked why people don't change more quickly, he indicated, "Lack of proof, lack of research, they need to see it on paper, or actually see it happen". The discussion led to the resemblance to our Show-Me state icon and he stated, "if they don't see it, they don't believe it". This gives validity to the Land Grant mission and should inspire Extension educators that there is a lot of work yet to do.

My elder subject did not even see himself as an innovator even though he had lived diffusion of innovation his entire life. When I asked him if he would consider an interview, he stated, "Todd, I never saw myself as an early adopter". His vast knowledge of historical references included various forms of machinery and technological advancements, and field management practices such as terraces, soil testing, fertilizers, limestone, and even practiced on-farm trial and error research. Even though he had lived through these innovations and his family was typically the area diffusion of innovation leader, he still was modest in his recollection and slow to characterize late adopters. He stated jokingly, "One of the best days in my life was when the team of mules ran off with the wagon and strung corn from the front of the places and then another mile down the road past our house and there was nothing left but the two front wheels of the wagon. It was then that Dad went and bought a corn picker, one of the first in the county". This might be considered forced diffusion of innovation through Missouri mule intervention.

He had lived through many diffusions of innovation, so much so that he recalled missing 37 days of high school his senior year helping his father custom combine other farms in the community with the first combine in the county that his family purchased. Even though he acknowledged that he had just a high school education, he referenced many ways in which he self-educated himself through communication, observations, magazines, educational conferences and Extension programming to stay up with what was going on in production agriculture. His thoughts on slow adopters included, "I think the greatest challenge is just educating producers so they better understand how important soil health is". He went on to indicate that education is the great equalizer in socioeconomics and that, "No soil health improvements would occur (in feeding the growing world population) until they educate themselves as to why we are doing it".

The elder farmer even received opposition as he was trying to adopt the innovative practice of no-till. He stated that one farmer told him, "if you no-till, you are going to have a mess when you go to combine". His response to that harassment was, "I never combined so slick in all my life, that was 45 years ago and I have no-tilled ever since". One of the outliers brought to light was a statement that he shared with me from another farmer, "I am never going to no-till because one thing that I like doing in life is riding my tractor". The elder farmer went further to state, "All I wanted my whole life is to get off that tractor as quick as possible". We briefly touched on cover crops as a management tool in soil health. The elder farmer indicated, "This is a really good practice but I am at the age that I don't have the energy to change all of my equipment around".

He indicated that slow adopters are, "Really reluctant to do it differently than their Dad did it". In his mind, the farmer/producer hadn't spent any time educating themselves on the benefits of doing things differently.

Conclusions

There were both differences and similarities in what experiences, attitudes, and beliefs shaped the early adoption of Soil Health practices and how each interviewee perceived the most limiting factor of adoption from other producers. The major difference between the two will be characterized by "Blinding Energy" for the younger farmer and "Earned Wisdom for" the seasoned farmer.

28 Year Old Farmer with B.S. in Agriculture: Blinding Energy

1) Family farm lived in diffusion of innovations
2) They (slow adopters) are doing it the same as their father did.
3) They are not maximizing opportunities economically
4) Research and education are limited in soil health
5) Perceived older folks are slow adopters
6) Realized his farming operation had been adopting since before he was born.

76 Year Old Farmer with a High School education: Earned Wisdom

1) Family farm lived in diffusion of innovations
2) Slow adopters are still doing things the way that Dad did
3) greatest challenge is just educating producers
4) education is the great equalizer in social economics
5) This is a really good practice but I am at the age that I don't have the energy to change all of my equipment around…again"

Acknowledgements

Due to the limited number of interviews, a large difference in age was selected in an attempt to recognize any generational anomalies. While some differences occurred, much of the generational responses were similar.

In King and Rollins (1995) reflection of adopters and non-adopters suggested that the change agent's attitude, participant's economic concerns, and technical information can influence the adoption of innovation which gives some insight to possible directions from an Extension organization. Hubbard and Sandmann (2007) indicated that barriers to diffusion of innovation could include barriers and motivations external to an educational program could include the individuals' personality, socio-demographic characteristics, networks and prior knowledge on the subject.

The last "golden" nugget which ended the kind, elderly, and extremely humble farmer when asked if there was anything else he would like to add stated, " I could say this, check your crops often, and talk to them. They talk to you don't they…". Priceless wisdom!

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CHAPTER THREE

SOIL HEALTH FIELD SAMPLING AND HANDLING PROCEDURES FOR IMPROVED PLFA DATA COLLECTION

Abstract

Phospholipid fatty acid (PLFA) analysis is an increasingly popular method for assessing microbial community structure in soils. However, the effects of prescribed burns on prairie soil microbial ecology, the impact of proper sample handling on PLFA biomarkers, and the animal impact is not fully understood. In March 2015, soil samples were collected from the top 2-inches at three landscape positions from Golden Prairie (Barton Co.) and Stark Prairie (Hickory Co.) in Missouri, USA. Samples were collected immediately prior to a prescribed burn and immediately following the burn and analyzed for a suite of soil health indicators, including PLFA. Additionally, the effects of sample processing and handling were evaluated by comparing the PLFA profiles from soil samples freeze-dried within 24 hours of collection, oven-dried at 221 °F, air-dried for 7 and 14 days at 68 °F, and stored field-moist at room-temperature for 7 and 14 days at 68 °F. Significant differences ($p<0.05$) found between the PLFA profiles from the two prairies, were likely due to differences in soil type, vegetation, and restoration. No significant differences in PLFA profiles were

detected between the pre- and post-burn samples for any of the PLFA microbial groups. Air-dry storage and field-moist storage at room temperature resulted in an 11 – 14% reduction in total PLFA. Biomarkers of arbuscular mycorrhizae fungi (AMF) and saprophytic fungi were impacted the greatest by storage, showing a 13-53% decline due to air-dry or field-moist storage, resulting in a significant shift in the bacteria/fungi ratio. Oven-drying had the most dramatic effects on PLFA biomarkers, resulting in a 38% reduction in total PLFA and an 86% reduction in fungal biomarkers. This study highlights the influence of site characteristics on microbial community structure and emphasizes the importance of proper handling of soil samples for PLFA analysis.

The soil health comparison of the impact of bovine hoof compaction demonstrated a trend of lower PLFA markers across all microbial groups within the hoof samples relative to the non-hoof samples. The hoof treatment affected potentially mineralizable nitrogen, water stable aggregates, and bulk density. Each of these measures are indicative of reduced biological activity and may not be exclusive of each other. In the cow patty study, the center location (i.e., under the cow patty) showed major differences on soil health chemical indicators when compared to samples collected away from center by direction (N, S, E, W) and distance (6 and 12 inch). In particular, phosphorus content was dramatically elevated at the center location with increases ranging from 129-230%.

The sample depth study revealed all microbial components were affected by depth of sample and management system. The permanent pasture system increased microbial community structure, from the 6-inch depth when compared to the 3-inch depth, ranged 38 – 459% while the row crop system ranged 14-69%.

Key words: soil health, soil quality, eco-agriculture, phospholipid fatty acid, microbial community, prairie, control burn, fecal deposition, bovine, patty.

Abbreviations: WSA, water stable aggregates; AC, active carbon; PMN, potentially mineralizable nitrogen; TN, total nitrogen; SOC, soil organic carbon; AMF, arbuscular mycorrhizae fungi; GPOS, gram positive bacteria; GNEG, gram negative bacteria; PLFA, phospholipid fatty acid; Na, sodium; P, phosphorus; K, potassium; Ca, calcium; Mg, magnesium; CEC, cation exchange capacity.

Introduction

Soil Health can be broadly defined as the capacity of a soil to function collectively with environmental and agricultural sustainability (Doran and Parkin, 1994; Doran et al. 1994; Karlen et al. 2003). This is a concept that includes spatial variability among a number of taxonomically related soil series and within the same soil series. Physical properties and chemical nutrients have been extensively studied with little consideration of the biological component until most recently. Soil health research and understanding has been enhanced over the last several decades through scientific interest and newer methodologies for assessment; however, a lack of comprehensive investigation continues to this day.

Producers are starting to address this necessity to assess and improve a soil's health, or the capacity of a soil to function within ecosystem boundaries, in order to sustain biological productivity and maintain environmental health. This process has the potential to promote improved plant and animal health through the generations while meeting the growing population demand for food, fuel, and fiber. However, research based information is limited on the impact of various management systems utilizing biological indicators. Bossio et al. (1998) characterized variations in microbial community structure as influenced by agricultural management, seasons, and soil types.

Phospholipid fatty acids (PLFA) are essential microbial cell components and their specific chemical structures within microbial groups are relatively constant. Bossio et al. (1998) characterized variations in microbial community structure as influenced by agricultural management, seasons, and soil types. The PLFA analysis can provide an assessment of microbial community structure in soils and contribute to our understanding of sustainable land management.

Prairie soils are known to have a highly diverse microbial community in addition to a diverse above-ground plant community. Many native and restored prairies are managed through prescribed burn practices; however, the short-term effects of prescribed burns on biological soil properties are not fully understood. Several studies have shown that prescribed burns may affect the microbial community structure and function in prairie ecosystems (Knicker, 2007; Dunn, et al. 1985; Ohrtman et al. 2015). Several factors in burn management and conditions may play a role in the burn effect on soil microbial community. Ohrtman et al. 2015 showed that lethal temperatures (defined as > 140 °F) were achieved for longer periods with biennial fires than annual fires. The result was attributed to greater fuel load, higher temperatures, and longer duration of the biennial fires. However, Grasso et al. (1996) found no significant differences in microbial populations in pre and post burn scenarios in grassland soil, likely due to the history of repeated, controlled burns that diminished total biomass.

Studies by Veum et.al (2014, 2015) indicated that soil health improved with perennial vegetation including grasses and legumes in the claypan soil region of northeast Missouri; a reduced tillage/soil disturbance; incorporation of livestock grazing and manure into the system; increased rotation diversity including cash crops and forages; and cover crops for increased soil cover and diversity of the microbial population. Soil health indicators can emulate the status of soil properties, biological productivity, plant and animal health, and environmental stewardship. (Kremer, 2014 and 2016; Kremer and Veum, 2015).

The PLFA method is becoming more popular as a means of classifying soil microbial communities for soil health assessment, and thereby, characterizing variations due to agricultural management Veum et.al (2014, 2015). The introduction of PLFA analysis to the agriculture community as a means of estimating microbial biomass and microbial community structure and function within a given ecosystem provides new opportunities for education. For comparative purposes, soil health parameters in agricultural lands could be compared to adjacent undisturbed areas such as native prairies or undisturbed boundaries such as fencerows.

Routine soil sampling at the six-inch plow depth is a common practice in production agriculture. This procedure helps as a management tool in determining the nutrient status of soil. Laboratory analysis reports typically provide nutrient needs based upon the crop and yield goal expectations. This process of return (crop yield) on investment (fertilizer input) has often overlooked the comprehensive benefits of soil health. Prior to soil health considerations, as early as 1944, Cline discussed proper soil sampling procedures, which assume a consistent nutrient concentration within the plow depth. Later, Buchholz (1993) discussed the potential spatial variability that is inherent in any field sample even under intensive sampling. In addition, Stecker, et al (2001) discussed the potential movement of banded phosphorus fertilizer and its potential effect on distribution patterns. These examples only consider the chemical aspect of production agriculture and did not consider soil as a living, breathing entity full of biological activity.

The new “soil health initiative” requires a fresh look at potential errors in soil sampling procedure in order to protect the integrity of the sample and provide a basis for interpretation. The study of soil microbial communities must include the correct sample handling methodology in consideration of the sensitivity of these living, breathing biomarkers to prolonged storage and extreme temperatures. Yong Bok Lee, et al. (2007) determined that fungal markers and two enzyme assays were not affected by -4° F storage based on fatty acid methyl ester analysis. Two additional studies showed no statistical differences in total PLFA when stored at -4 or 39.2° F (Schnecker, et al. 2012; DeForest, 2009). However, DeForest (2009) suggested that storage could uniquely affect differences between soils. Peterson and Klug (1994) showed significant alteration of PLFA composition only after 21 days storage at 77° F. A study by Lauber, et al. (2010), indicated that samples collected and stored under field conditions without refrigeration could be used in microbial community analysis. A year-long frozen storage study by Wu, et al. (2009) showed a 30% decrease in total PLFA. The results of these studies indicate further research on the aspect of handling and storage are necessary. Peoples and Koide (2012) concluded that the change in enzyme activity ratio was generally smaller for frozen samples and larger for dried samples.

Minimal studies exist on the impact of livestock practices on the soil microbial community at a field scale. A soil laboratory study by Yao et al. (2014), with inoculated soil, determined the interaction between soil microbial communities and the invading *E. coli* suspension. This study showed that *E. coli* presented both pathogenicity and a marked effect on soil microecology. In another laboratory study, ruminant urine effects on soil microbial communities were determined to increase microbial stress under conditions of high soil moisture (Bertram et al. 2012). Frostegård et al. (2011) cautioned against the use of substrate procedures in determining the real turnover of native microorganisms.

Standardized methods for the proper handling of soil samples by producers prior to PLFA analysis have not been clearly established. Agricultural producers and technicians are typically not educated on proper handling procedures. Immediate laboratory analysis is not an option in most soil sampling scenarios. However, decomposition of microbial biomass occurs rapidly in soils after cell death (White, et.al 1979, and 1983). Therefore, soil sampling for PLFA analysis generally calls for prompt freeze-drying prior to analysis. Realistically, it may not be practical for producers to adhere to these handling and storage requirements, and it is unclear how differences in sample handling will impact PLFA biomarkers. In addition, it is often presumed that spatial soil uniformity exists within a given management practice. Livestock operations provide another opportunity to increase spatial heterogeneity through fecal deposition and site-specific soil impacts.

Therefore, the most reliable sampling and handling methods must be considered for educating producer and field technicians in proper sampling and handling of soils for biological analyses.

Due to inherent biological sensitivities, potential human errors in soil health sample handling can impede scientific understanding, and the validity of accurate sampling and handling processes is important in any research experiment. Several field sampling and handling procedures, emulating producer behavior patterns, were studied for the overall impact on PLFA markers using the samples from the two Missouri native prairies (n=17). These soil samples were subjected to storage and handling variations that may arise in a producer-collected sample. An additional study was conducted to compare variations that can exist from livestock impacts on soil health sampling. This study included depth and spatial distributions from cattle patty deposition and the impact of hoof compaction.

The objectives of this study are to compare chemical and microbial community structure using PLFA analysis on 1) two restored prairie sites in Missouri and the impact of a controlled prairie burn; 2) six sample handling and storage procedures; and 3) soils impacted by animal hoof compaction and patty deposition. 4) two sample depths from permanent pasture and conventional row crop managed systems.

The hypotheses of this research include: 1) prescribed prairie burns substantially influence the highly diverse soil microbial populations; 2) microbial populations are sensitive to improper handling upon sampling; 3) livestock can sway the microbial community through hoof compaction and patty deposition; 4) sampling for soil health microbial communities will be affected by sample depth across management systems.

Materials and Methods

Phospholipid Fatty Acid Analysis (PLFA)

PLFA analysis was used for this to measure microbial biomass and community composition in for this work. PLFAs were extracted and esterified into fatty acid methyl esters (FAME) (Buyer and Sasser 2012). The extracts were evaporated to dryness, dissolved in hexane, and transferred to gas chromatography vials for analysis. An Agilent 6890 gas chromatograph (Agilent Technologies, Santa Clara CA) with an autosampler, split-splitless inlet, and flame ionization detector coupled to an Agilent Ultra 2 column (25 m long x 0.2 mm internal diameter x 0.33 μm film thickness) was used to separate the FAMEs under a constant flow rate of 1.2 mL min-1 of H 2 carrier gas and a split ratio of 30:1. Oven temperature started at 374 °F, ramped to 545 °F at 50°F min-1, ramped to 591 °F at 140 °F min-1, and held constant at 590° F for 2 min. Injection and detector temperatures were 482 °F and 572 °F, respectively. The microbial identification system of (MID) Sherlock ® (MIDI, Inc., Newark DE) and Agilent Chemstation software were used to control the system, and the MIDI PLFAD1 software package was used to identify and categorize the FAMEs (Buyer and Sasser 2012).

Table 3.1 describes the PLFA markers assigned to saprophytic fungi, arbuscular mycorrhizal (AM) fungi, eukaryotes, and Gram-negative, Gram-positive, and actinobacteria (formally known as actinomycetes) microbial groups. For the purposes of this study, total PLFA was calculated as the sum of all microbial groups, total fungi was represented as the sum of saprophytic fungi, arbuscular mycorrhizal (AM) fungi, and total bacteria was calculated as the sum of markers assigned to Gram negative, Gram positive, and actinobacteria groups. The fungi to bacteria ratio was calucated as total fungi divided by total bacteria markers. Results were recorded in nanomoles per gram of soil (nmol/g).

Table 3.1. Microbial phospholipid fatty acid biomarkers specific for identifying microbial groups in soils analyzed in each study.

Microbial Group	Markers			
AM Fungi	16:1 w5c			
Fungi	18:2 w6c			
Gram Negative	10:0 2OH	10:0 3OH	12:1 w8c	12:1 w5c
	13:1 w5c	13:1 w4c	13:1 w3c	12:0 2OH
	14:1 w9c	14:1 w8C	14:1 w7c	14:1 w5c
	15:1 w9c	15:1 w8c	15:1 w7c	15:1 w6c
	15:1 w5c	14:0 2OH	16:1 w9c	16:1 w7c
	16:1 w6c	16:1 w4c	16:1 w3c	17:1 w9c
	17:1 w7c	17:1 w6c	17:0 cyclo w7c	17:1 w5c
	17:1 w4c	17:1 w3c	16:0 2OH	17:1 w8c
	18:1 w8c	18:1 w7c	18:1 w6c	18:1 w5c
	18:1 w3c	19:1 w9c	19:1 w8c	19:1 w7c
	19:1 w6c	19:0 cyclo w9c	19:0 cyclo w7c	19:0 cyclo w6c
	20:1 w9c	20:1 w8c	20:1 w6c	20:1 w4c
	21:1 w9c	20:0 cyclo w6c	21:1 w9c	21:1 w8c
	21:1 w6c	21:1 w5c	21:1 w4c	21:1 w3c
	22:1 w9c	22:1 w8c	22:1 w6c	22:1 w5c
	22:1 w3c	22:0 cyclo w6c	24:1 w9c	24:1 w7c
Eukaryote	15:4 w3c	15:3 w3c	16:4 w3c	16:3 w6c
	18:3 w6c	19:4 w6c	19:3 w6c	19:3 w3c
	20:4 w6c	20:5 w3c	20:3 w6c	20:2 w6c
	21:3 w6c	21:3 w3c	22:5 w6c	22:6 w3c
	22:4 w6c	22:5 w3c	22:2 w6c	23:4 w6c
	23:3 w6c	23:3 w3c	23:1 w5c	23:1 w4c
	24:4 w6c	24:3 w6c	24:3 w3c	24:1 w3c
Gram Positive	11:0 iso	11:0 anteiso	12:0 iso	12:0 anteiso
	13:0 iso	13:0 anteiso	14:1 iso w7c	14:0 iso
	14:0 anteiso	15:1 iso w9c	15:1 iso w6c	15:1 anteiso w9c
	15:0 iso	15:0 anteiso	16:0 iso	16:0 anteiso
	17:1 iso w9c	17:0 iso	17:0 anteiso	18:0 iso
	19:0 iso	19:0 anteiso	20:0 iso	22:0 iso
Actinobacteria	16:0 10-methyl	17:1 w7c 10-methyl	17:0 10-methyl	20:0 10-methyl
	18:1 w7c 10-methyl	18:0 10-methyl	19:1 w7c 10-methyl	

Prairie Variations

In March 2015, two Missouri prairie soils were selected for comparison of the sample storage and handling experiment (Missouri Prairie Foundation, 2017). Both soils are classified as a silt loam surface texture (University of Missouri Extension, 2017). Two-inch samples were collected using a 3-inch diameter ring.

