Soil health and methods evaluation in producer’s fields of central Kansas

by

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B.S., Northwest Missouri State University, 2022

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Agronomy
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2023

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Abstract

Soil health indicators are useful for evaluating dynamic soil properties, but there are concerns about their applicability across different regions spanning multiple management practices, soils, and climates. Cropland management practices have been shown to have measurable effects on dynamic soil properties, and many methods for measuring those properties have been, and are still being evaluated for their feasibility. This study assessed the efficacy of multiple methods measuring physical and biological dynamic soil properties in Central Kansas. In addition to evaluating the methods, this study examined the associations between various common management practices in this region and the differences between them in terms of these soil health indicators. The study was located in McPherson and Harvey counties of Kansas and included 100 pedons collected from producers' fields. Pedons were sampled from 0-5, 5-10, 10 cm to the remainder of the A horizon, and by genetic horizon thereafter to a depth of 1 m. The fields chosen for sampling were part of a survey dating back to 2010 and as late as 2022 that monitored management practices every year. The primary variables of concern were cropping systems and irrigation. The four methods used to measure total aggregation were a multi-sieve machine method, a single-sieve hand method, the Cornell method, and a smartphone application called SLAKES. The fields sampled with the most tillage and least crop diversity, particularly continuous wheat, had the lowest total aggregation percentage (as defined by the smallest sieve used to retain macroaggregates within each method) and lowest mean weight diameter aggregates in the 0-5 cm and 5-10 cm depths compared to all other management systems. Among the four methods for measuring total aggregation there was moderate to strong correlation between all methods except the SLAKES method. SLAKES was weakly correlated to the machine method and the Cornell method and very weakly correlated to the hand method. The biological methods were phospholipid fatty acid analysis (PLFA), autoclaved citrate extractable protein (ACEP), and permanganate oxidizable carbon (POXC). Among these methods, POXC was the least sensitive and was the only method unable to detect differences in cropping systems at both 5-10 cm and 10 cm to the bottom of the A horizon (10 cm-x). PLFA total biomass was unable to detect differences between cropping systems at 10 cm-x, whereas ACEP was the only method to show significant differences between cropping systems at all three depths. Continuous wheat (which was conventionally tilled for the most part) resulted in many of the lowest values amongst the biological indicators as well, including POXC (0-5 cm), and all PLFA groups except for fungi (0-5 cm). Fungi significantly differentiated between perennial and all other systems. These results can help inform future management decisions for producers in this region of Kansas as well as inform researchers on the evaluated methods.

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Chapter 1 - Review of Relevant Literature

Soil Health and Soil Quality

Since the late 1980's production agriculture and erosion concerns have slowly given way to sustainable agriculture, soil preservation, and environmental health as the primary concerns receiving the most attention within the scientific community (Wienhold et al., 2004). Tools were developed to address early concerns of erosion, including the Universal Soil Loss Equation, Water Erosion Prediction Project, and the Soil Loss Tolerance Standard (Karlen et al., 2015). Soil health emerged from soil quality (Lehmann et al., 2020). Soil quality gained popularity in the 1990s and soil health followed in the early 2000s. The phrases of soil health and soil quality are commonly used interchangeably, but there is a difference in what each emphasizes, or is understood to emphasize. Soil quality has been previously defined as the ability of the soil to function (Karlen et al., 1997) and is used when referencing how well a particular soil performs a specific function in relation to other soils or the same soil at a different time. This simple definition can be further represented by breaking down the function of soil into plant and animal health, environmental quality, and sustained biological productivity.

The dynamism of soil is stressed in soil quality and soil health with the interaction of chemical, biological, and physical properties that are ever changing (Karlen et al., 1997). Some have explicitly pointed out that the terms "soil health" and "soil quality" should not be used interchangeably, noting that soil quality is related to function, and soil health is related to a living biological entity (Lal, 2016). This is a slight contradiction to what earlier works said of soil quality, and how function could be taken to represent the living and dynamic nature of soil (Karlen et al., 1997). The concept of soil quality seemed unnecessary to some who thought that comparing soils in different orders or series would show the natural differences. However, an argument for paying closer attention to soil quality relies heavily on the fast adoption of new technology in the post-World War 2 era of agriculture that was taken on with little concern for long-term productivity or environmental quality (Karlen et al., 1997). Borggaard points out in *The Future of Soil Science* that soil quality is difficult to handle considering its multi-functionality with the example that soil could be examined as being of high quality as a plant growing medium if it is heavily fertilized but low quality in that it has high nitrate runoff (Hartemink and International Union of Soil Sciences, 2006). This contradiction points toward the need for methods of analysis that consider the simultaneity of the many soil functions. Maharjan et al. (2020) proposed that there should be what is referred to as a “soil health gap” that is used as the standard for all soil health indicators that essentially is presented as the gap between the current state of the soil being measured and the state of an equivalent soil that is still in native prairie. Borggaard also recognized that launching the soil quality concept placed a particular focus on soils. One of the key reasons for the interest in soil health is in trying to mitigate soil degradation (Karlen & Rice, 2015). Soil degradation almost always involves loss of soil organic matter (SOM); SOM is a valuable asset when in the soil but is a liability when released into the atmosphere as a greenhouse gas (Lal, 2016).

Soil Organic Carbon

One current estimate is that the world’s soils have lost between 115-154 Pg C from land use conversion (Lal, 2018). Another estimate puts SOC losses at 133 Pg C in the top two meters of soils globally (Sanderman et al., 2017). Cropland and grazing land contributed almost equally to this end, but it is worth noting that there is twice as much grazing land as cropland. Losses of SOC are highest in orchards and croplands and lowest in forests and grasslands, and the latter is likely attributable to ground cover and lack of cultivation (Abdalla et al., 2020). Cropping systems can affect SOC. Continuous wheat (*Triticum aestivum*) was shown to increase SOC relative to continuous sorghum (*Sorghum bicolor*), wheat-fallow, sorghum-fallow, and wheat-sorghum-fallow systems under no-till in the central Great Plains (Blanco-Canqui et al., 2010). It is possible to increase SOC through various practices such as no-till, cropping intensification, and integrating livestock into cropping systems, many of which have been referred to as regenerative practices (Prairie et al., 2023). There are some synergies within these practices. One instance of this is when cropping intensification was combined with integrated crop-livestock systems, the increase in SOC was greater than the sum total of the practices combined. A global meta-analysis demonstrated increases in SOC from 5 g kg^{-1} to 6 g kg^{-1} also improved yield by 2.4% independent of nitrogen (N) inputs or legume cover crops (Vendig et al., 2023). Increasing SOC can be done by converting operations to no-till, but there are limits to carbon sequestration through no-till production (Blanco-Canqui, 2021). To move past those limitations cover crops can be used and managed so as to maximize their biomass production, and cover crops can be adopted into systems that previously had a fallow year in rotation. The specific change from conventional tillage to no-till can sequester an average 57 g C m^{-2} (West and Post, 2002). Non-inversion tillage, particularly disk tillage, was shown in one long-term study of 39 years to be just as effective at accumulating SOC (Blanco-Canqui et al., 2021).

Adopting best management practices such as continuous ground cover, complex crop rotations, and no soil disturbance, can protect the existing SOC stock (Lal, 2018). In the 0-5 cm fraction, SOC was greater, but not in the 5-15 cm fraction of the no-till treatment in an experiment using no-till, conventional tillage, and reduced tillage for 44 years in Ashland Bottoms near Manhattan, Kansas (Lin et al., 2023). In a study of the northern Great Plains in eastern Montana the 30-year effect of tillage and cropping system showed that SOC was as much as 98% higher in spring-tilled continuous wheat than in no-till continuous spring wheat, fall and spring till continuous wheat, fall and spring continuous wheat-barley (*Hordeum vulgare*), and spring wheat-pea (*Pisum sativum*) cropping systems (Sainju et al., 2015). Carbon fractions, including SOC and potassium permanganate extractable carbon (POXC) were not associated with pH in a study in eastern Montana (Sainju et al., 2021). This same study suggested that SOC was more responsive to management changes over the long term. To detect short-term changes, the most effective analysis was potential carbon mineralization (PCM) and POXC. Soil organic carbon can be further divided into mineral-associated organic matter and particulate organic matter (POM), with POM being more responsive to short term change in temperature and CO_2 (Rocci et al., 2021). Microbial carbon use efficiency (CUE) could be as much as four times more important in storing SOC than carbon input, decomposition, or vertical transport, demonstrating how important it is to increase our understanding of what drives CUE (Tao et al., 2021). Initial SOC stocks appear to affect the potential for increases. However, that phenomenon has been shown to be caused by analyses that normalize changes using a % change that references the initial SOC stock. Another explanation for this observation is an eventual regression to the true mean SOC in a dataset that started with samples that were not representative of the true initial SOC stocks (Slessarev et al., 2023). The aforementioned statistical phenomenon can be corrected by not using normalized metrics when evaluating change in SOC and taking more replicate samples to better represent the average, therefore avoiding the likelihood of a future occurrence of regression to the mean. Frameworks have been put forth to help individuals capture SOC heterogeneity yet still have a feasible number of samples to get there (Dalzell et al., 2022).

Aggregate Stability

Aggregate stability has long been known to be an important dynamic soil property difficult to measure without the proper methodology (Yoder, 1936). Soil aggregates can be impacted through many different management practices or lack thereof, a few being tillage, residue management, manuring, compost, fertilizer and nutrient inputs, crop management, crop rotations, cover crops, and agroforestry (Bronick and Lal, 2005). Soil structure has been examined through multiple perspectives. One study proposed the idea of not looking at soil structure from the perspective of solids (aggregates) or pore spaces, but instead examining soil more holistically and consider pores and aggregates to be a duality that is soil structure (Yudina and Kuzyakov, 2023). One method to evaluate aggregate stability includes separating samples and giving them multiple indices originating from the stable small macroaggregates and the stable large macroaggregates (Marquez et al., 2004). Marquez et al. (2004) found that the soil under cool season grasses had the highest indices followed by riparian forest, switchgrass (*Panicum virgatum*), and lastly the cropped systems. Yoder (1936) significantly improved the methods at the time by introducing a unique machine method of measuring wet aggregate stability that is still used today with some modifications. Yoder's method was further modified by Kemper et al. (1985) to include improved equipment, an aggregate stability index, a slaking test, and improved data analysis among others.

There is agreement on the importance of aggregate stability, but there are many variations of how to measure it, which presents challenges when comparing data across studies (Garcia et al., 2022). Commercial labs have an interest in completing an aggregate stability analysis quickly and many of the methods available are not reconcilable with that need. One of the many methods available is the rainfall simulator method (Ogden et al., 1997; Moebius et al., 2007). Using the rainfall simulator method, the fraction of aggregates that was the most responsive to management effects and the easiest to obtain based solely on their abundance within samples, was the smaller fraction of macroaggregates sized 0.25-2 mm as opposed to the larger macroaggregates sized 2-8 mm aggregates (Moebius et al., 2007). A relatively recently developed method is an image recognition method called SLAKES which uses an algorithm paired with data from the images and time intervals to provide a slaking coefficient (Fajardo et al., 2016). A study used this image recognition method to look for differences in slaking coefficients in soils of Falls, Milam, and Williamson counties of Texas (Bagnall and Morgan, 2021). They compared coefficients between no-till, conventional till, and perennial grass and determined that increasing organic carbon, regardless of clay content, would decrease the slaking coefficient of a given soil. In addition, they found that it took a larger increase in organic carbon to have the same effect of lowering the slaking coefficient of a soil, if that soil had a higher clay content. In a comparison of multiple methods, including the rainfall simulator method, machine method, and SLAKES, the correlations between all methods were moderate, with SLAKES having the lowest correlation (Rieke et al., 2022). The aforementioned study presented all methods to be viable for measuring aggregate stability, yet the correlations were not close enough to suggest that they were interoperable.

In eastern Montana, there were positive associations between aggregate stability and many carbon pools, including potassium permanganate extractable carbon, potential carbon mineralization, water extractable carbon, SOC, and microbially active carbon, which suggests that these pools enhance soil aggregation or that soil aggregation enhances these pools (Sainju et al., 2021). Cropping systems can effect wet aggregate stability (Blanco-Canqui et al., 2010). Continuous wheat was shown to have two to five times higher wet aggregate stability than continuous sorghum, sorghum fallow, wheat sorghum fallow, and wheat fallow at the 0 to 2.5 cm depth. NT continuous wheat (NTCW) was found to have a higher average slake aggregate than conventional till wheat fallow (CTWF), NT wheat fallow (NTWF), and NT wheat pea (NTWP) cropping systems after fourteen years of the mentioned cropping rotations in Eastern Montana using image recognition (Sainju et al., 2021). Greater soil aggregation was observed in the NT treatment in a study at Ashland Bottoms near Manhattan, Kansas that compared plots that had been managed with NT, conventional tillage, and reduced tillage for 44 years (Lin et al., 2023).

Bulk Density

The soil bulk density is dependent upon particle size and is influenced by management (Pacini et al., 2023). Bulk density affects functionality, porosity, and aeration. Although some physical properties were affected, bulk density in the tall grass prairie of northern Texas had no difference between treatments after having been grazed with four different management styles for nine years, including multi-paddock, heavy continuous, light continuous, and complete exclusion of livestock (Teague et al., 2011). Bulk density was lowest under native pastures, higher under sown tropical pastures, and highest under conventionally tilled cropland (Schwenke et al., 2013). Bulk density was also negatively correlated with organic carbon. In Sheridan County, North Dakota, at the Conservation Cropping Systems Project, bulk density was negatively correlated with percent organic carbon (Augustin and Cihacek, 2016). Bulk density was significantly increased in the layer of 10-20 cm in cropland as compared to land enrolled in the cropland reserve program (CRP) in central Kansas (Huang et al., 2002). In the northern Great Plains, after 30 years of consistent management, bulk density was as much as 21% higher at 0-7.5 cm in the traditional till spring wheat-fallow rotation as compared to all other treatments, which included NTCW, spring till continuous wheat, fall and spring till continuous spring wheat, fall and spring till spring wheat-barley, and spring wheat-pea (Sainju et al., 2015). In the southern Great Plains, bulk densities were compared between cropland that was under a shallow tillage treatment <10 cm with wheat and sorghum in rotation, CRP, and native grasslands that were grazed to varying degrees (Schwartz et al., 2003). The cropland and native grassland were significantly lower in bulk density than the CRP from 1-4 cm, and from 5-8 cm the cropland was significantly lower in bulk density than the other two treatments. The authors thought that the lower value for the cropland at 5-8 cm was likely due to the tillage events, and they hypothesized that the CRP had not fully ameliorated the changes in soil structure from previous tillage events. There were no significant differences between treatments at a depth below 8 cm. In the semi-arid west, bulk density was lowered the most, and at the fastest rate, in a system that had been planted to perennial grasses (Benjamin et al., 2007). Bulk density in the annually cropped treatments decreased as well, but to a lesser extent, from 1.38 to 1.3 Mg m^{-3}, whereas the grass treatment decreased from 1.39 to 1.25 Mg m^{-3}. In Ashland Bottoms near Manhattan Kansas bulk density in a silt loam was found to be higher in a NT system (1.4 g cm^{-3}) than in a system tilled by chisel plow to a depth of 20 cm (1.36 g cm^{-3}) (White and Rice, 2009).

Permanganate Oxidizable Carbon (POXC)

The POXC method was developed by Weil et al. (2003), and at the time, the authors suggested this method was measuring a highly active pool of C. This initial assumption has continually been in question as it was pointed out that while POXC may potentially favor the labile pool of C, it is ultimately representative of a fraction with varying levels of aromaticity and lability (Romero et al., 2018). Another study that called into question the validity of the claim that POXC is measuring the labile pool of OM was put forth by Christy et al. (2023). They found that the initial assumption that a mild oxidant would preferentially target the active portion of OM was not demonstrated and that POXC was indicative of the concentration of phenolic and polyphenolic secondary metabolites commonly produced by living plants and some microbes. Nevertheless, POXC has been shown to be an effective indicator of conservation practices that are expected to accumulate and stabilize OM (Hurisso et al., 2016).

When looking at the relationship between SOC and POXC in an experiment in the northern Great Plains with varying soil textures there was no change in the relationship between the two when adjusting for texture based on sand, silt, or clay which suggested POXC was not differentially affected by soil texture when compared to SOC (Romero et al., 2018). Plots located at the North Dakota State University Dickenson Research and Extension Center were used to compare the usefulness of POXC, SOC, and hydrolysable C for detecting differences at 0-15 cm and 15-30 cm in the short term (2-4 years) of having implemented best management practices (Bhowmik et al., 2017). Their conclusion was that using hydrolysable carbon in conjunction with SOC was a better option than POXC considering it was more consistent and POXC has the potential to be influenced by the chemical protection of C, as primarily influenced by texture. The POXC parameter was the most sensitive indicator to crop rotation diversity and management amongst those tested, which included C mineralization, N mineralization, and soil inorganic N in the upper Midwest (Culman et al., 2013). A study in eastern Montana examined multiple C pools in dryland cropping systems including POXC, soil inorganic carbon (SIC), SOC, water extractable carbon (WEC), microbially active carbon (MAC), and potential carbon mineralization (PCM) with the objective of finding which pool related most to soil properties and crop yields as well as how these pools related to each other (Sainju et al., 2021). Samples were taken representative of the soil from 0-15 cm. The C pool represented by POXC was 49-59%

higher in both systems with continuous wheat, which included spring and fall till as well as NT, compared to spring till wheat-fallow systems. Among the C pool analyses PCM was the most sensitive to yield, soil properties, and management while also being reliable and inexpensive.

Autoclaved Citrate Extractable Protein (ACEP)

The ACEP method was initially understood as a measure of glomalin, glomalin-related soil protein (GRSP), or easily extracted glomalin (EEG) (Wright and Upadhyaya, 1996). Later it was discovered to be more representative of various proteins in the soil and therefore, researchers were urged to alter their terminology accordingly (Hurisso et al., 2018). In the northern Great Plains, ACEP was positively associated with WEC, PCM, POXC, SOC, and MAC (Sainju et al., 2021). In California, ACEP was evaluated for its correlation with potential net N mineralization (Geisseler et al., 2019). They concluded that ACEP was not a better predictor for potential N mineralization than total soil N, but that it still has usefulness as it correlates well with aggregate stability and sensitivity to land use changes. Concerns were also raised about the potential interference of coextracted humic substances. Aggregate stability was linearly correlated with ACEP in soils in the Mid-Atlantic (Wright and Upadhyaya, 1998). Aggregate stability was linearly correlated with ACEP across all treatments in the central Great Plains, and the highest values for both ACEP and aggregate stability were found in perennial grass (Wright and Anderson, 2000).

A comparison of systems managed for 8 years with chisel tillage, more intensive organic tillage, and NT was conducted and showed NT to have higher ACEP than the tillage treatments (Wright et al., 2007). This research also looked into the amount of ACEP within aggregates. It demonstrated that in NT ACEP was higher in macroaggregates and the opposite was true of the other tillage treatments. Tillage and corn (*Zea mays*) stover removal over a period of 32 years both negatively impacted ACEP content, with tillage having the larger effect (Moebius-Clune et al., 2008).

Phospholipid Fatty Acid Analysis (PLFA)

Phospholipid fatty acid analysis in soils is the most powerful method for demonstrating changes in microbial community structure but provides little information as to specific microbial populations (Ramsey et al., 2006). The abundance of bacteria and fungi relative to each other, commonly represented as a ratio, can be determined using PLFA (Frostegård et al., 2011). In addition, PLFA seems to be just as effective as other biomass methods in showing increases in microbial biomass in response to management but should not be used to detect decreases, as delays in PLFA degradation in the soil could lead to faulty conclusions that living microbial populations have not been reduced as PLFA does not differentiate living from dead microorganisms. Seasonal dynamics of PLFA were shown to be significant in a study showing pronounced differences driven by tillage during fallow periods and early in the growing season, whereas the soil microbial community was primarily influenced by root exudates, moisture, and temperature during the growing season (Feng et al., 2003). In the northern Great Plains when PLFA was calculated as total microbial community abundance with a sum of biomarkers C14:0 to C20:0 it was positively associated with SOC, POXC, and WEC (Sainju et al., 2021).