Golden Prairie is located in Barton County, Missouri, USA (N 37.365300, W 94.145750). This site consists of 1,100 acres that includes 1) an original 320 acres saved by the Missouri Prairie Foundation between 1970 and 1975, 2) 310 acres that were added in 2002 and are being restored, and 3) 480 acres cooperatively managed by the neighboring private landowner. A total of 345 plant species have been recorded at Golden Prairie. Soils at Golden Prairie are mapped as Creldon silt loam- (Fine, mixed, active, mesic Oxyaquic Fragiudalf).

Prairie Burn

Stark-Family Prairie is located in Hickory County, Missouri, USA, (N 38.01596, W 93.12599) and was bequeathed to the Missouri Prairie Foundation in 2013. Soils at Stark Prairie are mapped as Bardley very gravelly silt loam (very-fine, mixed, active, mesic Typic Hapludalfs).

A burn study was conducted to compare the microbial community structure of two different prairie sites in Missouri. Soil samples were collected the day of a prescribed burn conducted by the Missouri Prairie Foundation. A total of nine samples were collected at each prairie representing: 1) control (unburned), 2) pre-burn, and 3) post-burn soils at three landscape positions. Samples were collected from the 0-2” depth using 3 in-diameter rings. Samples were transported to the laboratory on ice, immediately split for the different storage treatments, and processed for PLFA following the University of Missouri Soil Health Assessment Center protocol.

Soil properties were measured using standard methods (USDA, 2004) and PLFA analysis was conducted following the Buyer and Sasser (2012) high-throughput extraction with peak identification and assignment using an Agilent 6890 gas chromatograph and the Sherlock Microbial Identification System (MIDI, Newark, NJ).

Soil properties and PLFA markers for the two prairie soils were compared using ANOVA ($\alpha = 0.05$) with PROC MIXED in SAS 9.2. (SAS Institute, Cary, NC). The prairie burn comparison was conducted on soil properties prior to and immediately following site burning utilizing an independent-sample t-test ($\alpha = 0.05$).

Soil Sample Handling and Storage Condition Utilizing Prairie Soils

The effects of sample processing and handling were evaluated by comparing the PLFA profiles from prairie soils collected March 2015. Fresh samples were freeze-dried within 24 hours of collection, air-dried at room temperature (68 °F) for 7 and 14 days, stored field-moist at room temperature in sealed containers for 7 and 14 days, and oven-dried at 221 °F. These treatments represent typical producer-collected sample handling scenarios when collected for chemical analysis. Typical producer sample handling will generally include collecting a sample and immediately deliver to the lab or collect a sample in a paper bag or plastic container and deliver it at some time in the future.

Animal Impact

Hoof Location Effect on Microbial Population

Soil samples were collected in May 2016 from a producer-cooperator family farm located in eastern Cooper County, Missouri, USA, (N 38.80834, W 92.86513). The past management included eight year managed intensive grazing pasture of Max Q® novel endophyte fescue (*Lolium arundinacea, Schreb.*).

Sample area was located on a 1-2% plateau consisting of a Wrengart silt loam- (Fine-silty, mixed, active, mesic Fragic Oxyaquic

Hapludalfs). These soils are formed in loess over pedisediment over residuum weathered from cherty limestone located on hills, hillslopes, ridges under tree cover and hardwoods, and comprise approximately 90% of the map unit. The natural drainage condition of the soil is moderately well drained. The top of the seasonal high water table is 33 inches. This mapunit is assigned to the nonirrigated land capability classification 4e (University of Missouri Extension, 2017).

For the hoof impact study, five individual sites were selected based upon visual determination of a hoof print. Two samples were collected at sites representing: 1) control (No Hoof) and 2) hoof (hoof print) positions. Samples were collected from the 0-3 inch depth using 3-inch diameter rings centered over selected hoof imprint and directly beside the first ring. Samples were immediately transported to the laboratory on ice and processed for PLFA analysis.

Soil properties were measured using standard methods (USDA, 2004) and PLFA analysis was conducted following the Buyer and Sasser (2012) high-throughput extraction with peak identification and assignment using an Agilent 6890 gas chromatograph and the Sherlock Microbial Identification System (MIDI, Newark, NJ).

Cow Patty Location Effect on Microbial Population

For the cow patty study, five sites were selected representing a mature and undisturbed fecal deposition (patty) by nature or existing livestock (Figure 3.1). Samples were collected from the 0-3 inch depth using 3-inch diameter rings. Center samples were positioned in the middle of the patty upon removing the deposition with a shovel. Additional samples were collected at 6-inch and 12-inch distances from center at each of the cardinal directions (N, S, E, W). Samples were immediately transported to the laboratory on ice and processed for PLFA analysis.

Soil properties were measured using standard methods (USDA, 2004) and PLFA analysis was conducted following the Buyer and Sasser (2012) high-throughput extraction with peak identification and assignment using an Agilent 6890 gas chromatograph and the Sherlock Microbial Identification System (MIDI, Newark, NJ).

Figure 3.1. Cow Patty center location established shown by flag position.

An independent-sample t-test ($\alpha = 0.05$) was conducted to compare soil properties on two hoof treatments. Two-way analysis of variance (ANOVA) was conducted using SAS Proc Mixed to compare soil properties under five random cow patties relative to 4 cardinal directions (N, S, E, W) and two distances (6-inch and 12-inch) from the center of each patty. The effects of cardinal direction and distance were analyzed separately.

Sample Depth of Pasture and Tilled Cropping System

Soil samples were collected in May 2016 from a producer-cooperator family farm located in eastern Cooper County, Missouri, USA, (N 38.80834, W 92.86513). This permanent pasture included eight year managed intensive grazing pasture of Max Q® novel endophyte fescue (*Lolium arundinacea, Schreb.*).

Sample area was located on a 1-2% plateau consisting of a Wrengart silt loam- (Fine-silty, mixed, active, mesic Fragic Oxyaquic Hapludalfs). These soils are formed in loess over pedisediment over residuum weathered from cherty limestone located on hills, hillslopes, ridges under tree cover and hardwoods, and comprise approximately 90% of the map unit. The natural drainage condition of the soil is moderately well drained. The top of the seasonal high water table is 33 inches. This mapunit is assigned to the nonirrigated land capability classification 4e (University of Missouri Extension, 2017).

For the permanent pasture depth of sample study, 9 samples were collected at the 0-3 inch depth using 3-inch diameter rings. Corresponding sample were collected adjacent to the 3-inch ring to a 0-6 inch depth. Samples were immediately transported to the laboratory on ice and processed for PLFA analysis.

For the row crop site, soil samples were collected during soybean harvest in October 2016 from a producer-cooperator family farm located in eastern Cooper County, Missouri, USA, (N 38.78648, W 93.0585). This row crop system is a typical corn-soybean-wheat rotation with seasonally variable potential cover crop scenarios.

Sample area was located on a 1-2% row crop production field consisting of a Arisburg silt loam–(Fine, smectitic mesic Aquertic Argiudolls). These soils are formed in loess located on hill, interfluves under grass/herbaceous cover and comprise approcimately 90% of the map unit. The surface water runoff class is high and the natural drainage condition of the soil is somewhat poorly drained. The top of the seasonal high water tavle is 24 inches. This mapunit is assigned to the nonirrigated land capability classification 2E (University of Missouri Extension, 2017).

For the row crop depth of sample study, four random samples were collected at the 0-3 inch depth using 3-inch diameter rings from 20 research plots to form a composite. Eight random samples were collected at the 0-6 inch depth using a 1.25 soil collection tube from the same 20 research plots to form a composite. Samples were immediately transported to the laboratory on ice and processed for PLFA analysis.

Soil properties were measured using standard methods (USDA, 2004) and PLFA analysis was conducted following the Buyer and Sasser (2012) high-throughput extraction with peak identification and assignment using an Agilent 6890 gas chromatograph and the Sherlock Microbial Identification System (MIDI, Newark, NJ).

The sample depth study was conducted on soil properties at 0-3 and 0-6 inch depths utilizing an independent-sample t-test (α = 0.05) at each location.

Results and Discussion

Prairie Variations

While native prairies have a more dynamic microbial population, there are differences. The two prairies differ in how they affect the microbial community (Table 3.2). Golden Prairie is a more robust ecosystem than Stark Prairie. Significant differences were found between the PLFA profiles from the two prairies, likely due to differences in soil type, vegetation, and restoration. Soil chemical resulted in P, K, and Ca differences (Table 3.3). These results may be a reflection of previous management practices on the younger reconstructed Stark prairie (Missouri Prairie Foundation, 2017). While similar in soil texture, these two prairie sites were established on separate soil series and have differences in prairie vegetation and species diversity. Variations in prairie vegetation rooting structures will also have significant impact on microbial communities with depth. Root polysaccharide exudates provide a symbiotic and protective interaction with microbes, which help bind soil particles together with root and fungal hyphae for improved aggregate stability (Tisdall and Oades, 1982). Prairie soils are considered an excellent source of reference or baseline indicator of historical PLFA communities. As producers continue to understand their dynamic agro-ecosystems, it is sensible for them to consider their best representative reference soil to compare and contrast current management effects on microbial populations and diversity. When prairie soils are not present, producers can select a reference area from a previously undisturbed area such as a fencerow or untilled field margins. The key is to garner as much baseline information as possible in order to have a better understanding of cropping system effects.

Table 3.2. Mean soil health properties for Golden Prairie and Stark Prairie in Missouri (standard error in parentheses). Values within columns followed by the same letter are not significantly different (α=0.05; n=17).

Prairie	WSA	AC	PMN	TN	SOC
	%	Mg kg^{-1}	ppm	%	%
Golden	89.8 A (1.03)	568 A (17.5)	134 A (12.02)	0.31 A (0.01)	3.36 A (0.10)
Stark	59.2 B (7.10)	492 A (47.1)	87.4 B (9.18)	0.18 B (0.02)	2.20 B (0.21)

WSA= water stable aggregates; AC=active carbon; PMN=potentially mineralizable nitrogen; TN=total nitrogen; SOC=soil organic carbon

Table 3.3. Mean soil chemical properties and standard errror in parentheses by prairie site. Values within columns followed by the same letter are not significantly different (α= 0.05; n=17).

Prairie	pH_s	pH_w	P	K	Ca	Mg	Na	CEC
			ppm	ppm	ppm	ppm	ppm	meq/100g
Golden	5.2 A (0.05)	5.8 A (0.07)	6.2 A (0.58)	181 A (16)	1840 A (170)	173 A (19)	15 A (9)	15.4 A (1.23)
Stark	5.3 A (0.14)	6.0 A (0.12)	4.1 B (0.42)	108 B (9)	1131 B (246)	328 A (75)	3 A (3)	11.1 A (2.12)

Prairie Burn

A prairie burn study conducted to determine the effects on microbial populations prior to and immediately following a prescribed burn at Golden Prairie and Stark Prairie, Missouri. While not significant, an unexpected increase in total PLFA occurred post burn (Table 3.4). Plausible explanations include inherent variations in soil series and plant diversity. Early spring environmental factors such as soil moisture conditions and cooler sampling period may have contributed to this lack of differences. The 3-inch sample depth could have buffered any burn differences that might have occurred near the surface. Additionally, the speed at which a fire burn occurs across an area is directly affected by the biomass fuel load and wind speed. The significant differences in gram negative (GNEG):gram positive (GPOS) ratio could reflect the stress tolerance abilities of GPOS in forming spores that are protective structures. The bacterial groups, while not statistically significant as individual microbes, produced an effect when considered in the ratio. The total PLFA community biomass was not affected by treatment.

Table 3.4. Pre and Post burn means for t-test comparison of PLFA microbial groups (nmol/g soil). Standard error in parentheses. NS=not significantly different. (α=0.05; n=17).

Variable	Pre Burn nmol/g soil	Post Burn nmol/g soil	P-value
Total PLFA	209.4 (58.2)	214.5 (61.2)	NS
AMF	10.5 (2.3)	10.6 (2.5)	NS
GPOS	94.8 (26.2)	96.1 (29.0)	NS
GNEG	60.9 (18.4)	63.5 (18.4)	NS
Eukaryote	4.4 (1.2)	4.6 (1.6)	NS
Fungi	7.6 (2.3)	7.0 (2.2)	NS
Actinobacteria	28.0 (8.6)	29.3 (8.9)	NS
Fungi:Bacteria ratio	0.099 (0.20)	0.094 (0.20)	NS
GPOS:GNEG ratio	1.57 (0.20)	1.52 (0.18)	0.04

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria;

Soil Sample Handling and Storage Condition

Prairie soils, split at sampling, were then used for comparing six storage and handling conditions that might occur in a traditional producer collected soil fertility sample. Lui, et al. (2009) showed a negative response to refrigeration when compared to freezing. This study also concluded that deep freezing followed by freeze-drying produced the most reliable data. A study by Lauber, et al. (2010), indicated that samples collected and stored under field conditions without refrigeration could be used in microbial community analysis. Our study however, showed that air drying reduced total PLFA markers by 11-14% and field moist reduced total PLFA markers by 13-15% (Table 3.5). As storage time increased from 2 to 4 weeks, bacterial groups (G-, G+, and actinobacteria) rebounded slightly but had overall loss from fresh samples by 3-18%. Riah-Anglet et al., (2015) showed that microbes do not have the same growth rate or competitive ability where microbial communities decreased in heat treated soil by an average of 80%. Each storage effect created intense losses of fungal markers. Losses of 13 to 20% with AMF markers and 36 to 56% losses of saprophytic markers occurred with storage treatments. Eukaryotes declined 5-17% across storage conditions. Storage conditions impacted G- more than G+ markers resulting in elevated G-:G+ ratios (Table 3.4). The GP+ may be more adaptable to the stress of sample handling. The Eukaryotes that rely heavily on water to survive were unable to rebound like other microbes. Oven drying provided the greatest losses across PLFA markers with fungi losses at 86% due to heat stress and lack of moisture which is critical for fungal survival. This treatment was selected to resemble a producer-collected sample being placed on the dash of a truck. This is why it is important to educate the producer on the significance of properly handling soil samples for biological data collection. In contrast, Wu, et al. (2009) demonstrated in a yearlong frozen storage trial that total PLFA decreased by 30%. Arithmetic means for PLFA groups by storage condition are listed in Table 3.6. Once removed from the natural environment, stress can begin to impact the biological communities. However, they have an inherent adaptability or survival mechanism where they can rebound (Table 3.5). Microbes more adaptable to the current environment may overwhelm the less-tolerant microbial groups and cause shifts in the overall community structure over time. In short, the strong survive.

Table 3.5. Percentage difference in PLFA markers (nmol/g soil) due to sample handling conditions relative to fresh, freeze-dried samples.

PLFA	Fresh	Air Dried 68 F		Field moist 68 F		Oven dry 221 F
	freeze-dried	2 weeks	4 weeks	2 weeks	4 weeks	24 hour
Total PLFA	223.0	-14	-11	-15	-13	-38
Gram -	100.2	-18	-12	-18	-16	-41
Gram +	65.1	-7	-6	-5.0	-3	-32
Actinobacteria	31.0	-12	-6	-15	-10	-34
AMF	10.8	-20	-15	-18	-13	-52
Fungi	7.4	-38	-36	-56	-53	-86
Eukaryote	4.9	-7	-17	-5	-9	-16
F:B ratio	0.094	-16	-16	-23	-19	-47
G-:G+ ratio	1.17	+18	+24	+15	+14	+14

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria

Table 3.6. Means for PLFA groups (nmol/g soil) by storage conditions. Standard error in parentheses. (n=17). α=***.0001**.009

PLFA	Fresh	Air Dried 68 F		Field moist 68 F		Oven dry 221 F
	freeze-dried	2 weeks	4 weeks	2 weeks	4 weeks	24 hour
Total PLFA	223 (15)	191*** (13)	199*** (13)	190*** (12)	195*** (15)	138*** (9.2)
Gram -	100 (6.5)	822*** (5.2)	878*** (5.7)	823*** (5.3)	844*** (6.4)	592*** (4.1)
Gram +	651 (4.9)	607*** (4.8)	614** (4.4)	619 (4.3)	631 (4.8)	442*** (2.9)
Actinobacteria	31 (2.6)	27*** (2.1)	29 (2.2)	26*** (2.1)	28*** (2.5)	20*** (1.4)
AMF	108 (0.6)	8.6*** (0.5)	9.1*** (0.5)	8.8*** (0.5)	9.3*** (0.5)	5.1*** (0.2)
Fungi	7.4 (0.6)	4.6*** (0.4)	4.8*** (0.3)	3.3*** (0.3)	3.5*** (0.3)	1.1*** (0.2)
Eukaryote	4.9 (0.5)	4.6 (0.3)	4.1 (0.5)	4.7 (0.4)	4.5 (0.4)	4.1 (0.4)
Fungi:Bact ratio	0.094 (0.004)	0.079*** (0.004)	0.079*** (0.003)	0.072*** (0.003)	0.076*** (0.004)	0.050*** (0.002)
G-:G+ ratio	1.17 (0.058)	1.385*** (0.046)	1.446 (0.043)	1.341 (0.034)	1.338 (0.032)	1.335 (0.032)

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria

Animal Impact

Hoof

Soil health comparison of the impact of bovine hoof compaction, while not significant trended lower within the hoof impression (Table 3.7). A hoof-induced compacted root zone is a plausible explanation for these lower trends. The compressed soil state along with damaged plant roots may have reduced the AMF ability to process P creating significant differences (Table 3.8).

Lynch and Poole, (1979) indicated that the most resilient soils occur in pastures with vigorous symbiotic relationships between bacteria and root. However, the hoof treatment negatively affected PMN, WSA, and BD (Table 3.8). Each of these measures are indicative of reduced biological activity and may not be exclusive of each other. As expected, bulk density increases with compaction within the imprint. This measure is indicative of impeded root growth, biological activity and water relations that are associated with WSA and PMN.

Table 3.7. Hoof impact on soil microbial components utilizing PLFA (nmol/g soil) analysis. (α=0.05; n=5 per treatment; total n=10) Standard error in parentheses.

Variable	No Hoof nmol/g soil	Hoof nmol/g soil	P-value
Total PLFA	112.5 (6.0)	96.4 (5.9)	NS
AMF	5.9 (0.4)	5.1 (0.3)	NS
GNEG	44.8 (2.6)	40.1 (2.7)	NS
GPOS	31.4 (1.3)	28.4 (1.9)	NS
Eukaryote	7.7 (3.2)	2.6 (0.1)	NS
Fungi	3.9 (5.8)	3.2 (10.9)	NS
Actinobacteria	18.9 (0.8)	17.2 (1.0)	NS
Fungi:Bacteria ratio	0.102 (0.007)	0.099 (0.013)	NS
G-:G+ ratio	1.43 (0.031)	1.41 (0.025)	NS

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria

Table 3.8. Soil health biological and chemical indicators of hoof compaction. (α=0.05; n=5 per treatment; total n=10)

Variable	No Hoof Print	Hoof Print	P-value
Ca (ppm)	1836 (130)	1736 (58)	NS
Mg (ppm)	108 (4)	98 (6)	NS
Na (ppm)	0.00 (0.00)	0.00 (0.00)	NS
K (ppm)	140 (9.3)	133 (9.3)	NS
P (ppm)	21.8 (1.32)	16.9 (1.55)	0.04
CEC meq/100g soil	12.1 (0.33)	11.8 (0.21)	NS
SOC (%)	1.56 (0.06)	1.32 (0.04)	NS
pH_s	5.84 (0.16)	5.88 (0.12)	NS
pH_w	6.50 (0.13)	6.46 (0.09)	NS
TN (%)	0.16 (0.01)	0.11 (0.02)	NS
PMN (ppm)	131 (5.0)	104 (5.0)	0.03
AC (ppm)	466 (25.3)	410 (3.1)	NS
BD (g/cm^3)	1.3 (0.02)	1.6 (0.02	0.002
WSA (%)	42.2 (3.9)	22.4 (3.6)	0.01

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates

Cow Patty Distance and Spatial distribution

Cow patty location did not affect bulk density, active carbon, mineralizable nitrogen, and total nitrogen (Table 3.9). There were some directional effects on water stable aggregates. However, effects were unlikely related to the patty position but perhaps a legacy effect of previous cow patty deposits in this perennial grazing system. Organic carbon is highly correlated with many soil health biological and physical indicators (Whalen, et al. 2003, Treonis et al., 2010). While the highest OC contents occurred in the center sample, it was not significantly different from both south and east direction.