Different regions can have different community structures, as shown by McCulley and Burke (2004) when looking west as far as the shortgrass steppe in eastern Colorado along a gradient to the east as far as Konza Prairie in eastern Kansas. They found an increase in microbial biomass in shortgrass steppe compared to mixed grass and tallgrass prairie, and a decrease in fungi in the tallgrass prairie sites. In the northern Great Plains fungal and bacterial biomass were increased with NT when compared to tilled sites, and the idea that NT systems are fungal dominant was called into question (Helgason et al., 2009).

Fire in the northern Great Plains was shown to have no effect on microbial community composition or abundance (McGranahan et al., 2022). Plant community changes over time can alter microbial communities as shown in western Oklahoma where eastern redcedar encroachment has increased arbuscular mycorrhizal fungi, as it is a symbiont with red cedar (Williams et al., 2013). At the Ashland Bottoms site near Manhattan Kansas on a silt loam two plots were compared that were both continuous grain sorghum for 20 years with one being NT and the other being chisel plowed to a depth of 20 cm (White and Rice, 2009). Analysis of PLFA data revealed that gram positive (g+) and gram negative (g-) bacteria were both higher in the NT treatment, as was the microbial biomass. The authors suggested that C sequestration could be increased when using NT through increased production of recalcitrant byproducts due to a greater amount of soil fungi. On a silt loam in Belle Mina, Alabama plots that were NT and conventionally tilled since 1990 and 1994, respectively, were compared using PLFA (Mathew et al., 2012). The NT plot had significantly higher N, C, and total PLFA at a depth of 0-5 cm, while differences from 5-15 cm were not significant. A 44-year tillage comparison in Ashland Bottoms near Manhattan, Kansas demonstrated greater arbuscular mycorrhizal fungi, contributing to increased macroaggregate stability and higher N and C retention in the NT treatment (Lin et al., 2023).

Soil Health and Soil Quality Indicator Selection

Karlen et al. (2003) states that the first step of indexing dynamic soil quality lies in “selecting appropriate soil quality indicators to efficiently and effectively monitor critical soil functions”. In order to truly index soil quality, it is then necessary to make a scoring system with an appropriate scale that considers the likely maximums and minimums as they relate to the relative conditions of the selected site. Indicators can be inherent or dynamic; inherent indicators relate to soil formation factors, and dynamic indicators reflect soil properties as affected by management within the last decade (Wienhold et al., 2004). Soil health indicators must be informative, sensitive, effective, and relevant (Lehmann et al., 2020). Some properties are relevant but may not qualify as a soil health indicator, such as texture or soil depth.

Soil quality indices can be a helpful tool in assisting land managers with assessing their effects on soil properties and processes through their short-term management (Karlen et al., 2015). One example of a proposed index was put forth by Serri et al. (2022), and it included total nitrogen, SOC, basic infiltration rate, hydrolysis of fluorescein diacetate, and microbial respiration. In their case these indicators clearly showed differences in sequence of crops. Soil quality indices can be built upon a minimum dataset that has been put forth which includes various physical, chemical, and biological attributes (Wienhold et al., 2004).

Chapter 2 - Objectives, Hypotheses, and Methods

Objectives and Hypotheses

The objectives of this study were twofold. One was to evaluate the current major cropland management practices in central Kansas based on soil health using a set of physical and biological analyses. Secondly, the methods used were evaluated for their ability to detect management differences and their reliability and precision. The first hypothesis for this study was that SOC would be strongly correlated to the methods evaluating aggregate stability. The second was that increased crop diversity and decreased tillage would result in better soil health outcomes as signified by the methods used. Lastly, the single sieve method of aggregate stability analysis would have the weakest correlation to other aggregate stability methods, likely due to the amount of human interaction and involvement with the methodology.

Methods

Sample Collection

Samples were taken from a survey area within Harvey and McPherson counties of Kansas. The survey provided management information and contained 900 fields. Of the 900 fields there were 100 pedons sampled. All sampling was done with a Giddings truck-mounted probe (Giddings Machine Company, Windsor, CO). Five 5 cm-diameter cores were collected per pedon, each to at least one meter. Pedons were described using the nomenclature of Schoneneberger et al. (2012) and split into 0-5, 5-10, 10 to the remainder of the genetic horizon, and by genetic horizon to a depth of 1 m. This totals 596 samples for the 100 pedons.

Sites and Management

The fields involved were all surveyed for 11 years of management practices (Figure 1) and were soil sampled on a permission-granted basis. Fields were surveyed in spring and fall and documented tillage and crop. The survey was designed to capture major cropland management practices within Harvey and McPherson counties. The evaluated cropping systems were placed into one of four categories based on their tillage practices and crops planted. The first category was labeled “perennial”. This category included a relatively small sample size (n=14) as compared to the other three categories and was comprised of land enrolled in the Cropland Reserve Program (CRP), pasture, native prairie, and pollinator plantings. The second category (n=26) was the systems that used corn and soybean as their two crops in rotation (corn soy). This category had varying tillage intensity. The lowest intensity was 5 out of 11 years being tilled, while the highest was 11 of 11 years. The third category (n=23) included systems that used 3 or more crops in rotation (3 plus) and again had varying intensities of tillage ranging from 0 of 11 years up to 8 of 11 years being tilled. The fourth and final category was continuous wheat (n=35) made up of fields in which the producer planted wheat and tilled every year. Also evaluated was irrigation effects. The irrigated fields (n=20) were a mix of corn and soybean rotation and corn, soybean, and wheat rotations. These fields ranged from tilling 5 out of 11 years to 11 out of 11 years. The non-irrigated fields (n=27) included fields with corn and soybean rotation, corn, soybean, and wheat rotation, and wheat, soybean, and sorghum rotations. These fields spanned the entire range of tillage from 0 of 11 years being tilled to 11 of 11 years.

Autoclaved Citrate Extractable Protein

Autoclaved citrate extractable (ACE) protein content as modified (Hurisso et al. 2018) from Wright and Upadhyaya (1998) and Keen and Legrand (1980). Samples were air dried and further ground and sieved using a 2 mm sieve. Samples (3g) were placed in autoclave tubes and 24mL of 20mM sodium citrate pH 7.0 was added into the tube. Tubes were capped and shaken for 5 minutes at 180 rpm. The tubes were then autoclaved for 30 minutes at full temperature.

After being autoclaved, tubes were shaken for one minute. Two mL of mixture was withdrawn, placed into 2 mL centrifuge tube and centrifuged at 10,000 x g for three minutes. One mL of the clear extract was transferred to a 1.5 mL centrifuge tube and centrifuged at 10,000 x g for three minutes. Next, 200 µL of the clear extract was transferred to corresponding 8-plug polyethylene strips. Ten µL of the samples were transferred into the 96-well clear flat-bottom chimney well polystyrene plate in available wells, and 200 µL of Pierce bicinchoninic acid (BCA) reagents A and B were added. The plate was then placed on a heat block at 61.5 ºC for 60 mins. A BioTek Synergy H1 hybrid reader (Agilent Technologies, Santa Clara, CA) was used to obtain absorbances. Standard curve was derived using a bovine serum albumin pre-diluted protein assay set that included 125, 250, 500, 750, 1,000, 1,500, and 2,000 µg L^{-1}.

Permanganate Oxidizable Carbon

Active C was determined using $KMnO_4$ and the method developed by Weil et al. (2003). Samples were air dried, ground, and sieved using a 2mm sieve. Samples (2.5 g) were weighed into opaque falcon tubes. Samples were mixed with 20 mL 0.02 M $KMnO_4$, and was adjusted to pH 7.2. Samples were then shaken at 120 rpm for 2 min. A 0.20 mL solution sample was then diluted with 20.0 mL of deionized water in another opaque falcon tube and shaken on a vortex for 10 seconds. The absorbance of the solution was measured at 550 nm with a Shimadzu UV-1900i Spectrophotometer (Shimadzu Scientific Instruments, Columbia, MD). The method detection limit used was an Environmental Protection Agency method taken from revision 2 of 40 CFR 136 appendix B.

Phospholipid Fatty Acid Analysis

The PLFA was completed using the method developed by Buyer and Sasser (2012). The method prepares 96 samples and blanks in 1.5 days. All drying and centrifuging steps took place in a centrifugal evaporator. Soil samples in test tubes were dried overnight and then a Bligh–Dyer lipid extraction was performed. The extract is dried, dissolved in chloroform, and loaded onto a 96-well solid-phase extraction plate. Phospholipids are eluted into glass vials in a 96-well format, dried, and transesterified. The resulting fatty acid methyl esters were analyzed by gas chromatography and quantified relative to an internal standard.

Soil Organic Carbon

An aliquot of 20 g of each sample was cleared from visible fine roots and if present, carbonate nodules, and ground with a mortar and pestle and passed through a 250 µm sieve and analyzed via dry combustion for total carbon (TC) and total nitrogen (Thermo Scientific Flash 2000 Organic Elemental Analyzer, United States) (Poeplau and Don, 2013). For soils containing carbonates the soil inorganic carbon (SIC) content was determined after ignition of the sample at 450 °C for 16 h in a muffle kiln. The SIC was then subtracted from TC to obtain SOC concentration.

Bulk Density

Bulk density samples were taken during the sampling process in 2022. The core method from Blake & Hartge (1986) was used. The samples were taken with a truck-mounted probe, separated at 5 cm, 10 cm, and genetic horizon thereafter and then placed into an autoclavable plastic bag to be dried at 105°C for 48 h. Once the allotted time had passed, bulk density was calculated as shown:

$$\rho\ b = W_{ods}/V_s$$

Where ρ b is the dry bulk density (g cm^{-3}), Wods is the weight of oven-dry soil (g), and Vs is the total volume of soil (cm^3).