Distance from cow patty center did not effect water stable aggregates, bulk density, mineralizable nitrogen and total nitrogen. While the center location showed numerically higher active and organic carbon, values were statistically similar to those obtained at the 6-inch distance (Table 3.9). Carbon measurements were not different beyond the 6-inch distance increment suggesting a localized patty effect.

The center location showed major effects on soil health chemical indicators when compared to direction and distance from center (Table 3.10). Potassium was the only soil nutrient not affected in either direction or distance. Calcium content significantly differed only in the north direction but likely an anomaly. Phosphorus content was dramatically elevated at the center location ranging from 129-230%.

While P is non-mobile in the soil, site selection of decomposed deposition may have provided more opportunity for rainfall events creating movement. Additions of P through fertilizer and manures can temporarily overpower the balance of P in solution (Kleinman et al., 2001). Uniform application or spread may be necessary for the most efficient plant uptake of nutrients, thereby reducing any negative environmental impact. Uniform distribution of cow patty is not always a possibility in a livestock grazing system.

Cow patty location and distance did not affect overall eukaryotes, G-, G+, and PLFA totals (Table 3.11). While both actinobacteria and AMF components have directional separation, the data set is not robust and more samples would likely improve the analysis. Fungi component totals were significantly higher in the center location. Fungi are primary decomposers of lignin content in plant tissue and other complex plant substances that comprise ruminant processed material deposited within the patty. They are necessary in breaking down organic matter into plant available nutrients. Total PLFA content did not differ among sites or within direction suggesting cow patty deposition affected total soil microbial biomass; however, the significant effects detected for individual PLFA components at different sampling sites suggests that cow patties may affect specific microbial groups in the soil surface.

Table 3.9. Soil health biological and physical indicators of soils collected from surface 3-inch depth and along 6-inch and 12-inch transects in four directions from cow patty position centers. Values are means of five patty locations from samples collected at two positions along each transit direction. Means followed by different letters within columns by direction or distance are significantly different. Standard errors are in parentheses. (α=0.05; n=5 per treatment; total n=45)

Patty	WSA	BD	AC	PMN	TN	SOC
Direction	%	g/cm^3	ppm	ppm	%	%
Center	47.2 A (2.13)	1.18 A (0.05)	643 A (53.2)	145 A (8.83)	0.21 A (0.01)	2.14 A (0.14)
North	52.3 A (3.07)	1.27 A (0.05)	563 A (15.6)	153 A (6.54)	0.19 A (0.01)	1.83 B (0.06)
South	51.3 AB (3.13)	1.23 A (0.05)	572 A (49.0)	158 A (14.16)	0.20 A (0.01)	1.88 AB (0.12)
East	43.8 B (2.79)	1.27 A (0.04)	563 A (28.3)	153 A (12.55)	0.19 A (0.01)	1.83 AB (0.10)
West	52.2 A (2.78)	1.29 A (0.03)	537 A (21.6)	138 A (8.58)	0.19 A (0.01)	1.75 B (0.07)
Distance						
Center	47.2 A (2.13)	1.18 A (0.05)	643 A (53.2)	145 A (8.83)	0.21 A (0.01)	2.14 A (0.14)
6 inches	47.8 A (2.26)	1.16 A (0.03)	601 AB (23.8)	154 A (8.43)	0.20 A (0.01)	1.93 AB (0.08)
12 inches	52.1 A (1.99)	1.27 A (0.02)	531 B (18.0)	144 A (6.65)	0.19 A (0.01)	1.74 B (0.06)

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregate

Table 3.10. Soil health chemical indicators of soils collected from surface 3-inch depth and along 6-inch and 12-inch transects in four compass directions from cow patty position centers. Values are means of five patty locations from samples collected at two positions along each direction. Means followed by different letters within columns are significantly different based on Fisher's protected LSD at α = 0.05. Standard error are in parentheses. (α=0.05; n=5 per treatment; total n=45)

Patty Sample	pHs	pHw	P	K	Ca	Mg	Na	CEC
Direction			ppm	ppm	ppm	ppm	ppm	%
Center	6.3 A (0.10)	6.7 A (0.07)	91 A (23)	195 A (20)	1700 A (75)	331 A (61)	18.4 A (9)	13.8 A (0.38)
North	5.8 B (0.06)	6.5 B (0.06)	36 B (4.1)	199 A (37)	1590 B (31)	163 B (13)	6.9 B (3.5)	12.73 B (0.17)
South	5.9 B (0.07)	6.5 B (0.04)	34 B (11.0)	55 A (27)	1734 A (58)	143 B (13)	4.6 B (2.8)	13.08 AB (0.24)
East	5.9 B (0.09)	6.5 B (0.07)	40 B (11.0)	171 A (23)	1796 A (44)	150 B (12)	2.3 B (2.3)	12.96 B (0.23)
West	5.7 B (0.04)	6.4 B (0.04)	28 B (2.7)	148 A (11)	1748 A (36)	128 B (6)	0.0 B (0.0)	12.89 B (0.16)
Distance								
Center	6.3 A (0.10)	6.7 A (0.07)	91 A (23)	195 A (20)	1700 A (75)	331 A (61)	18.4 A (9)	13.8 A (0.38)
6 inch	5.9 B (0.05)	6.5 B (0.04)	40 B (7)	165 A (13)	1740 A (36)	157 B (9)	3.5 B (1.8)	13.01 B (0.16)
12 inch	5.8 B (0.04)	6.4 B (0.04)	27 B (3)	187 A (23)	1694 A (32)	135 B (6)	3.5 B (1.8)	12.82 B (0.13)

Table 3.11. Influence of soil sampling direction and distance from cow patty on soil microbial components detected using PLFA (nmol/g soil) analyses. Values are means of five patty locations from samples collected at two positions along each transect direction. Means followed by different letters within rows within direction or distance are significantly different based on Fisher's protected LSD at α = 0.05. Weight is based on amount individual microbial component relative to total soil PLFA. Standard error are in parentheses. (α=0.05; n=5 per treatment; total n=45)

PLFA	Cow Patty Direction						Cow Patty Distance unbalanced		
	Center	North	South	East	West		Center n=5	6 inch n=20	12 inch n=20
Total PLFA	140 A (12.0)	121 A (8.0)	139 A (11.0)	123 A (7.1)	127 A (8.0)		140 A (12.0)	132 A (6.3)	123 A (6.1)
Actinobacteria	18.6 AB (1.2)	18.8 B (0.9)	21.2 A (0.9)	19.1 AB (0.6)	20.3 AB (0.9)		18.6 A (1.2)	20.2 A (0.6)	19.5 A (0.6)
AMF	9.1 A (8.8)	6.8 B (0.5)	8.4 AB (10.0)	7.0 AB (0.3)	7.1 AB (0.5)		9.1 A (0.9)	7.5 A (0.4)	7.1 A (0.5)
Eukaryotes	5.8 A (1.2)	5.8 A (1.5)	5.9 A (1.5)	8.5 A (3.2)	7.7 A (3.7)		5.8 A (1.2)	8.1 A (2.3)	5.8 A (1.1)
Fungi	7.7 A (1.9)	4.6 B (0.5)	5.0 B (1.0)	4.2 B (0.5)	4.1 B (0.4)		7.7 A (1.9)	4.8 B (0.5)	4.2 B (0.4)
GNEG	63.2 A (5.7)	51.6 A (3.2)	60.3 A (5.3)	51.4 A (2.5)	52.7 A (3.2)		63.2 A (5.7)	55.5 A (2.2)	52.5 A (2.9)
GPOS	35.2 A (2.5)	33.5 A (2.0)	38.2 A (2.6)	33.1 A (1.3)	35.0 A (2.0)		35.2 A (2.5)	35.6 A (1.3)	34.2 A (1.5)

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria

Sample Depth of Pasture and Tilled Cropping System

Sample depth affected all microbial components in the permanent pasture system (Table 3.12). Overall increases in the microbial community from the 6-inch depth occured compared to the 3-inch depth ranged from 38 – 459%. The eukaryote and fungi populations were affected the greatest by depth. This may be explained by the continuous livestock input and cycling of nutrients at the surface.

Sample depth affected many of the biological and chemical indicators in the permanent pasture system (Table 3.13). Potassium results showed a 78 % increase, which could be reflected in the 0.2-pound K per day as-excreted manure production (Lorimor et al., 2004). While P was not significant, it was 131% greater at the 3-inch depth

Each of the biological indicators were affected by sample depth (3.13). Significant increases occurred with TN, PMN, AC, and WSA at the 3-inch depth while BD decreased. In a survey of cropping systems in selected Midwestern watershed, Karlen et al. (2014) reported similar increases in biological, chemical, and physical soil quality indicators in the surface 2-inch increment.

Sample depth affected all microbial components in the row crop system (Table 3.14). Overall increases in the microbial community from the 6-inch depth occurred compared to the 3-inch depth ranged from 14 – 69%.

While not significant, eukaryote populations were 14% greater at the 3-inch depth. The fungal populations were affected greatest by depth. This may be explained by the concentration of soybean root mass near the surface at harvest.

Sample depth affected many of the biological and chemical indicators in the row crop system (Table 3.15). While the percentage change from the two depths was much less than those in the permanent pasture, there were also some significant decreases in Na, P, and pH_w. The significant decrease of P at the surface may have been a product of incorporation prior to planting. P is a less mobile chemical and may have stayed in higher concentration with depth. With the exception of WSA, each of the biological indicators were greater at the 3-inch depth. However, the WSA indicator developed a 5% increase.

Table 3.12. Sample depth impact on soil microbial components from permanent pasture utilizing PLFA (nmol/g soil) analysis. (α=0.05; n=5 per treatment; total n=10) Standard error in parentheses.

Variable	6 inch	3 inch	P-value	% Change
Total PLFA	83.3 (3.3)	149 (8.8)	0.0001	79
AMF	4.2 (1.7)	7.8 (0.4)	0.001	86
GNEG	33.6 (4.5)	60.2 (3.1)	0.0001	79
GPOS	24.3 (1.3)	38.4 (1.6)	0.0001	58
Eukaryote	2.7 (0.16)	15.1 (4.6)	0.02	459
Fungi	2.5 (0.3)	5.6 (0.8)	0.0007	124
Actinobacteria	15.9 (0.6)	21.9 (0.8)	0.001	38
GPOS %	29 (0.4)	26 (0.8)	0.002	
Actinobacteria %	19 (0.3)	15 (0.8)	0.002	

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria

Table 3.13. Soil health biological and chemical indicators from 2 depths on a permanent pasture. (α=0.05; n=5 per treatment; total n=10)

Variable	6 inch depth	3 inch depth	P-value	% Change
Ca (ppm)	1620 (61)	1680 (89)	NS	4
Mg (ppm)	116 (39)	191 (127)	0.03	65
Na (ppm)	5 (0.00)	5 (0.00)	NS	0
K (ppm)	112 (53)	199 (82)	0.0005	78
P (ppm)	16 (2.4)	37 (13)	NS	131
CEC (meq/100g soil)	11.6 (0.33)	12.7 (0.21)	0.0004	9
SOC (%)	1.2 (0.06)	1.8 (0.04)	0.0002	50
pH_s	5.9 (0.16)	6.0 (0.12)	NS	2
pH_w	6.5 (0.13)	6.5 (0.09)	NS	0
TN (%)	0.13 (0.01)	0.19 (0.02)	0.0001	46
PMN (ppm)	106 (5.0)	181 (5.0)	0.0001	71
AC (ppm)	337 (25.3)	552 (3.1)	0.0001	64
BD (g/cm^3)	1.3 (0.02)	1.2 (0.02	0.001	-8
WSA (%)	33 (3.9)	52 (3.6)	0.003	58

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates

Table 3.14. Sample depth impact on soil microbial components from corn-soybean-wheat row crop PLFA (nmol/g soil) analysis. (α=0.05; n=20 per treatment; total n=40) Standard error in parentheses.

Variable	6 inch	3 inch	P-value	% Change
Total PLFA	84 (2.3)	116 (2.4)	0.0001	38
AMF	4.4 (0.13)	6.8 (0.22)	0.0001	55
GNEG	32.4 (0.89)	46.9 (1.0)	0.0001	45
GPOS	26.6 (0.69)	35.0 (0.65)	0.0001	32
Eukaryote	2.9 (0.72)	3.3 (0.27)	NS	14
Fungi	1.6 (0.1)	2.7 (0.1)	0.0001	69
Actinobacteria	16.4 (0.5)	20.8 (0.5)	0.0001	27
GPOS %	31 (0.3)	30 (0.2)	0.0001	
Actinobacteria %	19 (0.4)	17.7 (0.2)	0.0001	

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria

Table 3.15. Soil health biological and chemical indicators from 2 depths from corn-soybean-wheat row crop. (α=0.05; n=20 per treatment; total n=40)

Variable	6 inch depth	3 inch depth	P-value	% Change
Ca (ppm)	2873 (100)	2973 (107)	0.01	5
Mg (ppm)	269 (10)	271 (7)	NS	1
Na (ppm)	13 (3.2)	12 (2.5)	NS	-8
K (ppm)	88 (8)	109 (8.6)	0.0001	24
P (ppm)	37 (1.32)	16 (1.55)	0.0001	-57
CEC (meq/100g soil)	18.2 (0.45)	18.8 (0.45)	0.01	3
SOC (%)	1.8 (0.04)	2.0 (0.04)	0.0001	11
pH_s	6.3 (0.07)	6.3 (0.06)	NS	0
pH_w	6.71 (0.07)	6.67 (0.06)	.04	-1
TN (%)	0.16 (0.004)	0.19 (0.004)	0.0001	19
PMN (ppm)	60 (1.2)	79 (1.9)	0.0001	32
AC (ppm)	419 (9.4)	556 (9.5)	0.0001	33
WSA (%)	19 (0.8)	20 (1.0)	NS	5

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates

Conclusion

In order to meet the expected growing world population demand for consistent and accessible food production, producers will be forced to reevaluate traditional management systems in order to maintain profitability coupled with ecological and social sustainability. After decades of overlooking the important role that soil microbiology contributes in this process, there has been recent increased focus on soil health and its effect on sustainability.

The slow adoption and diffusion of soil health management in Missouri provides key opportunities for Extension educators to provide research-based information. An integral component of soil health adoption by producers could include a better understanding of the biological functions within a soil. The diversity of biological communities can be disrupted dramatically within a given production system.

The current understanding of assessing PLFA in eco-agriculture systems includes comparison to a reference location. It was expected that PLFA totals would vary between the two selected prairie environments. The lack of significant difference between pre and post burn sites was unexpected.

Due to inherent biological sensitivities, potential human errors in soil health sample handling can create the greatest sample errors and impede accurate scientific understanding. The validity of precise sampling and handling processes is important in any research experiment and for the education of producers collecting biological samples. Producers have a limited understanding of correct soil health sampling procedures, which can potentially lead to collection of samples that reveal limited meaningful results. Our results compared sample handling treatments representing a typical producer-collected sample handling and the potential errors associated. Our results showed 6-38% total PLFA losses when air dried, 3-56% losses when stored moist in a plastic container, and up to 86% when oven dried representing a sample stored in a vehicle. This amount of error is substantial and would likely impede the progress of producers adopting soil health management practiced in a meaningful way.

Our studies included potential sampling errors and potential educational opportunities for livestock producers.   The hoof treatment affected AMF, PMN, WSA, and BD level compared to the control. While BD levels decreased as expected, the additional reduced measurements are indicative of impeded root growth, biological activity and water relations. While cow patty center location had no effect on total PLFA content, it significantly increased fungi, which are primary decomposers of lignin.

Since 1914, Extension educators have been responsible for adult education and improving the lives and economy of citizens at the local level. It is well known that this delivery model enables adults to have the ultimate determination in what action they take as a result of that education (Battel and Krueger, 2005). The slow adoption and diffusion of soil health management in Missouri provides key opportunities for Extension educators to provide research based information.

The results of this experiment will provide useful PLFA sample recommendations for Missouri producers who are interested in understanding:

1) While prairie soils potentially provide the most dynamic community of microbes, variations can exist between prairies. Likewise, prairies may not be the best reference source when determining a baseline for an individual management practice. Unless a prairie is within close proximity and similar soil series, a good reference choice for producers will be an undisturbed area such as a fencerow. The undisturbed area could provide the most dynamic community of microbes for comparison.
2) In our study prairie burns did not affect total PLFA populations. Therefore, burns may not be a factor of consideration on sample timing following a burn depending on the conditions at the time of burning.
3) This study highlights the influence proper sample handling procedures for accurate analysis of microbial community structure. Correct sample handling procedures are imperative for meaningful results that a producer can utilize when considering changes in

management practices. Producer sampling protocols for PLFA analysis upon sampling should include immediate cold storage and transportation to the lab. Mailing samples to the lab should include shipping on dry ice or frozen cool packs. Delayed submittals can result in 86% error in results.

4) Hoof imprints result in impeded root growth, biological activity and water relations that are associated with WSA and PMN. Bulk density was significantly increased within the sample area. Producers should select sample sites that do not have hoof traffic.
5) The most significant animal impact on chemical and microbial communities occurred directly under the patty. The sampling process should include observations for latent or remnant cow patties that might produce a legacy affect.
6) Sample depth has a great impact on biological and chemical indicators. More microbial activity takes place at the soil surface. The typical soil fertility sample depth at 6-inch can mask or dilute biological activity. Sampling for PLFA should remain consistent at the 3-inch depth.

In order to meet the expected growing world population demands on food production, producers are reevaluating traditional management systems and considering soil health in order to maintain profitability as well as ecological and social sustainability. It is critically important for producers to have a better understanding of proper PLFA sample handling procedures when utilizing microbial data for determining management changes based on soil health assessments.