SLAKES, the Smartphone App Method

The SLAKES app is available from the Google Play store for Android devices and was installed on a Lenovo Tab 8 tablet. Note that SLAKES is not an acronym, it is the name of the app. The tablet was suspended 30 cm above a laboratory bench. A tabletop photography LED lightbox and an LED shadowless light panel were used to surround the sample with white LED light in all directions to avoid shadows. The light panel was placed inside the lightbox, and a clear petri dish was filled with distilled water. Three pea-sized aggregates (approximately 8 mm in diameter) were immersed in the petri dish, and the SLAKES app (using the tablet's camera) collected images over a 10-min period, at the end of which the SLAKES slaking value was displayed on the tablet.

Single-sieve Hand Method

The single-sieve hand method is method (3F1a1a) of the Kellogg Soil Survey Laboratory of the National Soil Survey Laboratory in Lincoln, Nebraska. This measures the retention of air-dry aggregates (2 to 1 mm) on a 0.5-mm sieve after the sample has been submerged in deionized water overnight followed by agitation of the sample. Approximately 5 g of soil was placed on top of a 2-mm sieve on top of a 1-mm sieve and crushed with mortar and pestle to pass the 2-mm sieve with a minimum reduction in size. Approximately 3.00 ±0.05 grams of the 2- to 1-mm material was weighed into aluminum foil dishes. A 0.5-mm sieve was placed into a plastic bowl and filled with water until the water level was at a 20-mm height above the base of the screen. Air bubbles were removed with a syringe. The 3.00 g sample (2 to 1 mm) was spread onto the 0.5 mm sieve in such a way as to keep the aggregates from touching each other. The sample was allowed to sit in water overnight. The next day, the sample was agitated by hand by raising and lowering the sieve in the water bowl 20 times in 40 s, and to keep time consistent, a metronome was used. On the upward strokes, the sieve was allowed to drain but not raised so high that air entered beneath the sieve. The sieve was removed from the water bowl, placed on a metal plate, and dried in an oven for 2 to 2.5 h at 110 °C, after which the sieve, plate, and sample were weighed. If no sand was present, the sieve and plate were then weighed. If sand was present, the sample was then dispersed and rinsed with reverse osmosis water and if any sand was remaining on the sieve, the sieve and plate were placed in the oven to dry for 2 to 2.5 h at 110 ºC. The sample was then removed from the oven, the weight recorded and the sample was discarded. The empty sieve and plate were then weighed. Five grams of soil or more was placed into a pre-weighed metal dish and then weighed to obtain the air-dried weight of the soil. This dish with the air-dried soil was then placed in the oven at 105 ºC for 24 h and then weighed for the oven-dry soil weight.

Calculations

$\text{Aggregates (\%)}=\{\{(WR-SW)/\{[IW/(AD/OD)]-Sw\}\}\text{x}100$

where:

IW=Initial sample weight (approximately 3 g)

WR=Total weight of aggregates retained on 0.5-mm sieve

SW=Weight of 2- to 0.5-mm sand

AD/OD=Air-dry/oven-dry weight (if not available, use 1.00)

Machine Method

Aggregate samples were processed to find water-stable aggregates according to the Agricultural Research Service method, which is a modified version of the Kemper & Rosenau (1986) wet method was accomplished using a machine (Grainger, Inc., Lake Forest, IL) that moved four nests of sieves separately with a vertical displacement of 35 mm at 30 cycles min^{-1}. Each nest of sieves contained two 127 mm diameter and 40 mm deep sieves with the following screen openings: 2 mm and 0.25mm (Newark Wire Cloth Company, Clifton, NJ). A 36 g sample of air-dried aggregates was placed on the top sieve (2 mm) and saturated with water for ten minutes. After the allotted time, the sieves were mechanically oscillated in a bucket with deionized water for another five minutes. Following oscillation, the sieves are placed on an aluminum dish, and dried at 105°C for 2 to 2.5 h. The water from each bucket is poured through a 0.053mm mesh sieve and this sieve is placed on an aluminum dish and allowed to dry for 2 to 2.5 h. After drying the sieve and plate assemblies are weighed. For the sand and coarse fragment corrections, the oven-dried samples are allowed to wet for five minutes and then broken up with a rubber policeman and deionized water is used to remove clay silt fractions. The sieves are placed on a metal plate and allowed to dry for 2 to 2.5 h. The particles in each sieve are then weighed to find the coarse fragment corrections. Five grams of soil or more was placed into a pre-weighed metal dish and then weighed to obtain the air-dried weight of the soil. This dish with the air-dried soil was then placed in the oven at 105 ºC for 24 h and then weighed for the oven-dry soil weight.

Using the calculation from Stone & Schlegel (2010), the mean weight diameter (MWD) was calculated as shown below:

Mean weight diameter (MWD) =

∑ for all aggregate fractions sieve mean diameter x Total water stable soil aggregate fraction

Total water stable soil aggregate fraction (%) = (Wr-Sw)/(Iw/(AD/OD))x100 where:

Wr = Oven-dry weight of aggregates retained on specified sieve fraction

Sw = Oven-dry weight of sand for specified sieve fraction (weight of tared sieve and oven-dried sand – weight of tared sieve)

IW = Initial weight of air-dry sample (≈36 g)

AD/OD = Air-dry/oven-dry weight (If not available, use 1.00.)

Rainfall Simulator Method

Aggregate samples were assessed for wet stability using a modified version of a method developed by Moebius et al. (2007). Air-dried soil that had previously been passed through an 8 mm sieve was passed through a 2 mm sieve and caught on a 0.25 mm sieve until enough volume was present to fill a tablespoon scoop. A separate 0.25 mm sieve was weighed while empty with an aluminum plate. The soil was moved into the tablespoon scoop and spread onto the weighed 0.25 mm sieve of 127 mm in diameter and 40 mm deep for testing. This sieve was placed into a bucket to contain the water. The rainfall simulator (Ogden et al., 1997) was calibrated to deliver 1.25 cm of water depth (as drops) in five minutes. The simulator was set up 0.5 meters above where the sieve and bucket would later be placed. The simulator was allowed to start and the bucket containing the sample on the 0.25 mm sieve was moved underneath the simulator while simultaneously starting a stopwatch set for five minutes. The bucket was moved laterally and rotated every twenty seconds to randomly and evenly apply water drops to all parts of the sieve. After the 5-minute period, the bucket was taken out from under the simulator, the sieve was removed and placed on the aluminum plate and put in an oven at 105 ºC for 2 to 2.5 h or until dry. The sieve and plate were then removed and weighed. The sieve was then placed under deionized water and a rubber policeman was used to break up and remove the soil. If sand remained on the sieve, it was dried at 105 ºC for 2 to 2.5 h or until dry and weighed. Five grams of soil or more was placed into a pre-weighed small metal dish and then weighed to obtain the air-dried weight of the soil. This dish with the air-dried soil was then placed in the oven at 105 ºC for 24 h and then weighed for the oven-dry soil weight. The calculations used for this method are from the single sieve hand-method.

Calculations

$\text{Aggregates (\%)}=\{\{(WR-SW)/\{[IW/(AD/OD)]-Sw\}\}x100$

where:

IW=Initial sample weight

WR=Total weight of aggregates retained on 0.25-mm sieve

SW=Weight of 2- to 0.25-mm sand

AD/OD=Air-dry/oven-dry weight (if not available, use 1.00)

Statistical Analysis

The data was analyzed by depth across the fixed factors of cropping systems and irrigation with an analysis of variance in SAS (version 9.4; Cary, NC) using Proc GLIMMIX and means were separated at $p<0.05$. A correlation between bulk density, SLAKES, machine, single sieve, rainfall simulator, MWD, POXC, ACEP, SOC, and PLFA total biomass was used in order to understand further each method’s sensitivity to change and relation to each other using Proc Corr in SAS with significance level of $p<0.05$.

Figure 1. McPherson (top) and Harvey (bottom) counties shown highlighted with routes of cropland survey (2010-2022) shown.

Chapter 3 - Results and Discussion

The effect of cropping system was significant (alpha=0.05) for every analysis measured at 0-5 cm and results will be presented throughout this section in multiple figures and graphs. At 5-10 cm there was a significant effect of cropping system on all analyses except for POXC and the same was true of the depth 10 cm-x (10 cm – the end of the horizon). When it came to the comparison of irrigated and non-irrigated fields there were fewer differences found. When including all depths and methods the majority of those differences were non-significant. The remainder of this section will be organized as follows: First, physical properties will be discussed with emphasis on a comparison among the aggregation methods. Next, chemical and biological properties and their results will be discussed while providing additional context for the methods which have been criticized in the literature. Lastly some correlations amongst all methods will be discussed.

Soil Physical Properties

Total Aggregation

Total aggregation percentage, defined as macroaggregates retained on the sieves used within each method, for the 0-5 cm depth was significantly affected by cropping system. Across the four methods used, the perennial cropping system had the highest total aggregation percentage and lowest slaking coefficient. In contrast, continuous wheat had the lowest total aggregation percentage and highest slaking coefficient (Figures 2 and 3). All four methods used were able to clearly and significantly demonstrate this difference between continuous wheat and perennial systems. In what could be seen as contrary to our results, Blanco-Canqui et al. (2010) studied sorghum fallow, continuous sorghum, winter wheat sorghum fallow, wheat fallow, and continuous wheat, each under reduced tillage and NT and found that NT continuous wheat resulted in the highest increases in wet aggregate stability in Kansas. Similarly, Sainju et al. (2021) found that NTCW had higher aggregate stability than conventional till wheat-fallow CTWF, NT wheat-fallow NTWF, and NT wheat pea NTWP in the northern Great Plains. Although the aforementioned studies suggest that continuous wheat can produce high levels of aggregate stability, they point to the practice of tillage as the likely culprit of poor aggregate stability, as opposed to the continuous wheat.