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CHAPTER FOUR

VARIABILITY OF MICROBIAL COMMUNITIES ACROSS SITES AND SYSTEMS FROM MISSOURI SOIL TYPES

Abstract

Scientific interest and newer methodologies to quantify soil health in all farming systems including eco-agriculture have increased over the last several decades, however, a lack of comprehensive investigation continues to this day. Slow adoption and diffusion of soil health management provides key opportunities for Extension educators to provide research-based information and educate the farming community about the comprehensive benefits of managing our living, breathing soils. This study viewed a multitude of crop management scenarios that are present in Missouri. Major soil series and unique site-specificity were selection factors in determining both short-term and long-term impact on soil health measurements. Ecosystems that maximize soil organic matter and good soil structure are thought to maintain higher soil biology, soil health, and plant growth. The challenge is to become more environmentally sustainable in this agro-ecosystem with limited quantitative assessment targets. As producers continue to understand their own dynamic agro-ecosystem, it is sensible for them to consider their best representative reference soil to

compare and contrast current management effects on microbial populations and diversity. Multiple microbial community groups important to soil health were determined in the phospholipid fatty acids (PLFA) assay and their values are likely useable for agricultural management decisions. When long-term prairie soil is not present, producers can select a reference area from a previously undisturbed area such as a fencerow or untilled margin that typically exist under a cool-season grass stand. Across-the-board decreases occurred in soil microbial measurements when comparing the row crop to a reference cool season crop. Total PLFA decreased 49% within row crop when compared to the cool season reference location. Bulk density increased 18% in row crop systems. Additional biological measurements decreased as much as 90% with potentially mineralizable nitrogen in the cropping system. Soil organic carbon declined 40-61% in row crop systems when compared to the reference. While chemical data varied by site-specific previous crop management, there was a measured decline with many chemical elements, across the state, when compared to the reference soil. This state-wide site specific study would indicate that developing a comprehensive soil health management plan would also be dependent on site specificity.

Keywords

Eco-agriculture, soil health, soil quality, phospholipid fatty acid, microbial community, Extension, native warm season grass, prairie.

Introduction

Ignoring the essential roles of millions of species of soil organisms (fungus, algae, bacteria, nematodes, earthworms, etc.) was a critical oversight in understanding soil as a living, breathing organism (Loynachan, 2012). Soil quality is a term that has been utilized historically in an attempt to quantify this living organism. Now the term soil quality and soil health are often use synonymously (Karlen et al., 2004).

This is a concept that includes spatial variability among soil series and within the same soil series. Typical production agriculture alters the soil microbial community due to soil disturbances or the quantity and quality of nutrient inputs. Ecologically based farming systems, or eco-agriculture, are those in which biological processers are managed on various scales from rhizosphere to field and watershed levels, to enhance efficiency, maintaining productivity, and promote sustainability (Deming et al., 2007). Scientific interest and newer methodologies to quantify soil health in all farming systems including eco-agriculture have been enhanced over the last several decades, however, a lack of comprehensive investigation continues to this day.

Utilizing the phospholipid fatty acids (PLFA) assay to measure a diverse microbial biomass with distinct PLFA markers is becoming a popular method (White, 1983; Zelles, 1999). Microbial community groups important to soil health can be determined in the PLFA assay and their values are likely useable for agricultural management decisions. Kremer (2014) discussed the benefits of understanding the microbial diversity and compared functional capabilities of soils in prairie and agriculture ecosystems.

Soil health and its effect on eco-agriculture have potential use to support sustainable producer management decisions (Kremer, 2016). Soil health parameters in agricultural lands could be compared to adjacent undisturbed areas such as native prairies or even boundaries such as fence rows. Thus began the (PLFA) analysis as a means of identifying microbial biomarkers and describing the specific community arrangement of biological activities and effects within a given ecosystem (Kremer and Veum, 2015).

The diversity of this microbiological community can be disrupted dramatically within a given agricultural ecosystem (Buyanovsky and Wagner, 1998). A key indicator of soil health is soil organic matter, which is typically measured as soil organic carbon (SOC). Tillage decreases SOC due to oxidation or mineralization, leaching and translocation, and the possibility of accelerated erosion (Lal, 2002). The increasing rate of microbial breakdown of SOC provides energy for microorganisms, which in turn releases nutrients through mineralization, becoming available for plant uptake and growth (Doran, 1987). Increases in SOC are closely associated with the activity and diversity of the microbial community which effect soil health over all (Kremer and Veum, 2015). Variable rates of respiration, which releases carbon dioxide back to the atmosphere, occur in soil. Thus, dramatic changes to this pool of SOC can result in corresponding changes to global carbon dioxide levels (Wolf and Wagner, 2005). Therefore, mineralized SOC for plant growth reduces additional energy for the community of microbial activity and presumed overall soil health.

It is well known that no-till management practices often increases SOC. Blanco-Canqui, et al. (2015) indicated those numbers could increase dramatically, as much as 20%, with the addition of cover crops and other technologies which can improve accumulations at deeper depths than no-till alone. A long-term study from Sanborn Field demonstrated that manure application coupled with residue retention could increase the overall SOM 50% above conventional tillage (Buyanovsky and Wagner, 1998).

Studies by Veum et.al (2014, 2015) indicated that soil health improves with perennial vegetation including grasses and legumes; a reduced tillage/soil disturbance; incorporation of livestock grazing and manure into the system; increased rotation diversity including cash crops and forages; and cover crops for increased soil cover and diversity of the microbial population. Utilizing these management options for improving soil health may not be practical in every ecosystem scenario. However, implementing some of these considerations in an integrated and diversified systems-management approach will likely improve soil health and benefit production agriculture overall. Figure 4.1 illustrates the continuum of soil health parameters based upon management systems (Veum et al., 2014).

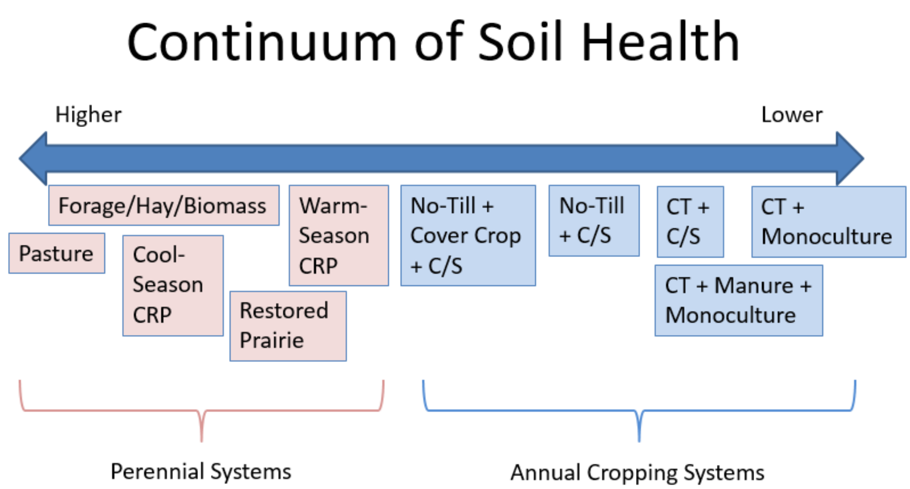

Figure 4.1: Continuum of soil health in various systems (Veum et al., 2014). {Conservation Reserve Program (CRP), Corn (C), Soybean (S), Continuous Tillage (CT)}

Soil biological properties that are critical for successful ecosystem functions and optimum soil health include microbial enzyme activity, microbial abundance, and microbial diversity (Kremer and Veum, 2015). Soil microbial diversity may be the most valuable biological component of any ecosystem. Natural ecosystems, such as prairies, are known to exhibit high microbial diversity, providing a greater range of pathways for primary production and ecological processes (e.g., nutrient cycling). These natural ecosystems also serve as valuable references for developing sustainable crop and soil management practices. In addition, reconstruction of native prairie ecosystems are often targeted on sites that have been subjected to long-term intensive cultivation with degraded soil conditions.

In order to meet the expected growing world population demand for consistent and accessible food production, producers are reevaluating traditional management systems to maintain profitability as well as ecological and social sustainability. Hunter et al. (2017) encourages consideration of the need to improve targets for production capabilities and the environment simultaneously. Ecosystems that maximize soil organic matter and good soil structure are known to maintain high biological activity, soil health, and plant growth. The challenge is to become more environmentally sustainable in this agro-ecosystem with limited quantitative assessment targets. As producers continue to understand their own dynamic agro-ecosystem, it is sensible for them to consider their best representative reference soil to compare and contrast current management effects on microbial populations and diversity. When long-term prairie soil is not present, producers can select a reference area from a previously undisturbed area such as a fencerow or untilled margin that typically exist under cool season grass stands. The key is to garner as much uncultivated baseline information as possible in order to have a better understanding of cropping system effects.

The slow adoption and diffusion of soil health management in Missouri provides key opportunities for Extension educators to provide research-based information. An integral component of soil health adoption by producers could include a better understanding of the biological functions within a soil. The diversity of biological communities can be disrupted dramatically within a given production system.

The objectives of this Missouri study are to compare selected chemical properties and microbial community structure using PLFA analysis on 1) regionally paired cropping systems where a row crop is located on the same major soil series as an adjacent cool season grass. 2) regionally paired cropping systems from a variety of management scenarios.

The hypotheses of this research include: 1) row crop systems substantially influence the highly diverse soil microbial populations when compared to perennial systems; and 2) microbial populations are useful in comparing on-site variability that exist in various management scenarios throughout the great state of Missouri.

Since 1914, Extension educators have been responsible for adult education and improving the lives and economy of citizens at the local level. It is well known that this delivery model enables adults to have the ultimate determination in what action they take as a result of that education (Battel and Krueger, 2005). The slow adoption and diffusion of soil health management in Missouri provides key opportunities for Extension educators to provide research-based information to help educate the farming community about the comprehensive benefits of managing our living breathing soils. However, data is lacking at the local level for determining the best management decisions to positively impact soil health.

Materials and Methods

PLFA analysis was used to measure microbial biomass and community composition for this work. PLFAs were extracted and esterified into fatty acid methyl esters (FAME) (Buyer and Sasser 2012). The extracts were evaporated to dryness, dissolved in hexane, and transferred to gas chromatography vials for analysis. An Agilent 6890 gas chromatograph (Agilent Technologies, Santa Clara CA) with an autosampler, split-splitless inlet, and flame ionization detector coupled to an Agilent Ultra 2 column (25 m long x 0.2 mm internal diameter x 0.33 µm film thickness) was used to separate the FAMEs under a constant flow rate of 1.2 mL min-1 of H 2 carrier gas and a split ratio of 30:1. Oven temperature started at 374 °F, ramped to 545 °F at 50°F min-1, ramped to 591 °F at 140 °F min-1, and held constant at 590° F for 2 min. Injection and detector temperatures were 482 °F and 572 °F, respectively. The microbial identification system of (MID) Sherlock ® (MIDI, Inc., Newark DE) and Agilent Chemstation software were used to control the system, and the MIDI PLFAD1 software package was used to identify and categorize the FAMEs (Buyer and Sasser 2012).

Table 4.1 describes the PLFA markers assigned to saprophytic fungi, arbuscular mycorrhizal (AM) fungi, eukaryotes, Gram-negative and Gram-positive bacteria, and actinobacteria (formally known as actinomycetes) microbial groups. For the purposes of this study, total PLFA was calculated as the sum of all microbial groups, total fungi was represented as the sum of saprophytic fungi, arbuscular mycorrhizal (AM) fungi, and total bacteria was calculated as the sum of markers assigned to Gram negative, Gram positive, and actinobacteria groups. The fungi to bacteria ratio was calculated as total fungi divided by total bacteria markers. Results were recorded in nanomoles per gram of soil (nmol/g).

Table 4.1. Microbial phospholipid fatty acid biomarkers specific for identifying microbial groups in soils analyzed in each study.

Microbial Group	Markers			
AM Fungi	16:1 w5c			
Fungi	18:2 w6c			
Gram Negative	10:0 2OH	10:0 3OH	12:1 w8c	12:1 w5c
	13:1 w5c	13:1 w4c	13:1 w3c	12:0 2OH
	14:1 w9c	14:1 w8C	14:1 w7c	14:1 w5c
	15:1 w9c	15:1 w8c	15:1 w7c	15:1 w6c
	15:1 w5c	14:0 2OH	16:1 w9c	16:1 w7c
	16:1 w6c	16:1 w4c	16:1 w3c	17:1 w9c
	17:1 w7c	17:1 w6c	17:0 cyclo w7c	17:1 w5c
	17:1 w4c	17:1 w3c	16:0 2OH	17:1 w8c
	18:1 w8c	18:1 w7c	18:1 w6c	18:1 w5c
	18:1 w3c	19:1 w9c	19:1 w8c	19:1 w7c
	19:1 w6c	19:0 cyclo w9c	19:0 cyclo w7c	19:0 cyclo w6c
	20:1 w9c	20:1 w8c	20:1 w6c	20:1 w4c
	21:1 w9c	20:0 cyclo w6c	21:1 w9c	21:1 w8c
	21:1 w6c	21:1 w5c	21:1 w4c	21:1 w3c
	22:1 w9c	22:1 w8c	22:1 w6c	22:1 w5c
	22:1 w3c	22:0 cyclo w6c	24:1 w9c	24:1 w7c
Eukaryote	15:4 w3c	15:3 w3c	16:4 w3c	16:3 w6c
	18:3 w6c	19:4 w6c	19:3 w6c	19:3 w3c
	20:4 w6c	20:5 w3c	20:3 w6c	20:2 w6c
	21:3 w6c	21:3 w3c	22:5 w6c	22:6 w3c
	22:4 w6c	22:5 w3c	22:2 w6c	23:4 w6c
	23:3 w6c	23:3 w3c	23:1 w5c	23:1 w4c
	24:4 w6c	24:3 w6c	24:3 w3c	24:1 w3c
Gram Positive	11:0 iso	11:0 anteiso	12:0 iso	12:0 anteiso
	13:0 iso	13:0 anteiso	14:1 iso w7c	14:0 iso
	14:0 anteiso	15:1 iso w9c	15:1 iso w6c	15:1 anteiso w9c
	15:0 iso	15:0 anteiso	16:0 iso	16:0 anteiso
	17:1 iso w9c	17:0 iso	17:0 anteiso	18:0 iso
	19:0 iso	19:0 anteiso	20:0 iso	22:0 iso
Actinobacteria	16:0 10-methyl	17:1 w7c 10-methyl	17:0 10-methyl	20:0 10-methyl
	18:1 w7c 10-methyl	18:0 10-methyl	19:1 w7c 10-methyl	

Regional Missouri Sample Locations

North East Missouri Region

Soils were collected from two Linn County producer/cooperator sites in March 2016:

- Fatima silt loam, 1-2% slope bottom: The soil from Missouri 39° 55' 48" N 93° 13' 51" W consisted of a corn – soybean crop rotation with a reference sample collected from a cool season grass filter strip in the Fatima series: (Fine-silty, mixed, superactive, mesic Fluvaquentic hapludolls) - These soils are formed in alluvium located on flood plains, river valleys under tree cover, and comprise approximately 90% of the map unit. The surface water runoff class is low and the natural drainage condition of the soil is moderately well drained. The top of the seasonal high water table is at 33 inches. This map unit component is assigned to the nonirrigated land capability classification 3w.
- Armstrong clay loam, 5-9% slope: The soil from Missouri 39° 57' 15" N 93° 15' 24" W consisted of a no-till, corn – soybean crop rotation with two reference samples collected from a cool season grass pasture and a road bank in the Armstrong series: (Fine, smectic, mesic Aquollic Hapludalfs) – These soils are formed in

silty loess over clayey till located on interfluves, till plains under grass/herbaceous cover and tame pastureland, and comprise approximately 96% of the map unit. The surface water runoff class is high and the natural drainage condition of the soil is somewhat poorly drained. The top of the seasonal high water table is 24 inches. This map unit component is assigned to the nonirrigated land capability classification 3e.

Soils were also collected from two Shelby County producer/cooperators on adjacent sites in March 2016.

- Putnam silt loam: The soil from Missouri N 39.814503, W -91.863613 consisted of 40-year conservation reserve program (CRP) with the last 6 years in native warm season grasses and a 4-year CRP with predominantly cool season grass in the Putnam series: (Fine, smectitic, mesic Vertic Albaqualfs) - These soils are formed in loess over pedisediment located on interfluves, till plains under crop cover and row crop, and comprise approximately 90% of the map unit. The surface water runoff class is high and the natural drainage condition of the soil is poorly drained. The top of the seasonal high water table is at 8 inches. This map unit component is assigned to the nonirrigated land capability classification 3W.

East Central Missouri Region

Soils were collected from one Franklin County producer/ cooperator at three adjacent sites in early April 2016.

Useful silt loam, 1-2% slope: The soils from Missouri 38° 26' 29" N 91° 3' 46" W consisted of a 5-year fallow followed by 6-year cultivation with last 4-years in continuous pasture; a family garden; and a near proximity fencerow in the Useful Series - (Fine, mixed, active, mesic Oxyaquic Hapludalfs). These soils are formed in loess over residuum weathered from dolomite over dolomite located on hills, hillslopes under grass/herbaceous cover and tame pastureland, and comprise approximately 90% of the map unit. The surface water runoff class is high and the natural drainage condition of the soil is moderately well drained. The top of the seasonal high water table is 33 inches. This map unit component is assigned to the nonirrigated land capability classification 3e.

Southeastern Missouri Region

Soils were collected from Scott County and Cape Girardeau County producer/cooperators in March 2016.

- Scotco sandy loam, 1-5% slope: The soils from Scott County Missouri N 37° 2' 46" -89° 35' 5.7" W consisted of a corn-soybean-soybean-soybean-wheat row crop rotation with a cool season grass reference. This producer is adopting management with more cover crops and no-till. Samples were collected from the Scotco series – (Siliceous, thermic Typic Udipsamments). These soils are formed in sandy alluvium located on alluvial plant remnants, bars on stream terraces under crop cover and row crop, and comprise approximately 90% of the map unit. The surface water runoff class is negligible and the natural drainage condition of the soil is excessively drained. The seasonal high water table is at a depth of more than 6 feet. This map unit component is assigned to the nonirrigated land capability classification 3s.

- Menfro silt loam, 5-9% slope: The soils from Cape Girardeau County Missouri 37° 18' 26" N, -89° 41' 35" W consisted of a no-till corn-soybean row crop rotation with a tillage after corn and a cool season grass reference. This producer shifted to no-till milo due to prices and samples were collected in milo residue from the Menfro Series – (Fine-silty, mixed, superactive, mesic Typic Hapludalfs). These soils are formed in loess located on hills, hillslopes under grass/herbaceous cover and tame pastureland, and comprise approximately 100% of the map unit. The natural drainage condition of the soil is well drained. The seasonal high water table is at a depth of more than 6 feet. This map unit component is assigned to the nonirrigated land capability classification 3e.

Central Missouri Region

Soils were collected from central and southern Cooper County producer/cooperators in March 2014 and again in August 2015. These locations were selected for comparison of microbial impact from 2 years of row crop following a lengthy perennial crop.

- Pershing silt loam, 2-5% slope: The soils from Missouri, 38° 48' 36" N, 93° 58' 31" W consisted of 10 year of cool season grass followed by two year of continuous soybean in an attempt to eliminate the pasture weed pressure and reestablishment of cool season grasses on the Pershing Series- (Fine, smectic, mesic, Vertic Epiaqualfs). These soils are formed in loess located on ridges on uplands under grass/herbaceous cover and tame pastureland, and comprise approximately 90% of the map unit. The surface water runoff class is very high and the natural drainage condition of the soil is somewhat poorly drained. The top of the seasonal high water table is 12 inches. This map unit component is assigned to the nonirrigated land capability classification 3e.
- Bunceton silt loam, 3-8% slope: The soils from Missouri 38° 45' 57" N, 93° 2' 40" W consisted of 50+ years of continuous cool

season grass followed by two years of a soybean-wheat rotation in an attempt to eliminate pasture weed pressure and reestablishment of cool season grasses on the Bunceton Series – (Fine-silty, mixed, active, mesic Mollic Hapludalfs). These soils are formed in loess over pedisediment over residuum weathered from chert limestone located on hills, hillslopes, ridges under grass/herbaceous cover and tame pastureland, and comprise 95% of the map unit. The surface runoff class is high and the natural drainage condition of the soil is well drained. The seasonal high water table is at a depth of more than 6 feet. The map unit component is assigned to the nonirrigated land capability classification 3e.