Differentiation of corn and soybean (*Glycine max*) systems (corn soy) from systems using 3 or more crops (3 plus) at 0-5 cm was dependent upon the method used (Figure 2). The machine method and the smartphone application (SLAKES) could not differentiate between the two systems at 0-5 cm (Figures 2 & 3). Furthermore, at 0-5 cm with the single sieve method, there was significantly higher in total aggregation (41.7%) in corn soy than 3 plus (30.3%). The rainfall simulator method (Cornell) showed the opposite, with 3 plus (52.1%) as higher than corn soy (41.0%). Moving to comparisons of corn soy and 3 plus at 5-10 cm demonstrated that the single sieve method could no longer show a difference between corn soy and 3 plus (Figure 4), whereas SLAKES showed a difference between corn soy and 3 plus (Figure 4). Corn soy having had a lower slaking coefficient (2.06) compared to 3 plus (2.80). Yet Cornell had a difference in the opposite direction between corn soy (36.2%) and 3 plus (50.8%). At 10 cm-x Cornell continued this trend with 3 plus (56.0%) as higher than corn soy (40%), and no significant difference between 3 plus and perennial systems. This was the only depth in which there seemed to be some agreement between methods about the issue of corn soy compared to 3 plus, considering the machine method also showed at 10 cm-x that 3 plus (57.3%) was significantly greater than corn soy (46.2%) (Figure 5).

Comparison of corn soy and 3 plus systems indicate a difference in aggregate stability between these two treatments. The difference between the methods pointed in opposite directions. One could point to the differences in sieve sizes to try to explain this difference, but the similarities were too substantial to warrant the observed differences between the method results. For instance, both single sieve and Cornell started with aggregates that had been passed through a 2 mm sieve. Cornell used a 0.25 mm sieve while the single sieve method used a 0.5 mm sieve. This may point to a need for more study of this issue using equal sieve sizes to determine if this is still repeatable, and if it is, to determine which method is a truer measure of aggregate stability and which method may need to be referred to as a proxy for something different. Both methods are numerically providing measurements of total aggregation percentage, but the implications of those percentages ultimately are manifesting themselves as a more generalized phenomena referred to as aggregate stability. If they can both consistently report differences such as this, in which they show differences with opposing orientations, then it would seem that by definition, only one of them could be referring to aggregate stability.

Generally, less differentiation between management practices was possible as depth increased. A long-term study in Kansas (McVay et al., 2006) had a similar conclusion, which was that changes in soil aggregation due to crop rotation and tillage were primarily exhibited at the 0-5 cm depth. Even though there were less differences to be found with more depth, there were still trends and differences worth noting. The SLAKES method could no longer tell a difference between 3 plus and continuous wheat at 5-10 cm (Figure 3). At 10 cm-x depth SLAKES now could only tell a difference between perennial and all other cropping systems. Based on the number of differences that SLAKES could show, and lack thereof, it seemed to be the least sensitive method. Bagnall and Morgan (2021), used the SLAKES application and partitioning around medoids to test if the application would cluster NT treatments with perennial grass treatments or with conventional till treatments. In the Bagnall and Morgan study (2021) the results were mixed, as the clusters showed 3 of the NT fields clustered with the perennial grass and 4 of the NT fields clustered with the conventional till.

In this central Kansas study there were fewer differences when comparing irrigated to non-irrigated fields than there were differences between fields based on cropping systems. All differences in aggregation based on irrigation took place at a depth of 5-10 cm and 10 cm-x. In the few instances that there was a significant difference between the irrigated and non-irrigated fields regarding aggregate stability it was the irrigated fields that had the higher stability. At 5-10 cm with the single sieve method the irrigated fields (31.0%) (p = 0.0253) had a significantly higher mean total aggregation percentage than non-irrigated fields (20.6%) (Table 1). At 10 cm-x irrigated fields had higher total aggregation percentages in both the single sieve (28.9%) (p = 0.0302) and machine methods (56.7%) (p = 0.0388) than the non-irrigated fields (18.5% and 45.8%). Kenney et al. (2015) found that aggregate stability was not negatively impacted by stover removal in Kansas, yet in the rainfed fields stover removal did negatively impact aggregate stability. Their results may suggest that irrigated fields can have higher aggregate stability than non-irrigated fields, or at least for there to be more resistance to aggregate degradation given certain disturbances.

MWD

Cropping system had a significant effect on MWD at all three depths (Figure 6). Only at a depth of 0-5 cm was the MWD of all systems significantly different from one another. At this depth corn soy had a larger MWD than 3 plus, whereas no difference was observed at 5-10 cm or 10 cm-x. At all depths perennial had the largest MWD and continuous wheat had the smallest

(Figure 6). The result of continuous wheat having the lowest MWD reaffirms studies in Kansas that have shown that an elimination of tillage increased MWD (Presley et al., 2012). When comparing irrigated fields to non-irrigated fields there was a difference at 10 cm-x (p = 0.0273) which showed irrigated as having a 0.76 mm MWD and non-irrigated having a 0.61 mm MWD (Table 1). Lenka et al. (2014) showed that with increased irrigation in corn and wheat cropping systems that there was increased SOC which led to increased MWD.

Bulk Density

At 0-5 cm continuous wheat had a significantly higher bulk density (p = 0.0076) (1.33 g cm^{-3}) than perennial (1.06 g cm^{-3}), corn soy (1.11 g cm^{-3}), and 3 plus (1.14 g cm^{-3}). Unger and Jones (1998) found that tilled treatments had lower bulk density than NT in the tilled layer (0-10 cm), but that there was not a significant trend of differences between NT and tillage beyond 10 cm. Bulk density was significantly lower in the perennial fields than in any of other cropping systems for the depth of 5-10 cm and 10 cm-x. Similar results were found when Schwenke et al. (2013) noted that sown pasture and native pasture both had a lower bulk density than conventionally cropped fields. At 5-10 cm non-irrigated fields had a significantly higher bulk density than did irrigated fields (Table 1). There were no differences in bulk density between irrigated and non-irrigated fields at 0-5 cm or from 10 cm-x. The method used for this study was prone to inaccuracy when it came to determining the depth measured in tilled soil (0-10 cm), and therefore inaccuracies in the resultant bulk density as calculated. This may explain some of the incongruencies in the trends of tilled fields in this study compared to tilled fields in the scientific literature. The excavation method could be an alternative that would provide improved accuracy albeit at the cost of increased labor (Gross and Harrison, 2018).

Soil Chemical Properties

Autoclaved Citrate Extractable Protein (ACEP)

Perennial cropping systems had the greatest value for ACEP at all three depths (Table 2). Wright and Anderson (2000) also found perennial grass to have the highest ACEP values. At 0-5 cm corn soy was significantly higher in ACEP than continuous wheat or 3 plus. All cropping systems showed a decrease in ACEP with lower depths. The 3 plus cropping system was significantly lower in ACEP than all other systems throughout all three depths. Considering continuous wheat was the most intensively tilled system in this study these results are not aligned with results from Wright and Anderson (2020), Wright et al. (2007), and Moebius-Clune et al. (2008), who all showed that tillage negatively impacted ACEP. The mentioned studies drew their conclusion from data represented by NT, continuous-till, and other more clearly delineated treatments like reduced till. This is much more difficult to accomplish on producer’s fields, meaning fields that have a mixed history of tillage with tillage before some crops but not others, as compared to experiment stations.

The difference in ACEP due to tillage may be disguised by other management differences. If management differences are producing different amounts of humic substances in the soil then this further complicates the issue of determining true differences in ACEP content. Roberts and Jones (2008) demonstrated that this protein assay kit overestimates protein content with increasing levels of coextracted humic substances. At 5-10 cm and 10 cm-x corn soy is no longer significantly different from continuous wheat. The ACEP method was unable to detect differences between irrigated and non-irrigated fields at any depth. Data was available for ACEP at all depths to a meter, so an ANOVA was run between cropping systems using all depths after the third horizon to a meter. Corn soy systems (1773 µg protein g^{-1} dry soil) were significantly higher in ACEP content than perennial (1333 µg protein g^{-1} dry soil) and continuous wheat (1265 µg protein g^{-1} dry soil) which were higher than 3 plus (1010 µg protein g^{-1} dry soil). There is a dearth of data demonstrating that the ACEP method can effectively tell differences between cropping systems at these depths. It seems likely that this reflects a difference in parent material and other inherent soil characteristics that led producers to choose to plant higher value crops in soil more capable of being profitable with those crops.

POXC

POXC was the only method that was unable to detect any effect of cropping system at 5-10 cm and 10 cm-x. At 0-5 cm POXC did show an effect ($p < 0.0001$) (Table 2). The perennial systems had the highest mean POXC value (602 mg kg^{-1} soil), and continuous wheat had the lowest (345mg kg^{-1} soil). Corn soy (434 mg kg^{-1} soil) and 3 plus (504 mg kg^{-1} soil) were not significantly different from one another but were both significantly higher than continuous wheat. Although POXC was unable to show effects based on cropping system at 5-10 cm and 10 cm-x, it was one of the few methods able to show differences between irrigated and non-irrigated fields at 0-5 cm and 5-10 cm (Table 3). At both 0-5 cm ($p = 0.0217$) and 5-10 cm ($p = 0.0005$) the irrigated fields had significantly higher mean levels of POXC. Worth noting is that the single sieve method also found a difference at 5-10 cm and it showed that the irrigated fields had significantly higher total aggregation (31%) ($p = 0.0253$) than non-irrigated fields (20.6%) (Table 1). This has some precedent in the literature as Sainju et al. (2022) found that POXC was positively associated with water stable aggregation.

The results given by the POXC method in this study need to be considered while at the same time recognizing some of the shortfalls of this method. When Weil et al. (2003) introduced this method, it was a modified version of a previous method that significantly reduced the concentration of $KMnO_4$ to 0.02 M from previous methods (Blair et al., 1995) that used 0.333M $KMnO_4$. The initial assumption that MnO_4^- oxidation was nearly analogous to microbial oxidation (Loginow et al., 1987) was how the basis was formed to claim that POXC as a method was in fact an active carbon method (Weil et al., 2003). Weil et al. (2003) stated that "the proposed active C method is designed to measure an operationally defined fraction of soil C, there may be no good way to estimate the *accuracy* of the method". Soon this method was further demonstrated to be sensitive to management changes (Wuest et al., 2006) and eventually was adopted in the *Recommended Soil Health Indicators and Associated Laboratory Procedures* (Stott, 2019) technical note where it was referred to as a method that "measures the portion of soil organic matter that can serve as a readily available food and energy source for the soil microbial community".