West Central Missouri Region

High Lonesome Prairie:

Soils were collected from northern Benton County from a corn soybean row crop and cool season grass hay producer/cooperator and prairie conservation area on the same soil series in March 2016.

- Eldon gravelly silt loam, 3-8% slope: The soils from Missouri 38° 26' 29" N 91° 3' 46" W consisted of a 30+ years of no till corn/soybean rotation, a continuous cool season hay field, and a 30+ years native warm season grass prairie on an Eldon Series - (Clayey-skeletal, mixed, active, mesic Mollic Paleudalfs). These soils are formed in slope alluvium over residuum weathered from limestone located on hills, hillslopes under grass/herbaceous cover and tame pastureland, and comprise approximately 95% of the map unit. The surface water runoff class is very high and the natural drainage condition of the soil is well drained. The seasonal high water table is at a depth of more than 6 feet. This map unit component is assigned to the nonirrigated land capability classification 3e.

North West Missouri Region

Soils were collected from a northern wildlife refuge, a Holt County producer cooperator and prairie conservation area in March 2016.

Squaw Creek National Wildlife Refuge:

- Wabash silty clay, 0-2% slope: The soils from Holt County Missouri 40° 4' 32" N 95° 15' 36" W consisted of a national wildlife refuge wetland pool on the Wabash Series – (Fine, smectitic, mesic Cumulic Vertic Endoaqualls). These soils are formed in alluvium located on river valleys, stream terraces under crop cover and row crop, and comprise approximately 90% of the map unit. The surface water runoff class is very high and the natural drainage condition of the soil is poorly drained. The top of the seasonal high water table is at 6 inches. This map unit component is assigned to the nonirrigated land capability classification 3w.

- Napier silt loam, 0-2% slope: The soils from Holt County Missouri 40° 3' 52" N 95° 13' 52" W consisted of a national wildlife refuge loess bluff bottom on the Napier-Gullied land complex – (Fine-silty, mixed, superactive, mesic Cumulic Hapludalls). These soils formed in alluvium located on drainageways on uplands under tree cover and other grass/herbaceous cover, and comprise approximately 35% of the map unit. The seasonal high water table is at a depth of more than 6 feet. This map unit component is assigned to the nonirrigated land capability classification 7e.

Little Tarkio conservation area native prairie:

- Contrary silt loam, 9-14% slope: The soils from Missouri 40° 12' 8" N 95° 18' 55" W consisted of a native warm season prairie on a Contrary Series – (Fine-silty, mixed, superactive, mesic Dystric Eutrudepts). These soils are formed in loess located on hills, hillslopes under tree cover and other grass/herbaceous cover, and comprise approximately 95% of the map unit. The surface water runoff class is medium and the natural drainage condition of the soil is well drained. The seasonal high water table is at a depth of more than 6 feet. This map unit component is assigned to the nonirrigated land capability classification 4e.

- Monona silt loam, 5-9% slope: The soils from Missouri 40° 12' 7" N 95° 18' 44" W consisted of a no-till corn or soybean row crop adjacent to the conservation area on a Monona Series – (Fine-silty, mixed, superactive, mesic Dystric Eutrudepts). These soils are formed in fine-silty loess located on loess hills on uplands under crop cover and row crop, and comprise approximately 75% of the map unit and the natural drainage condition of the soil is well drained. The seasonal high water table is at a depth of more than 6 feet. This map unit component is assigned to the nonirrigated land capability classification 3e.

Soil properties were measured using standard methods (USDA, 2004) and PLFA analysis was conducted following the Buyer and Sasser (2012) high-throughput extraction with peak identification and assignment using an Agilent 6890 gas chromatograph and the Sherlock Microbial Identification System (MIDI, Newark, NJ).

A study was conducted to compare the microbial community structure with paired samples of row crop and cool season grass as a reference point. Samples collected in the same soil series were utilized to test the use effectiveness of data in determining comparable row crop management impact. Soil properties and PLFA markers for the row crop and reference check soils were compared using ANOVA ($\alpha = 0.05$) with PROC MIXED in SAS 9.2. (SAS Institute, Cary, NC). Other comparisons will be regionally site specific based upon the Extension Specialists' selection of major soil series in their area and the impending site collaboration between local producers and conservation areas. With too many variables statewide, a simple percentage variation was used for comparisons at each site-specific management variable.

Results and Discussion

Row Crop and Reference Variations

Across-the-board decreases occurred in soil microbial measurements when comparing the row crop to a reference cool season crop (Table 4.2). Although comparisons of fungi and actinobacteria tended to differ greatly, significance at $p<0.05$ was not detected. The percentage decrease in fungi and actinobacteria from row crops were 55 and 48%, respectively.

Table 4.2. Statewide management impact on soil microbial components utilizing PLFA (nmol/g soil) analysis. (ɑ =0.05; n=6 per treatment; total n=12) Standard error in parentheses.

Variable	Reference	Row Crop	P-value	% Change
Total PLFA	185 (26.8)	94 (10.9)	0.01	-49
AMF	10.9 (1.6)	5.0 (0.9)	0.03	-54
GNEG	84.5 (11.5)	40.6 (4.6)	0.01	-52
GPOS	49.0 (6.8)	28.3 (2.6)	0.02	-42
Eukaryote	3.9 (0.5)	1.9 (0.2)	0.01	-51
Fungi	7.1 (1.4)	3.2 (0.6)	(0.051)	-55
Actinobacteria	29.1 (6.9)	15.2 (2.7)	(0.054)	-48

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria

While not significant, across the board percentage decreases occurred in soil health chemical indicator measurements when comparing the row crop to a reference cool season crop (Table 4.3). Overall CEC was decreased 33% with row crop soil.

Soil biological data declined across each row crop measurement compared with the reference soil. The percentage decrease in biological measurements from row crop to the reference location ranged from 18 to 90%. Row crop management significantly increased bulk density weight by 18%.

Table 4.3. Soil health biological and chemical indicators of statewide management. (α =0.05; n=6 per treatment; total n=12)

Variable	Reference	Row Crop	P-value	% Change
Ca (ppm)	5813 (1218)	4680 (1272)	NS	-19
Mg (ppm)	684 (152)	464 (81)	NS	-32
Na (ppm)	15 (9.7)	0.00 (0.00)	NS	-
K (ppm)	676 (106)	415 (110)	NS	-39
P (ppm)	45.2 (11.3)	52.9 (15.8)	NS	17
CEC meq/100g	19.4 (3.5)	13.0 (1.8)	0.04	-33
SOC (%)	3.1 (0.58)	1.8 (0.25)	0.03	-42
pH_s	6.1 (0.16)	5.9 (0.42)	NS	-3
pH_w	6.8 (0.14)	6.6 (0.37)	NS	-3
TN (%)	0.29 (0.04)	0.17 (0.02)	0.03	-41
PMN (ppm)	207 (47.5)	78 (11.9)	0.03	-90
AC (ppm)	791 (100)	449 (59)	0.02	-43
BD (g/cm^3)	1.1 (0.11)	1.3 (0.11)	0.005	18
WSA (%)	44.0 (7.5)	26.6 (10.3)	NS	-40

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates

Missouri Site Specific Variations

Northeast Missouri Region

Linn County Location 1: Conventional tilled corn and soybean rotational row crop management reduced total PLFA collected from Fatima silt loam (Table 4.4). This site was under a typical no-till scenario; however, management included minimal tillage for soybean in 2015 as the flood plain flooded in 2014. Soil samples were collected in March 2016.

Row crop Total PLFA decreased 60% from a non-disturbed filter strip (Table 4.4). Individual microbial components were reduced because of management from 57-74%. Fungi populations were reduced 74% within the row crop when compared to the reference.

Chemical soil health indicators decreased 6-42% Table (4.5). Potassium had the greatest decline likely due to major depletion by soybean, a crop with major K requirements (Buchholz, et al. 1983. Rev. 2004). Biological indicators decreased across the board. Potentially mineralizable nitrogen in the row crop was 60% less than the reference. Water stable aggregates had a 94% decline from the reference likely due to effects of flooding and subsequent tillage. Bulk density increased 21% in the row crop system compared to the reference.

Table 4.4. Management impact on soil microbial components utilizing PLFA (nmol/g soil) analysis of row crop and reference soil from a Fatima silt loam in Linn County.

Variable	Reference filter strip	Row Crop C-SB	% Change
Total PLFA	174	69	-60
AMF	12.2	3.5	-71
GNEG	86.2	29.2	-66
GPOS	49.8	21.4	-57
Eukaryote	3.9	1.5	-62
Fungi	11.3	2.9	-74
Actinobacteria	25.4	10.8	-57

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria; C=Corn; SB=soybean

Table 4.5. Soil health biological and chemical indicators of row crop and reference soil from a Fatima silt loam in Linn County, Missouri.

Variable	Reference	Row Crop C-SB	% Change
Ca (ppm)	2000	1660	-17
Mg (ppm)	216	204	-6
Na (ppm)	0	0	-
K (ppm)	273	156	-42
P (ppm)	34.1	32.2	-6
CEC meq/100g	13.5	11.5	-15
SOC (%)	1.8	0.94	-48
pH_s	5.7	5.6	-2
pH_w	6.4	6.4	-
TN (%)	0.18	0.1	-44
PMN (ppm)	151	61	-60
AC (ppm)	479	275	-43
BD (g/cm^3)	1.4	1.7	21
WSA (%)	38	2.3	-94

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates

Linn County Location 2: No-till corn and soybean rotational row crop management reduced total PLFA collected from Armstrong clay loam (Table 4.6). The 2015 crop was soybean and samples were collected in March 2016.

Row crop reduced total PLFA in the row crop sample when compared to both pasture and road bank references by 60 and 68%, respectively. The pasture management reduced total PLFA by 20% when compared to the undisturbed road bank alone. This may be attributed to sample location and possible concentration of livestock in that area.

With few exceptions, chemical soil health indicators were reduced from both pasture and road bank comparisons (Table 4.7). However, overall CEC was reduced 16 and 21% when compared to the pasture and road bank, respectively. This reduction could be attributed to the fertility management in row crop. Pasture management resulted in a 24% decrease when compared to the road bank, which reflects the impact from livestock. With one exception, across the board decreases in biological indicators occurred when comparing the row crop to pasture and road bank. Karlen, et al. (2014) showed similar results of significant reductions in WSA and BD when manure was applied within the past one or two years before sampling.

Water stable aggregates were higher in the row crop when compared to the pasture likely due to the potential concentration of livestock in that area. However, bulk density was greatest with row crop management. Further investigation is necessary to differentiate results. In contrast to our study, Kennedy and Schillinger (2006) showed fungal biomarkers were greater and both gram positive and gram negative bacteria were lower in no-till systems. The short-term effects, of recent tillage due to flooding in this no-till system, may explain these differences.

Table 4.6. Management impact on soil microbial components utilizing PLFA (nmol/g soil) analysis on three references sources from an Armstrong clay loam in Linn County, Missouri.

Variable	Row Crop C-SB	Pasture	% Change	Road bank	% Change
Total PLFA	69.2	172	-60	216	-68
AMF	2.1	7.9	-73	15.8	-88
GNEG	29.0	81.5	-64	103	-72
GPOS	25	48.5	-48	53.9	-54
Eukaryote	1.2	2.8	-57	4.9	-76
Fungi	0.9	5.6	-84	6.7	-87
Actinobacteria	11	25.8	-57	31.6	-65

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria; C=Corn; SB=soybean.

Table 4.7. Soil health biological and chemical indicators of row crop and reference soil from an Armstrong clay loam in Linn County, Missouri.

Variable	Row Crop C-SB	Pasture	% Change	Road bank	% Change
Ca (ppm)	1680	2700	-37	3860	-43
Mg (ppm)	408	312	31	264	55
Na (ppm)	0	0	0	23	-
K (ppm)	117	312	-63	312	-63
P (ppm)	6.6	6.4	3	12	-45
CEC meq/100g	16.1	19.2	-16	20.5	-21
SOC (%)	1.9	3.4	-44	3.7	-49
pH_s	4.5	5.5	-18	6.7	-33
pH_w	5.3	6.0	-12	7.1	-25
	0.18	0.37	-51	0.33	-45
PMN (ppm)	27	226	-88	155	-83
AC (ppm)	312	740	-58	1033	-70
BD (g/cm^3)	1.4	1.3	7	1.1	27
WSA (%)	21	15	40	54	61

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates; C=Corn; SB=soybean.

Shelby County: Two adjacent samples, collected in March 2016, were selected from a Putnam silt loam. A previously cropped corn, soybean and wheat rotation was converted to a continuous cool season grass CRP for the past five years. The adjacent sample had previously been in the CRP program for the past 30+ years as a cool season grass and in 2012, it was no-tilled to native warm season grass (NWSG). The past five year's management included a 2014 burn.

With the exception of gram positive bacteria and fungi, soil microbes were 6-31% lower in the 30-year CRP when compared to the younger CRP (Table 4.8). Both microbe increases could be explained by the accumulation of plant residue at the surface on the 30-year CRP. Allison et al. (2005) discussed the importance of fungi in more effective decomposition of substrates than bacteria as soils return to a more natural state. The continuum of soil health (Figure 4.1) would confirm the higher microbial population in the cool season grass (Veum et al. 2014).

Soil organic carbon, total N, and potentially mineralizable N were all greater in the 40-year CRP sample (Table 4.9). This result also corresponds to the accumulation of plant materials at the surface. The pH variance was likely a result of remnants of the previous cropping management, which would have included periodic additions of lime.

Table 4.8. Management impact on soil microbial components utilizing PLFA (nmol/g soil) analysis from a Putnam silt loam from Shelby County, Missouri.

Variable	5 year Cool CRP	5 year NWSG CRP	% Change
Total PLFA	181	150	-17
AMF	13.6	9.4	-31
GNEG	83	78	-6
GPOS	45	48	7
Eukaryote	4.9	4.2	-14
Fungi	6.2	7.2	16
Actinobacteria	28	26	-21

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria; Cool=cool season grass NWSG=native warm season grass; CRP=conservation reserves program

Table 4.9. Soil health biological and chemical indicators of row crop and reference soil from a Putnam silt loam in Shelby County, Missouri.

Variable	4 year Cool CRP	5 year NWSG CRP	% Change
Ca (ppm)	4060	2580	-36
Mg (ppm)	192	180	-6
Na (ppm)	0	23	-
K (ppm)	117	195	66
P (ppm)	12.6	14.2	13
CEC meq/100g soil	19.1	17.2	-10
SOC (%)	2.4	3.2	33
pH_s	6.9	5.3	-23
pH_w	7.4	6.1	-18
TN (%)	0.23	0.32	39
PMN (ppm)	130	194	46
AC (ppm)	786	708	-10
BD (g/cm^3)	1.1	1.3	18
WSA (%)	34	44	29

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates

East Central Missouri Region

Soils collected from Franklin County included adjacent locations of garden with frequent tillage, pasture, and fencerow reference.

The impact from garden management resulted in a 43 and 37% decrease in total PLFA from both the pasture and fencerow references, respectively (Table 4.10). With the exception of fungi, soil microbes were 21-52% lower in the garden soil. This increase in fungi was unexpected and likely, a result of winter annual populations or an accumulation of previously tilled residue. The high accumulation of K and P in the pasture likely is a product of the cool season grazing system where subsurface mining by roots occurs and is ultimately, deposited on the surface (Table 4.11). Active carbon was considerably lower in the garden sample than both the pasture and fencerow at 75 and 71%, respectively. Repeated tillage throughout the season was likely the cause of this reduction in active carbon.

Table 4.10. Garden management impact on soil microbial components utilizing PLFA (nmol/g soil) analysis and two reference locations from a Useful silt loam in Franklin County, Missouri.

Variable	Garden	Pasture	% Change	Fencerow	% Change
Total PLFA	92	160	-43	146	-37
AMF	4.4	9.3	-53	9.1	-52
GNEG	40	73	-45	67	-40
GPOS	27	44	-39	41	-47
Eukaryote	1.9	2.4	-21	2.4	-21
Fungi	4.7	2.3	105	2.7	74
Actinobacteria	14	29	-52	24	-42

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria.

Table 4.11. Soil health biological and chemical indicators of garden crop and reference soils from a Useful silt loam in Franklin County, Missouri.

Variable	Garden	Pasture	% Change	Fencerow	% Change
Ca (ppm)	1660	1420	17	1480	12
Mg (ppm)	252	444	-49	360	-30
Na (ppm)	23	0	-	0	-
K (ppm)	234	819	-71	312	-25
P (ppm)	51	61	-16	24	113
CEC meq/100g	12.2	17.3	-29	15.1	-19
SOC (%)	2	2.4	-17	2	0
pH_s	5.2	5.9	-12	5.6	-7
pH_w	5.8	6.5	-11	6.1	-5
TN (%)	0.18	0.27	-33	0.23	-22
PMN (ppm)	91	137	-34	148	-39
AC (ppm)	200	800	-75	699	-71
BD (g/cm^3)	1.3	1.4	-7	1.2	8
WSA (%)	15	23	-35	41	-63

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates

Southwest Missouri Region

Scott County: Soils were collected from a corn-soybean-soybean-soybean-wheat row crop rotation with a cool season grass reference in Scott County in March of 2016. The field was previously corn with fall tillage and wheat sown in the fall.

The rotational row crop management reduced total PLFA 37% on soils collected from Scotco sandy loam (Table 4.12). Individual microbial components were reduced from the reference ranged 18-58%. The greatest impact occurred with fungi populations.

Chemical soil health indicators decreased 25-58% Table (4.13). Biological indicators decreased across the board. Total nitrogen and potentially mineralizable nitrogen in the row crop were 75 and 76% less than the reference, respectively. This may be attributed to the row crop management system. Water stable aggregates had a 32% decline from the reference likely due to effects of flooding and subsequent tillage. Bulk density increased 67% in the row crop system compared to the reference.

Table 4.12. Management impact on soil microbial components utilizing PLFA (nmol/g soil) analysis from a Scotco sandy loam in Scott County, Missouri.

Variable	Reference cool	Row Crop C-SB-SB-W	% Change
Total PLFA	135	85	-37
AMF	6.2	5.1	-18
GNEG	64	40	-38
GPOS	35.5	24.6	-31
Eukaryote	3.4	2.1	-38
Fungi	11.3	4.8	-58
Actinobacteria	14.9	8.8	-41

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria; Cool=cool season grass; C=Corn; SB=soybean; W=wheat.

Table 4.13. Soil health biological and chemical indicators of row crop and reference soil from a Scotco sandy loam in Scott County, Missouri.

Variable	Reference cool	Row Crop C-SB-SB-W	% Change
Ca (ppm)	2220	940	-58
Mg (ppm)	228	168	-26
Na (ppm)	23	0	-
K (ppm)	156	117	-25
P (ppm)	50	34	-32
CEC meq/100g	15.3	6.4	-58
SOC (%)	4.4	1.7	-61
pH_s	6.2	6.4	3
pH_w	6.7	7.0	4
TN (%)	0.4	0.1	-75
PMN (ppm)	432	103	-76
AC (ppm)	708	786	11
BD (g/cm^3)	0.6	1.0	67
WSA (%)	59	40	-32

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates

Cape Girardeau County: The soils were collected from a corn-soybean no-till row crop rotation with a cool season grass reference from a producer/cooperator in Cape Girardeau County in March of 2016. The previous crop was no-till milo and the spring soil sample was collected from residue and cover crop.

The corn and soybean rotational row crop management reduced total PLFA 7% on soils collected from Menfro silt loam (Table 4.14). With the exception of actinobacteris, individual microbial components were reduced from the reference ranged 1-32%. The greatest impact occurred with both fungi and eukaryote populations by 31 and 32%, respectively. Edwards et al. (1992) showed that due to the additional carbon provided by pesticides, bacteria numbers continued to sustain growth when compared to the non-treated soil.

With the exception of Ca, chemical soil health indicators decreased 11-69% Table (4.13). The pH levels were also increased in the row crop management due to recent lime applications. Biological indicators decreased across the board and ranged from 11-20% losses in the row crop. Bulk density increased 18% in the row crop system compared to the reference, which is reflective of increased mechanization.

Table 4.14. Management impact on soil microbial components utilizing PLFA (nmol/g soil) analysis from a Menfro silt loam in Cape Girardeau County, Missouri.

Variable	Reference cool	Row Crop C-SB	% Change
Total PLFA	123	114	-7
AMF	7.2	6.1	-15
GNEG	56	47	-16
GPOS	34.1	33.9	-1
Eukaryote	2.8	1.9	-32
Fungi	4.8	3.3	-31
Actinobacteria	17.8	21.3	20

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria; Cool=cool season grass; C=Corn; SB=soybean.

Table 4.15. Soil health biological and chemical indicators of row crop and reference soil from a Menfro silt loam in Cape Girardeau County, Missouri.

Variable	Reference cool	Row Crop C-SB	% Change
Ca (ppm)	2400	3240	35
Mg (ppm)	276	120	-57
Na (ppm)	0	0	-
K (ppm)	507	156	-69
P (ppm)	88	78	-11
CEC meq/100g soil	16	12	-25
SOC (%)	1.9	1.6	-16
pH_s	6.4	6.9	8
pH_w	6.9	7.4	7
TN (%)	0.19	0.17	-11
PMN (ppm)	123	98	-20
AC (ppm)	604	526	-13
BD (g/cm^3)	1.1	1.3	18
WSA (%)	11.7	10.4	-11

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates; Cool=cool season grass; C=Corn; SB=soybean.

Central Missouri Region

Central Cooper County

Location 1: This site was selected due to an impending management change. A thinning 10-year old stand of perennial cool season grass hay was being prepared for a renovation. The renovation choice was a chemically killed stand followed by two seasons of soybean. Samples were collected in spring 2014 prior to renovation and fall 2015 after two seasons of soybean.

Total PLFA was reduced by 30% within the two-year succession of soybean (Table 4.16). Individual microbial components were reduced from 24 to 52% as a result of the cropping system. The greatest reduction occurred with fungi at 52%.

The K level dropped 50%, likely due to soybean removal of this nutrient (Buchholz, et al. 1983. Rev. 2004) (Table 4.17). The poor cool season grass condition prior to a more intense row crop scenario likely explains any increases in biological and chemical indicators.

Table 4.16. Management impact on soil microbial components utilizing PLFA (nmol/g soil) analysis from a 10 year old perennial cool season grass followed by 2-year soybean crop from a Pershing silt loam in central Cooper County, Missouri.

Variable	10 year Cool	Row Crop SB-SB	% Change
Total PLFA	148	103	-30
AMF	9.6	5.7	-40
GNEG	59	45	-24
GPOS	43	29	-33
Eukaryote	4.0	2.5	-38
Fungi	8.2	3.9	-52
Actinobacteria	24	17	-29

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria; Cool=cool season grass; SB=soybean.

Table 4.17. Soil health biological and chemical indicators of row crop and reference soil from a 10 year old perennial cool season grass followed by 2-year soybean crop from a Pershing silt loam in central Cooper County, Missouri.

Variable	10 year Cool	Row Crop SB-SB	% Change
Ca (ppm)	2460	2860	16
Mg (ppm)	144	132	-8
Na (ppm)	0	0	-
K (ppm)	78	39	-50
P (ppm)	9.4	20	113
CEC meq/100g soil	12.8	14.9	16
SOC (%)	1.6	1.8	13
pH_s	7.0	6.8	-3
pH_w	7.4	7.2	-3
TN (%)	0.16	0.18	13
PMN (ppm)	89	76	-15
AC (ppm)	467	533	14
BD (g/cm^3)	-	1.4	-
WSA (%)	35	42	20

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates; Cool=cool season grass; SB=soybean.

Southern Cooper County

Location 2: This site was also selected due to impending management changes. A thinning 40-year old stand of perennial cool season grass hay was being prepared for a renovation. The renovation choice was a chemically killed stand followed by one season of soybean followed by one season of wheat. Samples were collected in spring 2014, prior to renovation, and fall 2015 prior to reestablishment of cool season grass.

The two-year crop rotation reduced Total PLFA by 23% (Table 4.18). Individual microbial components reduced from 17 to 64%. The greatest individual reduction occurred with fungi at 64%. Tillage associated with row crops has greatest impacts on fungi populations. Tillage associated with row crop has the greatest impact on fungi populations (Lal, 2002).

Chemical indicators increased after two years of row crop (Table 4.19). Fertility applications necessary for row crop production can explain these increases. Most biological indicators increased with row crop management. However, WSA was reduced by 26%. Certain microbes involved in soil aggregate formation, including fungi, were also decreased (4.18), likely contributing to the correspondingly lower WSA due to tillage.

Table 4.18. Management impact on soil microbial components utilizing PLFA (nmol/g soil) analysis from a 40+ year old perennial cool season grass followed by 2-year soybean-wheat row crop from a Bunceton silt loam in southern Cooper County, Missouri.

Variable	40+ year Cool	Row Crop SB-W	% Change
Total PLFA	189	144	-23
AMF	10.5	7.7	-27
GNEG	76.6	63.4	-17
GPOS	57.1	43.9	-23
Eukaryote	4.7	2.8	-40
Fungi	6.9	2.5	-64
Actinobacteria	33	24	-27

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria; Cool=cool season grass; SB=soybean; W=wheat.

Table 4.19. Soil health biological and chemical indicators of row crop and reference soil from a 40+ year old perennial cool season grass followed by 2-year soybean-wheat row crop from a Bunceton silt loam in central Cooper County, Missouri.

Variable	40+ year Cool	Row Crop SB-W	% Change
Ca (ppm)	14.2	15.8	11
Mg (ppm)	288	312	8
Na (ppm)	0	0	-
K (ppm)	156	195	25
P (ppm)	18	34	89
CEC meq/100g soil	18	20	11
SOC (%)	2.4	2.8	17
pH_s	6.3	5.9	-6
pH_w	6.8	6.4	-6
TN (%)	0.25	0.3	20
PMN (ppm)	71	144	103
AC (ppm)	578	757	31
BD (g/cm^3)	-	1.04	-
WSA (%)	70	52	-26

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates; Cool=cool season grass; SB=soybean; W=wheat.

West Central Missouri Region

Benton County

The Hi Lonesome Prairie Conservation Area is an unplowed (since the early 1970s) native prairie. This area receives annual burning but not prior to sampling. Prior to that, the property was grazed native warm season grasses. The adjacent no-till row crop had recent minimal tillage necessary for surface rill erosion management on this Eldon gravelly silt loam with 3-8% slopes. The cool season hay field has never received cultivation.

Cool season hay produced greater total PLFA than both row crop and NWSG fields (Table 4.20). When compared to the cool season hay, NWSG reduced total PLFA by 33%. With most tillage operations, a typical reduction of eukaryotes and fungi occur. The recent tillage activity did not express this reduction at sampling. Bardgett and McAllister (1999) showed that, in some cases, N fertilizer increased fungi despite decreased root biomass.

Row crop chemical indicators were greater than both cool season grass hay and NWSG (Table 4.21). No-till cropping leaves much of the residue at the soil surface. An unexpected level of row crop SOC, similar to NWSG, is likely due to the limited time for decomposition following the recent tillage. Row crop BD was lowest likely due to recent tillage.

Table 4.20. Management impact on soil microbial components utilizing PLFA (nmol/g soil) analysis on three references sources from an Eldon gravely silt loam in Benton County, Missouri.

Variable	Row Crop C-SB	Hay Cool	% Change	NWSG	% Change
Total PLFA	165	209	26	139	-16
AMF	10.4	11.5	11	7.9	-24
GNEG	78.5	95.0	21	67.8	-14
GPOS	37.6	57.8	54	37.9	1
Eukaryote	7.7	6.0	-22	2.6	-66
Fungi	7.1	3.6	-44	4.3	-39
Actinobacteria	23.6	35.3	53	18.9	-17

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria; Cool=cool season grass; NWSG=native warm season grass.

Table 4.21. Soil health biological and chemical indicators of row crop and reference soil from an Eldon gravely silt loam in Benton County, Missouri.

Variable	Row Crop C-SB	Hay Cool	% Change	NWSG	% Change
Ca (ppm)	5660	2020	-64	2220	-61
Mg (ppm)	204	276	35	264	29
Na (ppm)	.1	0	-	0	-
K (ppm)	468	273	-42	117	-75
P (ppm)	13.7	4.3	-69	2.8	-80
CEC meq/100g soil	20.7	14.9	-28	18.3	-12
SOC (%)	3.7	2.8	-24	3.8	3
pH_s	7.3	6.1	-16	5.7	-22
pH_w	7.6	6.8	-11	6.2	-18
TN (%)	0.34	0.29	-15	0.32	-6
PMN (ppm)	147	202	37	152	3
AC (ppm)	578	689	19	760	31
BD (g/cm^3)	0.9	1.17	30	1.13	26
WSA (%)	33.6	85.2	154	70.5	110

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates; Cool=cool season grass; NWSG=native warm season grass.

Northwest Missouri Region

Holt County Location 1: Squaw Creek National Wildlife Refuge, changed to Loess Bluffs National Wildlife Refuge on January 11, 2017, was established in 1935. The habitat is a geological formation of fine silt deposited after the glaciation period and contains some of the last parcels of native prairie plants. The sample site includes a permanent intermittent wetland, which was dry during the March 2016 sample period. The second undisturbed location contains a loess bluff with naturally occurring erosion onto the NWSG toe slope.

Samples collected from Squaw Creek provided baseline soil health data measurements from both Wabash and Napier virgin Missouri soils (Tables 4.22 and 4.23). The differences are likely due to the inherent soil type and landscape position.

Table 4.22. Management impact on soil microbial components utilizing PLFA (nmol/g soil) analysis from Squaw Creek National Wildlife Refuge wetland and an adjacent bluff bottom native warm season grass on Wabash silt loam and Napier silt loam, respectively from Holt County, Missouri.

Variable	Wetland NWSG	Bluff Bottom NWSG	% Change
Total PLFA	297	138	-54
AMF	15.0	8.7	-42
GNEG	130	60	-54
GPOS	78.9	38.5	-51
Eukaryote	5.9	2.9	-51
Fungi	6.0	2.7	-55
Actinobacteria	62	26	-58

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria; NWSG=native warm season grass.

Table 4.23. Soil health biological and chemical indicators from Squaw Creek National Wildlife Refuge wetland and a bluff bottom native warm season grass on Wabash silt loam and Napier silt loam, respectively, from Holt County, Missouri.

Variable	Wetland NWSG	Bluff Bottom NWSG	% Change
Ca (ppm)	5480	5100	-7
Mg (ppm)	708	240	-66
Na (ppm)	0	0	-
K (ppm)	468	468	0
P (ppm)	64	115	80
CEC meq/100g soil	36.2	19.5	-46
SOC (%)	5.0	2.8	-44
pH_s	6.2	7.1	15
pH_w	6.8	7.7	13
TN (%)	0.39	0.24	-38
PMN (ppm)	237	93	-61
AC (ppm)	1106	666	-40
BD (g/cm^3)	0.83	1.0	20
WSA (%)	61	71	16

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates; NWSG=native warm season grass.

Holt County Location 2: Little Tarkio Natural Area is one of the few remaining deep prairie remnants in northwest Missouri with fertile loam soils that extend beyond five feet in depth. The sample site includes a row crop field adjacent to the natural area.

The two-year crop rotation reduced Total PLFA by 29% (Table 4.24). Individual microbial components reductions ranged from 27 to 55% when compared to the tilled row crop. The greatest individual reduction occurred with fungi at 55%. Tillage associated with row crop has the greatest impact on fungi populations (Lal, 2002).

Row crop chemical indicators were greater than NWSG (Table 4.25). This dramatic increase in P is likely a result of fertility requirements for row crop management. Bulk density increased 10% with row crop management likely due to the additional mechanical practices. The remaining biological indicators decreased with row crop management. Water stable aggregate decreased 91% when compared to the NWSG. A combination of the reduced arbuscular mycorrhizae fungi, fungi, and actinobacteria (Table 4.24) also contributes greatly to the reduction of WSA. The coarser silty soil under row crop is likely, not providing as much colloidal clay necessary to stick the larger particles together.

Table 4.24. Management impact on soil microbial components utilizing PLFA (nmol/g soil) analysis from Little Tarkio Natural Area and an adjacent bluff no-till corn-soybean row crop on a Contrary silt loam and Monona silt loam, respectively from Holt County, Missouri.

Variable	NWSG	Row Crop C-SB	% Change
Total PLFA	140	100	-29
AMF	8.3	4.5	-46
GNEG	58.6	44.0	-25
GPOS	41.6	30.5	-27
Eukaryote	3.1	2.1	-32
Fungi	6.7	3.0	-55
Actinobacteria	22	16	-27

AMF= arbuscular mycorrhizae fungi; GPOS=gram positive bacteria; GNEG=gram negative bacteria; NWSG=native warm season grass.

Table 4.25. Soil health biological and chemical indicators from Little Tarkio Natural Area and an adjacent no-till corn-soybean row crop on a Contrary silt loam and Monona silt loam, respectively from Holt County, Missouri.

Variable	NWSG	Row Crop C-SB	% Change
Ca (ppm)	2560	2680	5
Mg (ppm)	324	288	-11
Na (ppm)	0	0	-
K (ppm)	390	429	10
P (ppm)	21	61	190
CEC meq/100g soil	18.4	20.3	10
SOC (%)	2.4	2.0	-17
pH_s	5.8	5.3	-9
pH_w	6.3	5.7	-10
TN (%)	0.22	0.21	-5
PMN (ppm)	105	76	-27
AC (ppm)	492	490	-.4
BD (g/cm^3)	1.26	1.38	10
WSA (%)	83	7	-91

SOC=soil organic carbon; TN=total nitrogen; PMN=potentially mineralizable nitrogen; AC=active carbon; BD=bulk density; WSA= water stable aggregates; NWSG=native warm season grass.

Conclusion

Utilization of PLFA assay to assess variations in microbial populations and subsequent utilization as a management tool in eco-agricultural systems is in its infancy. This study viewed a multitude of crop management scenarios that are present in Missouri. In each scenario, major soil series and unique site-specificity were selection factors in determining both short-term and long-term impact on soil health measurements.

It is well know that reduced tillage or no-tillage promotes fungal growth and improved microbial activity. Tillage increased losses of SOC due to oxidation or mineralization, leaching and translocation, and the possibility of accelerated erosion (Lal, 2002). Soil health and its effect on eco-agriculture have potential use in developing sustainable producer management decisions (Kremer, 2016). Perennial systems rate higher on the continuum of soil health than annual cropping systems (Veum et al., 2014). Therefore, some of the regional results were anticipated when tillage was a part of the management. Adding no-till and crop rotation diversity improved soil health measurements. Soil health measurements improved with perennial vegetation such as cool season pasture, hay fields, and margins in each of our site-specific locations. A corresponding reduction of soil health indicators occurred when comparing NWSG to cool season grass in the side-by-side comparison of Conservation Reserve Program. Other site comparisons between virgin NWSG soils indicated that soil series and landscape position had great impact on microbial communities.

The slow adoption and diffusion of soil health management in Missouri provides key opportunities for Extension educators to provide research-based information to help educate the farming community about the comprehensive benefits of managing our living breathing soils. Producers have a working knowledge that SOC is the driving force of energy in production. However, a comprehensive understanding of the essential roles of individual components of soil health are less known. This state-wide site specific study would indicate that a comprehensive soil health management plan would also be dependent on site specificity. Further education would provide a means for producers to make informed management decision that can improve production capabilities in an ecological and sustainable way.

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CHAPTER FIVE

CONCLUSION

For centuries, human agriculture and forestry practices have often ignored important soil functions that sustain complex biological communities. The “Dirty Thirties” are an example where soil losses were tremendous. This dust bowl tragedy was the catalyst that resulted in the 1935 Congressional Soil Conservation Act, which ensured the diffusion of numerous soil conservation practices. The results stimulated the biggest shift in producer concepts and the direction of production agriculture and land management.

Simultaneously, academia was charged with providing a better understanding of soil. The 1938 Yearbook of Agriculture – Soils and Men primarily focused on soil as a single topic of interest to the public. The scientific community was beginning to address the underlying concern of food and fiber globally. Following World War II, munitions factories were converted into fertilizer factories and this new driving force led to substantial increases in production agriculture by replacing manure with commercial fertilizer. Mechanization was replacing animal power and less emphasis was placed upon livestock forages in the production system. Advances in mechanization and technology continue today providing global realities coupled with environmental and ecological awareness as agriculture progresses into the future.

Today, the United Nations Department of Economic and Social Affairs estimates a world population of nine billion by 2050. This dramatic increase will require producers to improve production capacities and reevaluate the foundational support that soils provide in this process. These global realities coupled with environmental awareness have resulted, most recently, in long-term ecological considerations of soil beyond the concept of soils simply as a medium for biological root growth. It is now necessary for producers to assess and improve a soil's health, or the capacity of a soil to function within ecosystem boundaries in order to sustain biological productivity, maintain environmental health, and promote plant and animal health through the generations while meeting this growing population demand.

After decades of overlooking the important role that soil microbiology contributes in this process, there has been an increasing focus on soil health and its effect on sustainability. Most recently, Soil Health was identified as an agency "national initiative" by the U.S. Department of Agriculture (USDA) in November 2012. Agricultural producers are bombarded by often conflicting or confusing "testimonials" and anecdotal information at workshops, seminars, in the popular press, and in local coffee shops. The confusion, resulting in slow adoption and diffusion of soil health management by producers in

Missouri, offers key opportunities for Extension educators to provide research-based information. An integral component of soil health adoption by producers should include a better understanding of the biological functions within a soil.

Studies indicated that soil health improves with perennial vegetation including grasses and legumes; a reduced tillage/soil disturbance; incorporation of livestock grazing and manure into the system; increased rotation diversity including cash crops and forages; and cover crops for increased soil cover and diversity of the microbial population. Utilizing all of these options for improving soil health may not be practical in every management scenario. However, implementing some of these considerations in an integrated and diversified systems-management approach will likely improve soil health and benefit production agriculture overall. There is currently a gap in the knowledge base determining the basic scientific implications of soil health data as impacted by production systems.

This research was conducted to present a snapshot of production management's variable impacts on microbial communities utilizing the phospholipid fatty acid (PLFA) assay to compare and characterize differences in the structure and activities of microbial communities in both natural and managed environments. The analysis includes quantifying saprophytic fungi, mycorrhizae fungi, Gram negative (G-) and positive (G+) bacteria, actinobacteria, and protists.

The validity of precise sampling and handling processes is important in any research experiment and for the education of producers collecting biological samples. Producers have a limited understanding of correct soil health sampling procedures, which can potentially lead to collection of samples that reveal limited meaningful results. Our results compared sample handling treatments representing typical producer-collected sample handling and the associated potential errors. Our results showed 6-38% total PLFA losses when air dried, 3-56% losses when stored moist in a plastic container, and up to 86% when oven dried representing a sample stored in a vehicle on a hot summer day. This amount of error is substantial and would likely impede the progress of producers adopting soil health management practices in a meaningful way. Producer sampling protocols for PLFA analysis should include immediate cold storage and transportation to the lab. Mailing samples to the lab should include shipping on dry ice or frozen cool packs.