Eventually studies started to challenge the idea that there may not be a way to estimate the accuracy of the method, and in particular they challenged a few of the claims that were the crux of the method. One of those two claims was that "dilute $KMnO_4$ reacts with the most readily oxidizable (active) forms of soil C" and the other was related, but a slightly different claim, that "$KMnO_4$ can be used to react with diverse soils to estimate a biologically active soil C pool" (Weil et al., 2003). Gruver (2015) mentioned that lignin rich materials were more reactive with permanganate than cellulose or gluten, seemingly pointing out that this method may be measuring the exact opposite of what it is broadly understood to measure. Gruver was not alone, as Woodings and Margenot (2023) later found that glucose, arabinose, sucrose and cellulose did not differ from a quartz control, in that they did not reduce permanganate, although they found that lignin did. Wade et al. (2021) recognized that MnO_4^- can oxidize many inorganic compounds found in soil including sulfur and N compounds. Christy et al. (2023) corroborated that carbohydrates were unreactive and lignin was reactive with permanganate, but specifically pointed out that it seemed POXC was primarily measuring phenolic and polyphenolic structures. Woodings and Margenot (2023) went as far as to state that their study provided “strong evidence that POXC does not measure the labile SOC pool the POXC assay was developed to quantify”, even though the use of POXC is commonly referred to in scientific literature as measuring “labile” or “active” fractions of C. It follows that this method in the future will likely be presented in different units than mg POXC kg^{-1} soil, and instead will be reported as Wade et al. (2021) recommended as µmol MnO_4^- reduced kg^{-1} soil. This approach was not used for this study, as one of the objectives was to evaluate the method that appears in the Soil Health Technical Note (Stott, 2019).

To summarize what all this means as a critique of POXC as a method to be used as a soil health indicator it is worth revisiting what Rinot et al. (2019) laid out regarding selection of a soil health indicator. There are four important qualifiers that should be satisfied in order to consider a particular soil attribute as a suitable descriptor of soil health status. One of those was that it should be a measurement of relevant scientific-based data, which POXC in its current form is not (Wade et al., 2021). The next qualifier was that the soil attribute needed to be sensitive to management changes, which POXC has satisfied (Weil et al., 2003; Wuest et al., 2006; Sainju et al., 2022). Next was that it needed to be cost-effective and accurate, and POXC may meet the cost-effective, but it does not meet the accurate qualifier (Wade et al., 2021; Christy et al., 2023; Woodings and Margenot, 2023). Lastly the indicator should be reflective of the connection between soil functions and management targets, but POXC does not seem to be representative of any one particular soil function as it has been inaccurately conflated to be representative of microbial oxidation when it is simply MnO_4^{-} oxidation (Loginow et al., 1987; Woodings and

Margenot, 2023). Soil health research into POXC going forward would seemingly be much better served by determining what exactly POXC is measuring, then determining if that has any relevance to soil health, and only then would it potentially make logical sense to move forward with POXC as a soil health indicator.

Soil Biological Properties

PLFA

Biomass determined with PLFA (total PLFA) was significantly affected by cropping system ($p < 0.0001$) at 0-5 cm and 5-10 cm (Table 2). The trends relating to the cropping systems changed with each depth. At 0-5 cm perennial systems had the highest total PLFA (112,981 pmol g^{-1} soil) and were followed by corn soy (75,281 pmol g^{-1} soil), continuous wheat (62,409 pmol g^{-1} soil), and 3 plus (55,043 pmol g^{-1} soil). At 0-5 cm continuous wheat was not significantly different from 3 plus or corn soy. At 5-10 cm the only difference was that perennial (81,436 pmol g^{-1} soil) was significantly higher than 3 plus (46,294 pmol g^{-1} soil), continuous wheat (40,372 pmol g^{-1} soil) and corn soy (44,599 pmol g^{-1} soil). At 10 cm-x there were no significant differences among cropping systems.

Continuous wheat not being significantly lower in total PLFA than other cropping systems other than perennial may be explained by observed short-term dynamics in the microbial community after a tillage event. Many of the samples were taken in tilled fields late in the summer just before winter wheat planting time and soon after a tillage event, but the exact date of tillage is not available to explain exactly how recently the event had taken place. Calderon et al. (2001) found that a tilled treatment had higher biomass determined using PLFA for as many as 12 days after the event when compared to a NT control. White and Rice (2009) found that microbial biomass was lower in a long-term tillage treatment than a NT treatment. Total PLFA was not significantly affected by irrigation at 0-5 cm, 5-10 cm, or 10 cm-x (Table 3).

When it came to the different estimates of group biomass based on cropping system at 0-5 cm within the PLFA, perennial was again in a class of its own, as it was significantly higher in every group when compared to any of the other cropping systems ($p < 0.0001$) (Table 4). Comparing the remaining cropping systems showed that corn soy and 3 plus were not different from each other, but had significantly higher amounts of arbuscular mycorrhizal fungi (AMF), gram negative bacteria (g-), eukaryotes, gram positive bacteria (g+), and actinobacteria than the continuous wheat fields at 0-5 cm. Others have found AMF, g(-), and g(+) to be higher in NT than continuous tilled fields (White and Rice, 2009; Lin et al., 2023). Although this study was not comparing NT to continuous tillage, the fields averaging moderate amounts of tillage (corn soy and 3 plus) did show higher values than continuous tilled wheat for the same mentioned groups that were reported by White and Rice (2009) and Lin et al. (2023). A similar trend from 0-5 cm continued at 5-10 cm for AMF showing perennial as significantly higher (2871 pmol g^{-1} soil) than other cropping systems, but in this case corn soy (1604 pmol g^{-1} soil) was significantly higher than continuous wheat (1241 pmol g^{-1} soil) while 3 plus (1366 pmol g^{-1} soil) was not significantly different from corn soy or continuous wheat. Outside of AMF the only distinction between systems for all other groups at 5-10 cm was between perennial and all other systems ($p < 0.0001$). At 10 cm-x there was not a significant effect of cropping system on AMF. Many of the groups at 10 cm-x continued the trend of perennial being the only system that was significantly different than the others including g(-) ($p < 0.0001$), fungi ($p < 0.0001$), g(+) ($p < 0.0001$), and actinobacteria ($p = 0.0003$). Eukaryotes at 10 cm-x were the highest in perennial (730 pmol g^{-1} soil) and 3 plus (477 pmol g^{-1} soil) which were not significantly different from one another, and lowest in the corn soy (187 pmol g^{-1} soil). Continuous wheat (281 pmol g^{-1} soil) was not significantly different from corn soy or 3 plus at 10 cm-x in the eukaryote group.

Irrigation had an effect on some microbial groups at 0-5 cm and 5-10 cm and no effect on any group at 10 cm-x (Table 5). Eukaryotes and fungi were unaffected by irrigation at any depth. AMF, g(-), g(+), and actinobacteria were all significantly higher in irrigated fields than non-irrigated fields at 0-5 cm and 5-10 cm (Table 5).

SOC

The full data set for SOC for all pedons was not available as sample analysis for SOC is still ongoing. The data available for SOC included all 22 pedons from Harvey county. Pearson correlation coefficients were obtained for all samples by depth including 0-5 cm (Table 7), 5-10 cm (Table 8), and 10 cm-x (Table 9). At 0-5 cm the significant correlations included ACEP (0.64) ($p = 0.0014$), POXC (0.64) ($p = 0.0108$), and bulk density (-0.48) ($p = 0.0268$). The same trend with the same indicators continued at 5-10 cm. Bulk Density and ACEP continued the trend through 10 cm-x, but POXC was no longer significantly correlated at 10 cm-x. Although these correlations were not able to be obtained for the full data set, which included an additional 78 pedons from McPherson county, the limited number of samples available do not agree with the first hypothesis of this study which was that there would be a strong correlation between aggregate methods and SOC. There was not an aggregate stability method that had a significant correlation to SOC at any of the three depths.

Correlations

Some noteworthy strong correlations among aggregation methods at 0-5 cm (Table 6) included positive correlations between the machine method and MWD (0.91) ($p < 0.0001$), machine and single sieve (0.89) ($p < 0.0001$), and single sieve and MWD (0.88) ($p < 0.0001$).

Correlations between the Cornell method and machine (0.77) ($p < 0.0001$) as well as Cornell and single (0.77) ($p < 0.0001$) were not as strong. These lower correlations with Cornell further point toward the possibility that Cornell may be fundamentally different than the other methods. SLAKES had the lowest correlations overall which seems to further indicate that SLAKES is the least sensitive method. The highest correlation SLAKES had with another aggregate method was with single (0.53) ($p < 0.0001$). When comparing SLAKES to other methods Rieke et al. (2022) also found SLAKES to have lower correlation coefficients. The weakest correlation Rieke et al. (2022) found was between SLAKES and MWD (0.45), and the strongest correlation was between Cornell and MWD (0.69). In our case SLAKES and Cornell (0.44) ($p < 0.0001$) was the weakest correlation, and machine and MWD was the strongest (0.91) ($p < 0.0001$). Some correlations of moderate strength were present between aggregate stability methods and ACEP (Table 6). MWD and ACEP were moderately correlated (0.64) ($p < 0.0001$) as well as single and ACEP (0.63) ($p < 0.0001$). This is a correlation that has been found by other researchers (Geisseler et al., 2019; Wright and Upadhyaya, 1998), and is one of the primary reasons for continued interest in the ACEP method.

Table 1. Single sieve total aggregation (p = 0.0253) and bulk density (g cm^{-3}) (p = 0.0161) measured at 5-10 cm. Single sieve (p = 0.0302) and machine (p=0.0388) total aggregation and MWD (mm) (p = 0.0273) measured at 10 cm-x. P values represent difference between irrigated (n=20) and non-irrigated (n=27) fields.