The current understanding of assessing PLFA in eco-agriculture systems includes comparison to a perennial reference location. While it was expected that PLFA totals would vary between perennial systems and eco-agriculture systems, this difference varied by site and management scenarios. This site specific variance occurred when comparing two selected prairie environments. The lack of significant differences between pre and post burn at the prairie sites were unexpected. As a result, prairies may not be the best reference source when determining a baseline for an individual production management practice. Unless a prairie is within close proximity and similar soil series, a good reference choice for producers will be an undisturbed area such as a fencerow. The perennial undisturbed area could provide the most dynamic community of microbes for comparison.

Our studies included potential sampling errors and educational opportunities for livestock producers as well. We studied both hoof and cow patty effects on the microbial community. The hoof treatment affected arbuscular mycorrhizal fungi, potentially mineralizable nitrogen, water stable aggregates, and bulk density compared to the control. While BD levels decreased as expected, the additional reduced values of other measurements are indicative of impeded root growth, biological activity and water relations. As expected, the most significant animal impact on chemical and microbial communities occurred directly under the patty. While, cow patty center location had no effect on total PLFA content, it significantly increased fungi, which are the primary decomposers of lignin and other complex plant substances that comprise ruminant fecal material. Sampling processes within livestock systems, should include observations for latent or remnant cow patties that might produce a legacy affect.

Utilization of PLFA assay to assess variations in microbial populations and subsequent application as a management tool in eco-agricultural systems is in its infancy. In cooperation with Missouri producers around the state, this study viewed a multitude of crop management scenarios. In each scenario, major soil series and unique site-specific criteria were selection factors in determining both short-term and long-term impacts on soil health measurements.

Variations in regional results were anticipated when tillage was a part of the management. Adding no-till and crop rotation diversity improved soil health measurements. Soil health measurements improved with perennial vegetation such as cool season pasture, hay fields, and margins in each of our site-specific locations. A corresponding reduction of soil health indicators occurred when comparing native warm season grass (NWSG) to cool season grass in the side-by-side comparison of Conservation Reserve Program sites. Part of this reduction may be indicative of the time-of-year sampling where the cool season grasses were actively growing. Further studies are necessary to discern these growing season variations.

Since 1914, Extension educators have been responsible for adult education and improving the lives and economy of citizens at the local level. It is well known that this delivery model enables adults to have the ultimate determination in actions they take as a result of that education. The slow adoption and diffusion of soil health management in Missouri provides key opportunities for Extension educators to provide research-based information to help “show me” the benefits of managing our living, breathing soils. This study indicates that a comprehensive soil health management plan would also be dependent on site-specific parameters with recommendations made accordingly. Further education would provide a means for producers to make informed management decision that can improve production capabilities in an ecological and sustainable way.

APPENDIX A

Demographic and Background Questions:

Sex: M F

Age: __76___

Race: __M____

Level of formal education: ____HS_______ if college, what field of study___________

Acres farmed___300________

-Alright, the recorder is on

-Tell me about your farming operation from a historical perspective…when it was established, basic farming philosophy, when you started and where you are now?

Well, I farmed first with my Dad, I grew up on the farm I learned all of his techniques; I would say that he was a very progressive farmer and then in about 1963 I bought this farm. It is not a large row crop farm and I did my farming myself in my spare time because I had an outside job or business. And then different things came along, you know the old practice was to plow your ground every year and work it in the spring, cultivate the weed, cultivate the corn or bean whatever you were putting out and as time went on I eliminated the plow I just disked the ground because I have creek bottom down here and if the creek got up I noticed that some of the dirt would leave.

1:40

-do you remember what year that was when you started that practice

It was probably about 30 years ago because we have been here 50 years. It has probably been more than 30 years because I remember talking to Dad about it and he said, Well give it a try and see how it works. It worked ok for me. But then when they started no-tilling, and then looking at the records, it was 20 seasons ago that I bought my planter and set it up for no-till a 7000 john Deere planter. And I went everything 100% no-till from then on and I remember several farmers from around saying well when you plant them beans in that stubble corn, you are going to find out that you are going to have a mess when you go to combine it. And I never combined so slick in my life as that was. And I went to different no-till conferences quite a bit. In fact there is a no-till magazine that comes out of Iowa that I subscribe to it and I got different ideas about no-till and pretty much set it up so that it work. It worked for me year after year so if it is working sometimes if it isn't broke don't change it. But then I went to a thing in Illinois it was a no till thing again. He said I want you to notice how much taller my corn is where I plant across the row. And he had planted across the rows and it was just so obvious that the corn was so much taller. So I got to thinking what would it be like to have an applicator with 6 row, 6row on 30 inch rows and just plant down the rows. I had that idea for 4-5 years before I did anything about it but mostly because I didn't have time to build one. And so, I built this applicator with markers and everything and started using them and that was 15 years ago and I have been using it consistently and there have been several farmers that have rented it since that do it. Over at Pilot Grove there is guy a farmer that does all of his corn ground with it. And that really you know really paid off. You have got to be careful because you can have some burn, nitrogen burn, you want to wait a week or so before you plant if you can. And it makes a difference too on the type of soil that you are planting it in and but the interesting point that even in that time the soil I noticed it came out of it and I took a guy back here to a back field where the soil is pretty much down to clay and I said I want to notice that you can't tell a lot difference between the clay over the good ground. I mean it just really made a difference so that to me was the I guess you would call it say now I don't know-till I strip till because it works the ground and I just plant it to rows.

5:40

-An so you said there was somebody else in the area that saw what you did and are using that same practice now. Do you have any other references of people shifting to some of things you are doing.

In this no-till magazine I saw a guy in Iowa in SW Iowa I saw a picture of him doing it and so I called him and we talked for a while, and in fact one of the things that I talked to him about was stabilizer in nitrogen. He asked me where I was from and told him he said you don't need nitrogen stabilizer in that area he said you are wasting your money. He said I sell the stuff but that was his opinion. I just remember that much about him.

6:40

-So, what we are really going to spend a little bit of time, I appreciate that, you were telling me a little bit of the things that your dad did in your life time. Would you tell me some of the things that your dad taught you?

Yes Dad back in the early 50s, was one of the first to spread 42% liquid nitrogen. It was a John Blue pump I remember that he used that pumped it. He had a 47 Chevrolet 2 ton truck that we put two tanks on. We had steel tanks first and they corroded out. So we got aluminum tanks and they held up. That was really, I think, the first source of nitrogen that we had available here. He would go down the road and just pull into a farmer's wheat field and just make a circle just to show them what it would do. And the next year, they was wanting it. He didn't even farm for several years because the demand was so great that he just custom applied. We took a, he had an A

John Deere and we put a regular cultivator on that you cultivate corn with and put knives on it and a tank mounted on the back and went all over the county went out other counties and just did it right up until the corn was side dressed. I can remember the corn sometimes being too tall that we would lean it over. I remember a farmer (######) came down there and said I don't care, lean that corn over, put it on. Then I was telling you back in late 50s we was already spreading lime and it might have been before that. I just remember one incident had to be in the late 50s we was putting lime on. Dad when I was very young kid we had a 38 Chevrolet and dad went to the quarry pulling a trailer behind that Chevrolet and filled it with lime and bring it home. I don't remember how he spread it or anything like that but he was aware that lime was a useful tool in your fertility system. Dad also bought the first John Deere combine that was sold down here in Cooper County in Boonville. There again he just didn't farm anything hardly anything at all he did was combine all fall long. In fact guys were waiting for us to combine so they could plant. So we combined all through the winter. My senior year of school I missed 37 days.

-So that was the year that corn husking stopped in Cooper County? That is pretty funny.

10:30

Well I have said too that the happiest day of my life was when the team of mules ran off with the wagon and strung corn from the front of the place and then another mile down another road past our house and there was nothing left but the two front wheels of the wagon and Dad went and bought a corn picker.

11:00

So I want to go back to more of the topic at hand here where most of my program is about here. The topic is soil health and I talked with you about diffusion of innovation so What experiences, attitudes, beliefs have shaped your early adoption of Soil Health practices and how do you perceive the most limiting factor of adoption from other producers? …your history from where you came from, you might approach it from that angle

Well one thing, I definitely believe in terraces. Without a doubt I almost feel like some of these farms should be taken away from some of these farmers because of terraces. We have got to be stewards to the soil health for the people to come after us and leave it in better shape than we found it and all. Of course the other thing, I definitely believe in no-till I don’t see why everybody don’t no-till because I don’t think that I ever had a year where it didn’t pay off financially. As far as the thing that has held me back from the cover crops, all of the meetings that they have had down here in cooper county have been really, really good and I believe it pays but I am of the age, I don't have the energy for it. That is just really the only drawback.

12:56

-You might perceive your operation as a little bit different as some of those folks attending there as I was at that conference there a lot of those guys are clean till producer so there is a little different thinking there as well.

What I have noticed with the no till is the earth worms. You can go down there a lot of time after the ground is dried down and you can see where the earth worms are working and you can see where there is little crumbles of earth at the top of their holes everywhere. To me that is a tremendous benefit. If ever I go fishing and I want worm, I just go down there and dig. A lot of times you can just go down there and move corn fodder out of the way and see earthworms underneath the fodder. I definitely see it as a benefit because of the earthworm population.

13:54

At one time I want to point out too. This may sound like a story that you can't hardly believe. But I got my son and my wife to witness it. I came home one evening and when came down into the bottom it looked like someone had broadcast straw all over the highway. It was at night and I though what is this? So I stopped and it was night crawlers…just millions of them. You couldn't lay your hands without touching 20 night crawler. I could not believe what I saw and I have never seen it since. But I got my son and my wife to come down I said come down here I want you to witness this. I have never seen anything like it since. The only thing that reason I could see was we threats of a large rain coming in. I thought are they for some reason moving because of the rain. But I know that sounds like a wild story but they were huge foot long night crawler. Ever heard anything like that?

-No I haven't

15:49

-As we are talking about all of these innovations over the years, what do you perceive as the things that separate the early adopters from the late adopters? What is the difference what is the major impact that maybe inhibits late adopters from jumping in?

Well you know what is interesting I remember one farmer tell me that he would never go to no till because the one thing that he does enjoys in life is riding that tractor. And in fact I couldn't believe what I was hearing because the one thing that I wanted to do was to get off of it as quick as I could. But I just think that there again this is something you know tilling the soil is something that worked for them maybe get out a week or so early to plant. I don't know but it just blows my mind to see large farmers that just work their ground they will no till their beans but thy will work their ground for corn.

-What keeps them from adopting it?

I don't know. It is like another farmer told me no-till no-crop. But I will put my yields up with any of them. I had one guy say when I was first no tilling "yah the only reason you got a stand was because you got a good rain right after you planted". Well for 20 years, I have got a good stand. The only time that I have had to replant is if it got flooded out.

17:48

-So kind of ask you the same question about the new term called Soil Health. What experiences or attitude or beliefs have shaped your early adoption of these practices?

I just wanted to get away from working the ground. That was a very time consuming thing and I have always said that I am just a Spare Time Farmer. I didn't want to spend more time at it than I had so that played a part in it too, But like I said I was going to no till meetings as it was just coming out and it just seemed like it would work for me.

-I didn't ask you this earlier but what level of education did you go through

High School

18:50

-But you have continually educated yourself over the years. You keep referencing..

I take farm magazines. I don’t take some of them like successful farming and some of them are way beyond my operation so in the last 10 years I have lost interest in them. I do have one that I subscribe….farmer walks to get one for example….the name of it is Missouri farmer today that comes out of Iowa. It has always got articles in it almost 90% of them will interest almost any farmer. It has to do with ….turn pages…it has to do with almost anything…starts reading article titles…collaboration builds healthy farm watersheds; elect your farm safety net; ag day recognizes abundance; it just always has a lot of good articles in it. Have you heard of it before?

-Yes I have actually contributed articles to it occasionally.

So anyway it has been, I enjoy it I pretty much read it cover to cover. It is kind of like the cover crop meeting they have at Boonville. They are always just interesting. There are practices that I wish I was younger. There was this young man from Avausse that told about how he feeds field corn right into lets his cows graze it down. In fact I told my son we need to go over and visit. I told him that you are young enough that one of these days if you want to get out of business and wanted to quit running the road that this might be and income that might take care of you. You get ideas like that you know, everything that I saw was good there with the program. It is kind of like paddock grazing, I told my wife a few days ago that this field back here is ideal for it, it has 5 ponds right down through the middle of it and it is 20 acres and I could put it in 5 acre plots by putting electric fence across. So it is just things like that that give you ideas.

22:07

-How do you define Soil Health?

You know, I go by the yields to see if I am doing things right. I also go by soil test and go by that. I sometimes think the university wants to sell fertilizer. Mostly the potash and phosphates. I went to a meeting several of this guy's meetings out of Iowa. He also did mission work in South America and had to do with soil helping them with their fertility and things. But when I went to this meeting, I had just taken soil tests and I had the results of the soil test so I just took them to get his read on it. And the first thing that he said was that you have been very generous to your soil. He said some of this you won't even have to put anything on for the rest of your life. He said university have a 3:1 balance. Is that right? What is it

23;52

-I have never heard of that before.

Anyway he said just take a wooded area that has never been fertilized. He said that you should be an 8:1 balance. I should be able to remember his name you should have heard of it. It was kind of out of the Midwestern part of Illinois.

-I have never heard of that unless it was back in Albrect era he was sort of the pioneer.

I have a feeling he is gone by now.

-In all of my years I have never heard

He said the university was high on that so actually I cut down on it but now I am kind of coming back to it as where the university soil test recommend on the potash and soil test.

25:30

-These are just some general questions but What are the benefits of a healthy soil and why does it matter to you or others?

It matters to me because of the yield. You know fertilizing pastures and hay ground and everything. You know if you are going to run over it you may as well run over it for a reason to get the maximum profit out of it that you can and the maximum yield that you can.

-There are costs associated with changing to new innovations in most cases so how have you over the year determine the cost benefit ratio of adopting something new?

I look at it for years that I might use this particular adoption whether it is machinery terraces or whatever and if there is a profit in it especially the machinery that is what I go with. I built my own sprayer you know, you have some cost in it but you figure out over the course of years how many time you use and it don't take many years to pay for it. I know it is not set up with the electronic that the newer sprayers have but if you look at my crop you will see that they are just as clean as the $250,000 sprayer.

27:17

-What are the greatest challenges in Soil Health?

The biggest challenge is the cover crop and working that into the program. I would definitely like to see my farm with cover crops on it.

-What is the greatest challenge to adoption by other producers What separates early adopters from later adopters?

I think that it can be a time consuming thing unless you have it areal sprayed in and you have the added concern of killing it in the spring and not letting it get too tall for the coming crop. That all has to be managed pretty accurately or you are going to have a problem with it. I can see with especially larger farmers that would be a problem with managing it all.

-We have talked all the way around this but if you could give a general answer or description or perception of what separates the early adopters from the late adopters just in general?

Some people are just really reluctant to do it any different than there dad did it. I think too that a lot of them don't care to go to the meetings to see how other people are making it work. I see that as a problem. Because I know that those cover crop meetings and we have 300 people down at the meeting and when we first had it it was packed full. I think it is always sold out and now it runs 3 days. I know for a fact there are some farmers that are considered pretty good row crop farmers that still till there lands and I never see them at these meetings. We had invite from many different counties so how many do we advertise?

-I think we advertise all over the state. So it is just a matter of how far somebody wants to drive.

So when you look at the amount of guys that you really know from this area it is not really that many. So they are not educating themselves. Now they are going to see their neighbor do it and are going to wonder even why they are doing it. Until they educate themselves as to why they are doing it. Their neighbor might say well

I think it pays; it really loosens the soil up and it increases the organic matter. Well they are not going to be too quick to believe their neighbor. Increasing organic matter has always been a big challenge. I think that until they come and see professional people doing it they are probably going to be reluctant to do it. And like I said a while ago that if it was working before so it is still working.

-…at the level that they understand.

-How do you describe sustainability in your operation?

I probably still don't understand it as good as I should. Are you talking about sustainability in soil?

-It is a term that is being used in every sentence and I think that the definition of what sustainability is is defined by whoever is using that term. I doesn't make any difference. What is your perception of sustainability in your operation in general.

32:05

I watch my pastures to make sure the growth of the grass is, I am not losing stand, let's put it that way. And that is one of the things that I wondered about with the paddock and letting it grow up and letting you cows eat it down. Are you going to lose some of your stand? I have watched this on some of the films they say you come back in a few weeks and your stand is back and you got even different grasses growing in there that have never been there before. But never the less when I look at what the cows did to this if they wouldn't in my case if I wouldn't lose some of the stand of grass. I guess that is what I look at with the pastures. But of course with the row crops I just feel like I am holding my soil. It doesn't bother me if the creek gets up anymore. I have filter strip all the way around my fields and the creek bottoms and if you are running across the field before it is planted, you hit those filter strips you automatically go up a little bit. In fact I am having a little bit of a drainage problem. So I feel like I am catching other people's soils. I am not worried about mine because it seems to really hold.

34:06

-Current estimates indicate that we will need to be feeding 9 billion people by 2050 and if so, our current production levels will need to increase by 70%. How do you perceive that occurring?

I think that technology has proven that they can do a great deal. I don't know how limited they are. You were talking in fact I read it too that the farmer hit the 500 bushel mark. I think there is potential out there. It could be that the amount of time it would take and intensity spoon feeding these crops. It could be that it is going to take more hands to put out these acres but I wish we could go back to smaller farms. I do think that technology will continue to play a part in it. Although in soybeans, they really haven't increased yields. In fact I don't think they have increased them at all.

-In my lifetime they haven't. We had Williams 82 when I was a kid and those yielded very well.

You know Clark beans some of them were pretty good to go by. In fact like I said in soybeans I just haven't seen that.

-Alright, we are getting closer to the end. I would like to spend the rest of the time talking a little bit about cover crop and that is something you would like to have in your operation but you don't have right now. But I know you have also gone to all of these meeting so you can answer these questions based upon your understanding. As we move into Soil Health management practices, cover crop sometimes is intermixed with the term soil health while others define cover crops as a management tool to help improve soil health. How do you define CC?

36:37

I think it is a good tool to improve soil health. It obviously increases the organic matter from what I have seen with these guys that give the presentation. I think it loosens the soils up sometimes when I see these radishes pulled out two inches in diameter. I wonder if they rot up and you plant into them will the seed drop down a foot and a half but I don't see that as a problems.

-What are the issues when talking to other farmers, what are the challenges when trying to include cc into an operation?

I think the challenges is getting it seeded. The big challenge is getting the seed and that it doesn't over grow and you have a problem with burn down further into spring when you plant. Someone was telling me that they had trouble burning down…I don't remember if it was radishes or what it was. Have you heard of that?

-sometimes the rye, well can get very large before they get in there. But also, in a wet year the moisture can draw down so you can get in their early. So if you kill it, it is time to plant because if you kill it and then it rains then it will be wet like a straw bed out there keeping all of the moisture out there

Well I think there again if they set there machinery up with a roller on the front of the tractor and a sprayer on the planter. Plant and kill. And you wouldn't want the roller any wider than what your planter is so that you plant with the material going down and I can see it working that way. In fact I thought that if I ever got into it and planted rye that would be the way I would want to have it set up. There again if you are planting 24 row like some of these big operators, you have a problem.

-you might need a little more horsepower.

You need a little more horsepower and you need a tractor that is big enough and that's going to be a lot of weight on that tractor.

-So as we get heavier and heavier stuff we have more compaction issues and all of those dynamics that play back in.

Yes

-I have kind of asked this ten different ways but what is the greatest challenge to adopting cover crops by other folks out here you know the innovation acceptance of this as something that we need to be doing?

Well I think they just don't want to make the change. Why should I put all that weight on my tractor; why should I spend money to do it? And what they don't realizes is that it will pay for itself. I just think that I don't want to make the change is just the way it is. There are farmers around here yet that ought to be doing terraces but they haven't terraced.

-Well that covers all of the questions that I have formally is there anything else you want to add to this subject in general that maybe I haven't addressed.

Not really.

-I appreciate your time

I could say this Check your crops often and talk to them
They talk to <u>you</u> don't they….

-that is great.

Demographic and Background Questions:

Sex: **M**

Age: __28___

Race: __w____

Level of formal education: _____BS______ if college, what field of study____Ag Business_______

Acres farmed___1000________

Alright, the recorder is on.

-Start off with, Tell me about your farming operation from a historical perspective…when it was established, your basic farming philosophy, when you started and that in contrast where you are now?

> Well the farm that we are farming right now, I think that we have been there since grandpa was there in the 70s, probably in the last 20 years we have expanded that farm right now we probably own about 1000 acres with probably about 40% of that tillable. Most of the acres that we farm to row crop is to feed our livestock. As far as that goes not much has changed over the years

-Since the 70s

> Yah it has kind of been the same type of operation

-So what are some of the…What do you perceive as some of the innovations that have happened in production agriculture in your lifetime that would demonstrate differing adoption or acceptance of that innovation?

Well, just in my lifetime, I have seen agriculture shift to technology pretty hard core, it seems like everything that we do or that I do that involves agriculture…one of the big things that I have noticed is the increased amount of grid sampling or precision farming and I think that innovation is a stepping stone to a lot of things to come down the road.

-Such as what, what are you thinking?

I just think that there will come a time when we will be regulated on how much fertilizer we can put on the ground based upon what the ground yields, what has been put on in the past, what the soil is holding at the time and I think that it is important because there is a lot of places that are over fertilized where there is probably going to be a lot of fertilizer going down streams that will be translocating itself and that can cause issues in the ecosystem

-And why do you think that is, what do you mean by translocation, what is causing translocation.

For example in creek bottoms and stuff where you've got a lot of moisture, phosphorous easily travels in that, the next place that it is going to go is in the streams or down the creeks mainly. Also sulfur and nitrogen they both move quite a bit in the soil and you can see that move.

-So this grid sampling then, back you know to the question of adoption or differing acceptance practices, what have you seen over time on that? You sound like you are on-board with it but what other kinds of perception have you seen from other folks, you seem to be a believer in it and what are some of the other down side to grid soil sampling process and why haven't others adopted those practices

Just thinking about soil health in general, I mean obviously, depending upon what you are trying to do with your land and health, I mean, things are going to change. And I have noticed that with some guys that are slow to adopt to the grid sampling program are ones that don't spend as much fertilizing which to me their ground is low in health because it's not keeping up with what they are trying to produce and they are not maximizing their opportunities. Whereas, the guys that have spent more money on fertilizer over the years have been more adopted to new things and have adapted their practices to new ideas, have a lot of times have over fertilized their ground which in turn then they have a lot of excess fertilizer in the ground that they haven't utilized, therefore the grid sampling program has benefitted them to use that fertilizer that is in the ground to prevent it from moving or running off or them losing it whereas the guys that are less adopted they don't want to spend the money, they don't, that is their negative impact to them is spending more money and fertilizer more than what they have.

5:20

-You mentioned the term Soil Health so that seems to be the newest thing out there on table for farmers today so, what experiences, attitudes, beliefs have shaped your early adoption of Soil Health practices and how do you perceive the most limiting factor of adoption from other producers? So we are going down that same path as we are talking about soil health.

Well to me, like I said, soil health is going to be different based on different types of soils, what you are trying to do with the soil and what you are trying to grow and how much nutrients that plant needs to take up. Because there's situations where we are in high producing grounds that's going to need more fertilizer, so we need to apply more fertilizer, that health is going to be higher than maybe some other ground might be that is a little bit less producing. To me, with that in mind, …State that last part again

-What do you perceive as the most limiting factor of adoption ss far as early adoption of these soil health type concepts?

I think some of the late guys that are adopting to it are just guys that are not wanting to put their money out there are used to producing it might be not completely directed at the older generation but somewhat directed toward them because they have done the same thing for the same way over the years and to them soil health might not be something that they are adapting to whereas a younger guy understands the importance of the soil and what we need to do to the soil to maintain good health and I think they are more adoptive to those practices.

-So how do you define Soil Health then from a Biological/Physical/Chemical process?

Humm. From a biological; chemical or process???

7:39

-Biological- bacteria, fungi; Physical- is the structure, reduced compaction, improved tilth; Chemical is the cations that are available.

So to me, Soil health to me is taking all of those and finding the correct level for your situation for your what you want to do and then trying to figure out if you are low maybe like in some situations there is low organic matter your soil health is poor or lower than in places where there is higher organic matter but you got to find that range but then there are situation where we have used or over use chemicals or we have used the same chemicals over and over again that have reduced soil health due to all of the chemicals that have been put in that ground where we see issues. So a lot of this is trying to find out what is best for your practice what you are trying to do and then keeping those levels regulated.

-So how would you define Soil health as a living breathing entity/or the complete biodiversity

9:00

If you are going to have good soil health, there is going to be a lot of microbial activity in that soil. I think the less healthy your soil is, the less activity is going to be going on in there. A lot is due to the organic matter. A lot of these chemical, commercial fertilizers, they say are high in salt and salt can affect the organisms in the ground that is just a lot of the things that we watch and think about.

-Lets back up to your operations. What is your overall goal/approach to Soil Health in your operation?

One thing that was taught to me when I was younger and what we still do is that we like to rotate our fields out on a three to five year window and we will raise corn rotate corn soybean 3-4 years and then put that field back into hay production and I think that which I didn't understand at first but now that I understand a little bit more about soil I think it really improves our soil health because we are keeping a high organic matter in our soils and we are just not over abusing it.

-So this might be a little bit of a repeat question but How do you define Soil Health in your management "toolbox" What is your perception of the current state of Soil Health adoption? So what are you doing and how are you including it in your tool box of production and what is your thought about what others are doing from an adoption standpoint?

11:00

I think in our production, in our operation, we understand that everything starts with the soil and we have to maintain a healthy soil to maintain a livelihood because if we are not producing like we should on that soil then our efficiency goes down and we are taking steps back so we've recognized that it is important to maintain soil health and to keep our production operation efficient for what we are trying to do. I think that there has been a slow adoption to these practices because a lot of people are not willing to change what they have done; there are a lot of producers out there that are thinking about the end product and once the corn is there they harvest it and they go on. They are not really thinking about where things start and everything starts with soil or soil health.

12:05

-Ok, so, making that statement they are not thinking about anything else, why do you think that is, what is your answer for that, the why producers are not, what keeps producers from adopting practices?

I think that they are a little less educated, Maybe, Maybe, it is not getting out to them how important soil health is and I think they, a lot of producers are looking at the bottom line.

-Bottom line meaning what?

Profitability. So what can I get out of the soil that I have and not worrying about putting it back or taking care of the soil that they have.

-So you kind of eluded to this before but I am going back to it again. How long ago do you believe that you started Soil Health practices? You said you started in the 70s.

13:11

Yah, I think in some sense we have been doing it the entire time that we have been farming, I guess I didn't realize that is why we are doing things the way that we do but as I grew older and started to understand things it all made more sense to me that you know our operation has valued what the soil has done for us and we want to take advantage of what we have been provided with you know a person is not going to farm for 5 years you are more likely to farm your whole life so you might as well take care of what you have.

-So What are the greatest challenge or challenges in Soil Health?

14:00

I think that the greatest challenge is just educating producers so they better understand how important it is what they are doing with soils on a daily bases. What chemicals are going on there or better records of how much chemical or how much fertilizer is being put on not only to increase their profitability not only for now but into the future. I think that is what most do not understand is if don't take care of something now ok it might be a quick fix for five years but after that you are going to start to see issues with that and it is important that we maintain that soil health year in and year out.

-So What is the greatest challenge to adoption by other producers?

15:00

I mean the greatest challenge is just to just get everyone on-board everybody educated and the biggest challenge is that you have to change the ways of producers who have been doing something the same way for 50 years. They are not just going to jump on the train and so ok I am going to do my entire operation different because someone came in here and told me I need to. And that is going to present a challenge as time goes on in a long term basis those producers are going to start to weed out and we are going to have to be dealing with a younger crowd and that is going to be important to educate not only the older crowd but the younger crowd because they are producers of the future.

-Ok, I am going to detract from my sheet here just a little bit because you dwelled on this point a couple of time and it hits pretty close to home for me. So you keep using the term educator educating them, whose role is that?

I mean, anyone involved in agriculture from the guys at the retail locations selling you fertilizer the guy selling you the chemical, the guy selling you the seed. I mean even in college, I mean it is just that not enough information is being passed down to the producer. This chemical works because of this but nobody knows what it actually could do. And the same with fertilizer, over fertilizing ground… well they don't know that they are sending some of their fertilizer down the river someone needs to be out there whether it is your retail sales location or anybody.

-So is there a role in our land grant university for this process?

For sure I mean there is a lot of things that the university already does to educate the farmers or the guys at retail locations. I still think, we still need to get more producers in the same type of classes or the same type of meetings that we seeing for retail locations and I know that there are opportunities to get them there but maybe on a local basis. I know that it is hard to get producers to do that.

-Sometimes. So it is close to home for me because I am an Extension agent so what is the role for Extension in this process. How do you define Extension? Are there any biases from the retail chain versus what the university should be offering?

Well I think from a retail side there is always going to be some biases. It is just hard, at the end of the day they are just thinking about dollars too. And that is where the Extension office is beneficial because they are trying to provide truthful information to help people make better decisions in their practices.

18:00

-Which ultimately means what for the producer in their practices?

Well hopefully over time that you will be more profitable and educated in what you are doing.

-Well I have detracted long enough and will get back to my list…

-So, One last time. What separates early adopters in these innovative practices that have happened over time, what separates early adopters from later adopters in your opinion?

I think that the early adopters are going to be guys that are going to be risk takers that are willing to put money out front to try to see a return on investment. They understand with a growing population the need for more food I mean just everything coming down the line is going to need us to change and they are jumping on that train to realize that hay we are going to have to change we can't do the same thing year in and year out and expect everything to go right whereas the other guy they are just floating along doing what they are doing and the next thing that you know they are going to be 20 years behind in 5 years.

-Current estimates indicate that we will need to be feeding 9 billion people by 2050 and if so, our current production levels will need to increase by 70%. How do you perceive that occurring?...what ways are we going to improve our production capacity by 70%

20:00

First of all it starts off with the soil. I mean, we have to find a way to make this soil produce like it never has. But with that being said, they talk that in the future..

-Who is “They”?

Seed guys, chemical guys, a lot of the reps that I deal with

-OK

Are talking in the future that we are going to have 600 bushel corn and 300 bushel beans

-Compared to what do we have now?

I am going to say on average 40-50 bushel beans on average ground and 175 average corn grounds I would say would be good. And so not only is the corn hybrid going to have to change but the way that we take care of our soil and our efficiencies are going to have to change.

-So, as we move into Soil Health management practices, cover crop sometimes is intermixed with the term soil health while others define cover crops as a management tool to help improve soil health. How do you define CC?

I have to say that it is a management tool I don't think it is the answer in every situation but there benefit that we get out of cover crops to help benefiting our soil health.

-Can you describe those benefits? What are you thinking there?

One of the biggest things is organic matter to me organic matter is important and you can see the high producing areas that organic matter is higher it increases the efficiency in the way the plant uses the nutrient that are there. So over time, I really think that cover crops are going to help increase the organic level in the soil which to me will increase soil health.

-Do you have CC in your operation?

Yes we do use cover crop but not at a big level.

-And so what kind of cover crops are you using?

A lot of time, we will put out some rye. And we will end up baling the rye off which can pose another problem but from some studies I've read and some guys that I talk to that if you bale it off at higher than 4 inches that a lot of the nutrients will be left behind before it heads.

23:00

-So in your diversified farming operation that you describe both from crops and livestock, that adds another dynamic to your operation and that benefits affects your livestock operation

Well rye can be a good source of protein, and you can grind that rye that is harvested at the right time can provide 12-14% protein. So we are seeing benefit in the crop field and we are also seeing benefit when we come to feed our livestock off of the same acre as long as we can avoid from taking out over using the nutrients in the soil without fertilizing more we are kind of getting a double benefit there.

24:00

-So what are some of the criteria that you see when you select which CC to plant?

Well I think in our operation, we I mean to me we have healthy soil we have some terrace fields that we like something on to keep them from washing. It is a field by field base on what we are trying to do and again, if we can benefit our livestock side of operations then that is direction that we are trying to do. We use oats, oats hold the ground well and also we can grind the oats up in our feed to feed our cattle. A lot of our decisions that have been made are for benefitting our livestock operation but at the same time, it has benefited our cropping operation.

-Are the current crop insurance regulations a concern in the cover crop operations out there you have exposure to other farmers around the area, have you heard that discussion out there?

Not, I really haven't heard a lot of guys talk about insurance concerns to cover crops.

-What is the greatest challenge to adoption cover crop practices by other producers?

It seems that a lot of things producers talk about is money. It is all about return on investment. Cover crops can be pretty expensive to put out they can be $30-40 per acre is pretty common I think. $30. So, getting these guys, especially right now while crops prices are low, is getting these guys to spend another $30 per acre on the ground that they are already spending more than they have every spent.

-And what is the benefit going to be for them on that $30 investment.

That is the ultimate question. Do we know the exact answer and that answer is no.

-And why is that?

There hasn't been enough research done on it and it is too new or I shouldn't say new because it has been used over the years cover crops have but we just don't have enough research on what it is actually doing.

-I would say that there has been a resurgence of interest on this topic.

Most certainly. I mean you go back and read old text books from years and years ago, they used cover crops in their operation but they probably didn't know why they used them just like we do.

-I probably asked this in your description then what is the most important benefits of CC for your farm?

On our farm, I think the benefits are that we are keeping are soil health were it is at, we are always improving soil health, another benefit we are providing another crop off of the same acre, we are using produced crops so to me there is some benefit but it is hard to know if we are getting enough benefit for the money that we spend on it. But we also know that that we are keeping our soil health up and our soil is doing well, we don't feel like we are abusing our soil.

-What is the payoff in the long term if you are not abusing your soil?

I think that if you are not abusing your soil and you are practicing good farming practices, I think you are maintaining your sustainability and not only providing yourself a chance to sustain yourself over long periods of time you are also providing yourself a chance to grow. And when we are talking 3-500 bushel corn the guy that is taking care of his soil now is a long way towards that production

-How do you describe sustainability?

Change.

-Change?

I think that if you are going to sustain yourself and the world that we live in, you are going to have to be change on a constant basis because if you are going to be keeping up with how things go by year in and year out things are changing practices are changing there are always new ideas. If you find yourself not adapting to what is new out there you are falling behind really quick.

30:00

-So I am going to ask you one last time. What are the greatest challenges to adoption or change like you are talking by those other producers, what is the nugget what is the reason if there is one reason or series of reason, what is their greatest challenge to change. You see yourself as being an early adopter I do as well. So as you are looking around the neighborhood now not just your own farm, what is the greatest challenge for those other folks to see what you perceive as being the next great change.

> Getting them to believe that what you are trying to get them to do is going to actually work and they are going to see a return which will require us to research these practices research everything that we are doing so that we can put it on paper and get those people to believe. Because if they don't believe in what they are doing and if they don't see it, then they are not going to adapt.

-You keep using that term "return on investment", so do you see cash flow as an impediment to the adoption of some of these innovations? Is cash flow ever a factor in there for let's say a smaller farmer that doesn't have as much cash flow as a larger farmer and those kind of dynamics from an economic standpoint, give me your perspectives on that.

> I mean cash flow is always going to be a factor in these things but just like everything else we do in life, we are always investing ourselves investing money in things so why don't we invest our money in the soils. And that is another thing is getting people to understand that you have to invest into it to get the payback and it might not be a return on investment in the first to five years, it might be a ten year thing. But money is always

going to be a factor but the little guy can make the investment just like the big guy I believe. And it is just trying to get them to understand why it is important to do that.

-I am going back the original question now that you are relaxed a little bit. What is your golden nuggets… what do you perceive as some of the innovations that have happened in production agriculture in your lifetime that would demonstrate differing adoptions or acceptance of change towards that innovation.

33:00

That is a long question.

-Let's break it up. What is it that you perceive as innovations that have happened in production agriculture in your lifetime?

I mean just from basic stuff; soil sampling, grid soil sampling you know that is the big push right now. I think that is one of the main things that I have seen along with the technology that goes with it.

-And now the other half of this question. If you look at all of those kind of things, what has cause the differences of adoption in utilizing those innovative practices.

So why is it not being adopted in some situations?

34:00

-So what is the key factor on this day we have this new idea, new innovation, then why is that the next day everybody isn't jumping what causes that difference in adoption or acceptance for change in practices.

Lack of data lack of research, I think farmers or producers a lot of time, they have to see it on paper, they have to see it or actually see it happening and see the benefit.

-We are the show me state

Amen, if they don't see it, they don't believe it.

-Alright, that concludes my line of questioning. Do you have anything else that you want to add overall anything that you think we missed. Or do you think you are good to go?

I think I am good to go.

Vita

Todd Lorenz attended Central Missouri State University (CMSU now UCM) for his B.S. in Agriculture Business. He completed his M.S. in plant science under the direction of Dr. J.R. Brown with the thesis "Wheat Management for Red Clover Establishment". During his M.S. he was employed by the Soils Department and conducted soil fertility and forage fertility research for the Missouri Agriculture Experiment Station. His primary responsibilities included management of historical Sanborn Field and the F.L. Duley-M.F. Miller Soil Erosion Plots where he has hosted many international tours.

In his current role, Todd is a University of Missouri Regional Horticulture/Agronomy Specialist located in Cooper County and is responsible for both Horticulture and Agricultural educational programming and has presented at regional, state, national and international meetings. He is simultaneously pursuing a PhD in Plant, Insect and Microbial Science where his program will focus on soil health parameters. Todd also has four children who are all currently enrolled in college.

Todd was recently awarded grants through The Mizzou Advantage and a NRCS Conservation Innovation Grant for the study of soil health with our agricultural producers. This process is utilizing the

1914 Extension delivery model with a multidisciplinary collaboration of campus and field faculty while expanding and strengthening collaborations with state, federal and private agencies and involving producers as adviser from the start. The ultimate goal is to have research based educational resources available to improve understanding of soil health and its value in our production systems and contribute to the nationwide interest.

In absence of a local experiment station, Todd works collaboratively with Regional Extension Specialists in the Clifton City area where they have cooperated to conducted on-farm research and field days on topics such as forage fertility, novel endophyte fescue, stand establishment, harvest management, precision agriculture nutrient applications to both forage and row crop systems.

Todd recently worked with the CAFNR International Cochran Fellowship Program on a High Value Horticulture Crop Production program for a group of internationals from Tajikistan and Turkmenistan. He also hosted the Directors of Agricultural Extension Services and Human Resource Development and Management Directors of the Ministry of Food and Agriculture to explore the potentials for re-orienting agriculture extension training in colleges and farms of Ghana by patterning University of Missouri Extension.   Todd utilized his local clientele, Extension Council and office to showcase Extension.

His Extension Teaching Philosophy is to provide a superior learning structure where research-based knowledge is provided in an assortment of approaches as necessary to address the high-priority needs of citizens. He establishes an open rapport with clientele, and encouraging participation and ownership beyond the program where he establishes a long term relationship with learner audiences that enhance the Land Grant Mission. Todd is a firm believer in taking research based educational information to the public.