Depth	*Method*	*Irrigated*	*Non-irrigated*	*p-value*
5-10 cm	Single sieve	31.0%	20.6%	0.0253
5-10 cm	Bulk density	1.4 g cm^{-3}	1.6 g cm^{-3}	0.0161
10 cm-x	Single sieve	28.9%	18.5%	0.0302
10 cm-x	Machine	56.7%	45.8%	0.0388
10 cm-x	MWD	0.76mm	0.61mm	0.0273

Table 2. ACEP, POXC, and Total PLFA shown by depths 0-5 cm, 5-10 cm, and 10 cm-x between cropping systems. Letters show differences by depth between cropping systems. Means sharing a letter indicate no statistical difference. NS indicates cropping system did not have a significant effect on results. ACEP is shown in µg protein g^{-1} soil, POXC is shown in mg POXC kg^{-1} soil, and total PLFA is shown in pmol g^{-1} soil.

Depth	*Method*	*Perennial*	*Corn Soy*	*3 Plus*	*Cont Wheat*	*p-value*
0-5 cm	ACEP	7525a	5779b	4348d	5017c	P < 0.0001
5-10 cm	ACEP	5053a	4627ab	3233c	4500b	P < 0.0001
10 cm-x	ACEP	3423a	3242ab	2334c	3025b	P < 0.0001
0-5 cm	POXC	602a	434b	504ab	345c	P < 0.0001
5-10 cm	POXC	NS	NS	NS	NS	NS
10 cm-x	POXC	NS	NS	NS	NS	NS
0-5 cm	Total PLFA	112981a	75281b	55043c	62409bc	P < 0.0001
5-10 cm	Total PLFA	81439a	44599b	46294b	40372b	P < 0.0001
10 cm-x	Total PLFA	NS	NS	NS	NS	NS

Table 3. ACEP, POXC, and Total PLFA shown by depths 0-5 cm, 5-10 cm, and 10 cm-x, between irrigated and non-irrigated. Means sharing a letter indicate no statistical difference. NS indicates irrigation did not have a significant effect on results. ACEP is shown in µg protein g^{-1} soil, POXC is shown in mg POXC kg^{-1} soil, and total PLFA is shown in pmol g^{-1} soil.

Depth	*Method*	*Irrigated*	*Non-irrigated*	*p-value*
0-5 cm	ACEP	NS	NS	NS
5-10 cm	ACEP	NS	NS	NS
10 cm-x	ACEP	NS	NS	NS
0-5 cm	POXC	520a	407b	P = 0.0217
5-10 cm	POXC	373a	257b	P = 0.0005
10 cm-x	POXC	NS	NS	NS
0-5 cm	Total PLFA	NS	NS	NS
5-10 cm	Total PLFA	NS	NS	NS
10 cm-x	Total PLFA	NS	NS	NS

Table 4. PLFA groups shown by depths 0-5 cm, 5-10 cm, and 10 cm-x between cropping system. PLFA groups include arbuscular mycorrhizal fungi (AMF), gram negative bacteria (g-), eukaryotes (Euk), fungi, gram positive bacteria (g+), and actinobacteria (actino). Means represent estimates of PLFA group biomass. Means sharing a letter indicate no statistical difference. NS indicates cropping system did not have a significant effect on results. All values are shown in pmol g-1 soil.

Depth	*Group*	*Perennial*	*Corn Soy*	*3 Plus*	*Cont Wheat*	*p-value*
0-5 cm	AMF	5492a	3082b	2769b	1453c	P < 0.0001
0-5 cm	g (-)	43281a	25678b	26277b	15868c	P < 0.0001
0-5 cm	Euk	3224a	1363b	1123b	702c	P < 0.0001
0- 5 cm	Fungi	8367a	2597b	2403b	2192b	P < 0.0001
0-5 cm	g (+)	29966a	20427b	20418b	15288c	P < 0.0001
0-5 cm	actino	15988a	10227b	10921b	7117c	P < 0.0001
5-10 cm	AMF	2871a	1604b	1366bc	1241c	P < 0.0001
5-10 cm	g (-)	26582a	15437b	13862b	14423b	P < 0.0001
5-10 cm	Euk	2057a	886b	735b	622b	P < 0.0001
5-10 cm	Fungi	5582a	946b	769b	1786b	P < 0.0001
5-10 cm	g (+)	22303a	14210b	12675b	14109b	P < 0.0001
5-10 cm	actino	11654a	7657b	7570b	7349b	P = 0.0002
10 cm-x	AMF	NS	NS	NS	NS	NS
10 cm-x	g (-)	15647a	7530b	9190b	8266b	P < 0.0001
10 cm-x	Euk	730a	187c	477ab	281bc	P = 0.0019
10 cm-x	Fungi	2926a	663b	399b	796b	P < 0.0001
10 cm-x	g (+)	15661a	8594b	9409b	9177b	P < 0.0001
10 cm-x	actino	8857a	5566b	6703b	6485b	P = 0.0003

Table 5. PLFA groups by depths 0-5 cm and 5-10 cm between irrigated and non-irrigated. PLFA groups include arbuscular mycorrhizal fungi (AMF), gram negative bacteria (g-), eukaryotes (Euk), fungi, gram positive bacteria (g+), and actinobacteria (actino). Means represent estimates of PLFA group biomass. NS indicates irrigation did not have a significant effect on results. All values are shown in pmol g^{-1} soil.

Depth	*Group*	*Irrigated*	*Non-irrigated*	*p-value*
0-5 cm	AMF	3386a	2454b	P = 0.0027
0-5 cm	g (-)	28541a	22657b	P = 0.0014
0-5 cm	Euk	NS	NS	NS
0-5 cm	Fungi	NS	NS	NS
0-5 cm	g (+)	21227a	18402b	P = 0.0483
0-5 cm	actino	11213a	9297b	P = 0.0067
5-10 cm	AMF	1742a	1320b	P = 0.0013
5-10 cm	g (-)	16484a	13363b	P = 0.0012
5-10 cm	Euk	NS	NS	NS
5-10 cm	Fungi	NS	NS	NS
5-10 cm	g (+)	14753a	12145b	P = 0.0036
5-10 cm	actino	8402a	6704b	P = 0.0002

Table 6. Pearson Correlation Coefficients for all pedons at 0-5 cm. Methods included are ACEP (Protein), SLAKES (SLKS), MWD, machine, single sieve (Single), Cornell, POXC, total PLFA, and bulk density. Cells contain correlation coefficient (upper) and associated p-value (lower).

	Protein	SLKS	MWD	Machine	Single	Cornell	POXC	Total PLFA	Bulk Density
Protein									
SLKS	-0.35 0.0005								
MWD	0.64 <0.0001	-0.49 <0.0001							
Machine	0.51 <0.0001	-0.49 <0.0001	0.91 <0.0001						
Single	0.63 <0.0001	-0.53 <0.0001	0.88 <0.0001	0.89 <0.0001					
Cornell	0.41 <0.0001	-0.44 <0.0001	0.68 <0.0001	0.77 <0.0001	0.77 <0.0001				
POXC	0.50 <0.0001	-0.20 0.0589	0.49 <0.0001	0.48 <0.0001	0.55 <0.0001	0.73 <0.0001			
Total PLFA	0.51 <0.0001	-0.20 0.0469	0.31 0.0019	0.36 0.0004	0.46 <0.0001	0.29 0.0037	0.31 0.0027		
Bulk Density	-0.16 0.1307	0.10 0.3685	-0.25 0.0194	-0.29 0.0075	-0.31 0.0039	-0.32 0.0029	-0.25 0.0217	-0.22 0.0377	

Table 7. Pearson Correlation Coefficients for ACEP (Protein), SLAKES, MWD, machine, single sieve (Single), Cornell, POXC, total PLFA, bulk density, and SOC % at 0-5 cm in Harvey county. Cells contain correlation coefficient (upper) and associated p-value (lower).

	Protein	SLAKES	MWD	Machine	Single	Cornell	POXC	Total PLFA	Bulk Density

SOC %	0.64 0.0014	0.04 0.88	0.20 0.36	0.29 0.2127	0.43 0.0609	0.30 0.2064	0.64 0.0108	-0.20 0.3778	-0.48 0.0268

Table 8. Pearson Correlation Coefficients for ACEP (Protein), SLAKES, MWD, machine, single sieve (Single), Cornell, POXC, total PLFA, bulk density, and SOC % at 5-10 cm in Harvey county. Cells contain correlation coefficient (upper) and associated p-value (lower).

	Protein	SLAKES	MWD	Machine	Single	Cornell	Active Carbon	Total PLFA	Bulk Density
SOC %	0.69 0.0007	-0.11 0.6275	0.20 0.4074	0.02 0.9310	0.43 0.0545	-0.08 0.7353	0.47 0.0348	-0.21 0.3632	-0.50 0.0252

Table 9. Pearson Correlation Coefficients for ACEP (Protein), SLAKES, MWD, machine, single sieve (Single), Cornell, POXC, total PLFA, bulk density, and SOC % at 10 cm-x in Harvey county. Cells contain correlation coefficient (upper) and associated p-value (lower).

	Protein	SLAKES	MWD	Machine	Single	Cornell	Active Carbon	Total PLFA	Bulk Density
SOC %	0.59 0.0045	0.25 0.2679	0.32 0.1455	0.26 0.2462	0.41 0.0568	0.38 0.0844	0.17 0.5147	0.30 0.1789	-0.42 0.0592

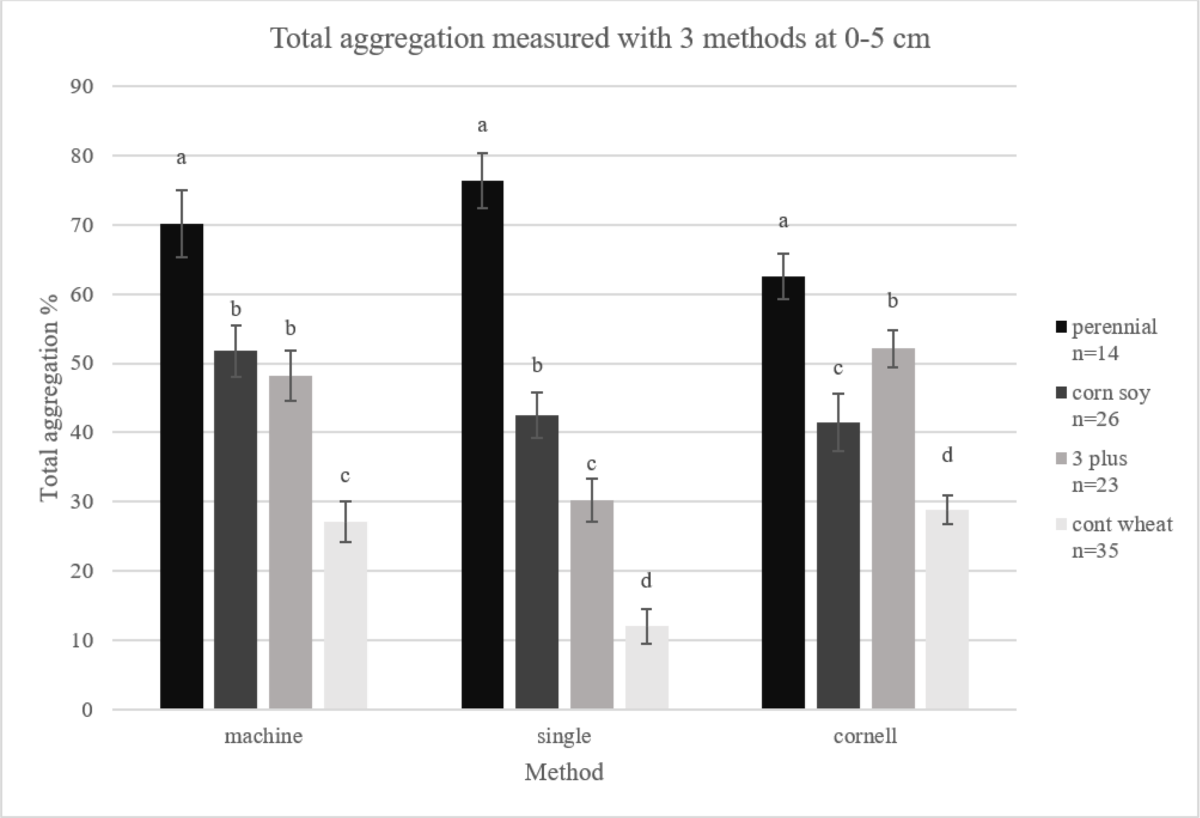

Figure 2. Total aggregation measured at 0-5 cm for each cropping system with machine ($p < 0.001$), single-sieve ($p < 0.001$), and Cornell ($p < 0.001$) methods. Letters show differences by method between cropping systems. Means sharing a letter indicate no statistical difference. Means separated at $p < 0.05$. Error bars are standard error of the mean.

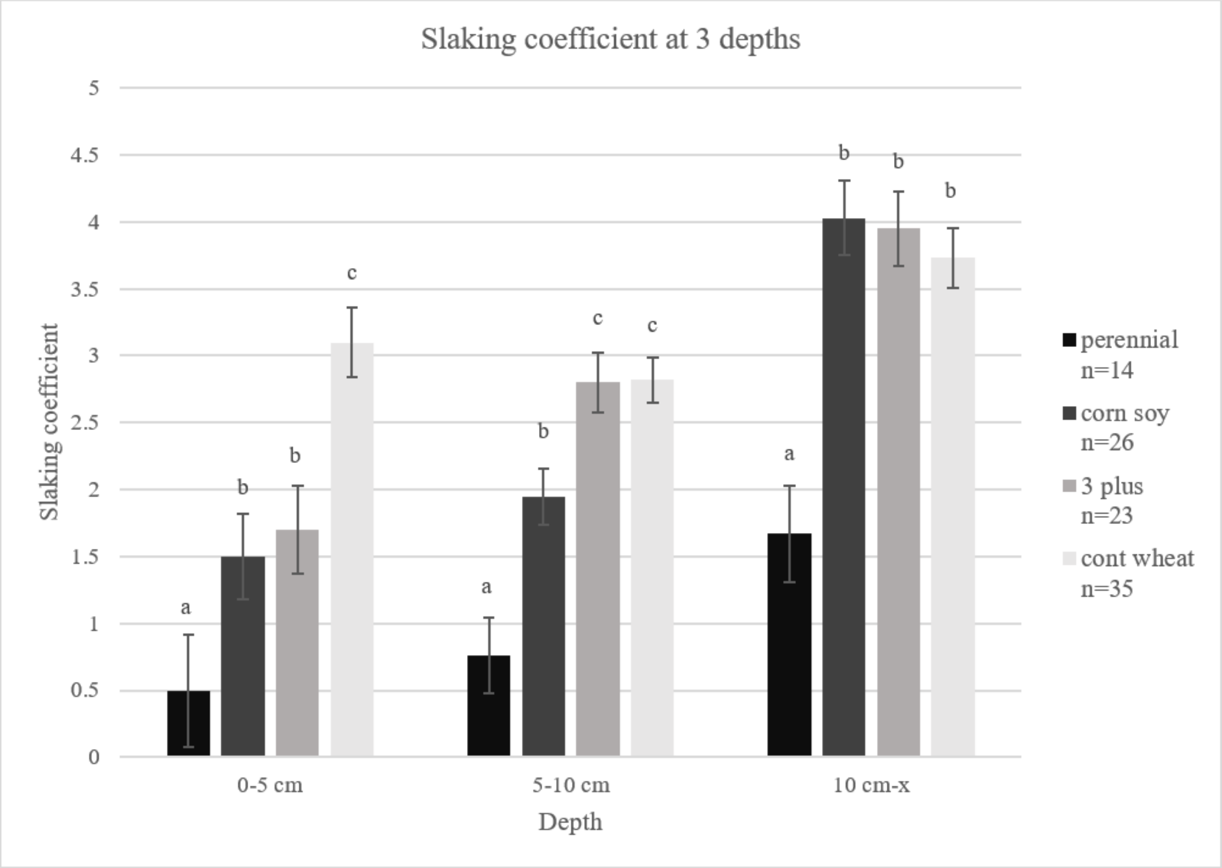

Figure 3. Slaking coefficient measured at 0-5 cm ($p < 0.001$), 5-10 cm ($p < 0.001$), and 10 cm to the end of the horizon (10 cm-x) ($p < 0.001$). Letters show differences by depth between cropping systems. Means sharing a letter indicate no statistical difference. Means separated at $p < 0.05$. Error bars are standard error from SAS.

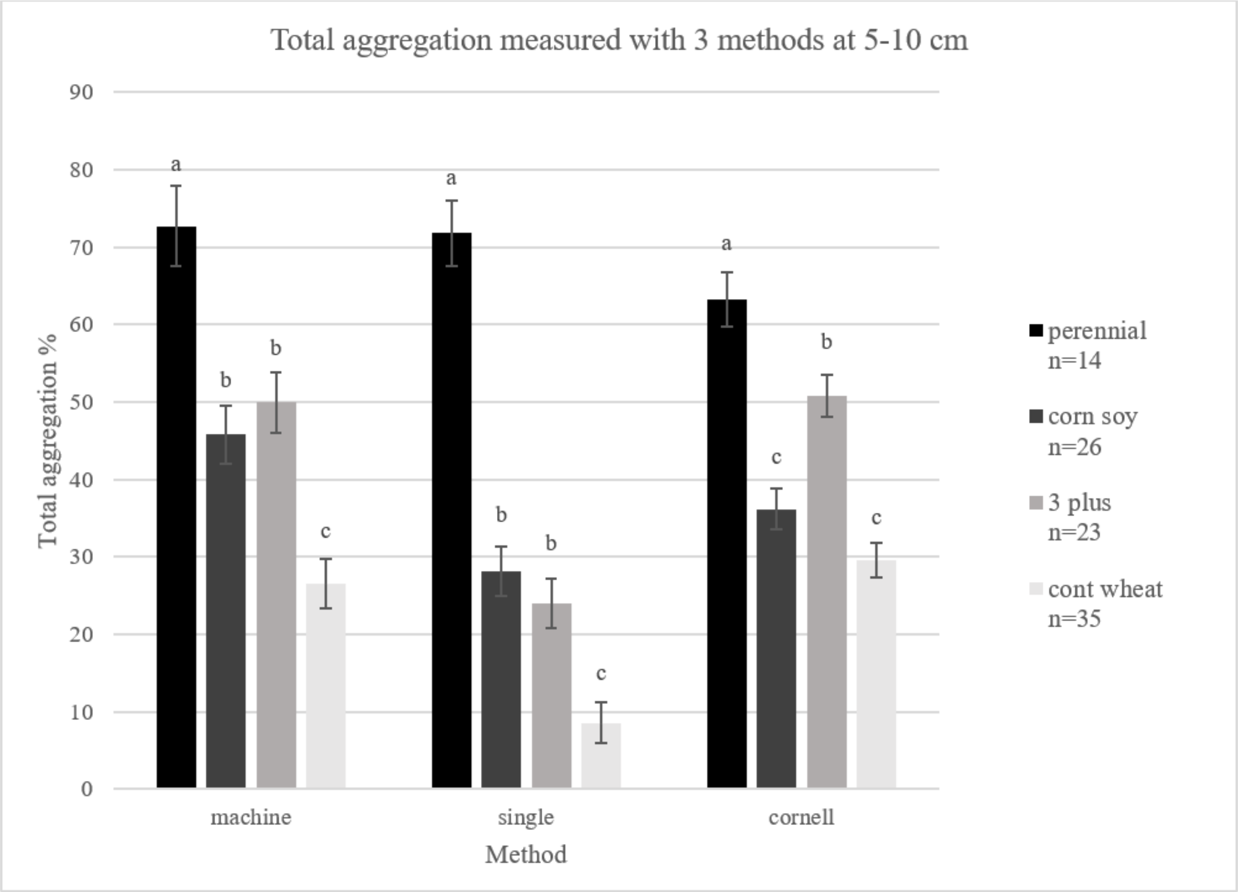

Figure 4. Total aggregation measured at 5-10 cm for each cropping system with machine ($p < 0.001$), single-sieve ($p < 0.001$), and Cornell ($p < 0.001$) methods. Letters show differences by method between cropping systems. Means sharing a letter indicate no statistical difference. Means separated at $p < 0.05$. Error bars are standard error from SAS.

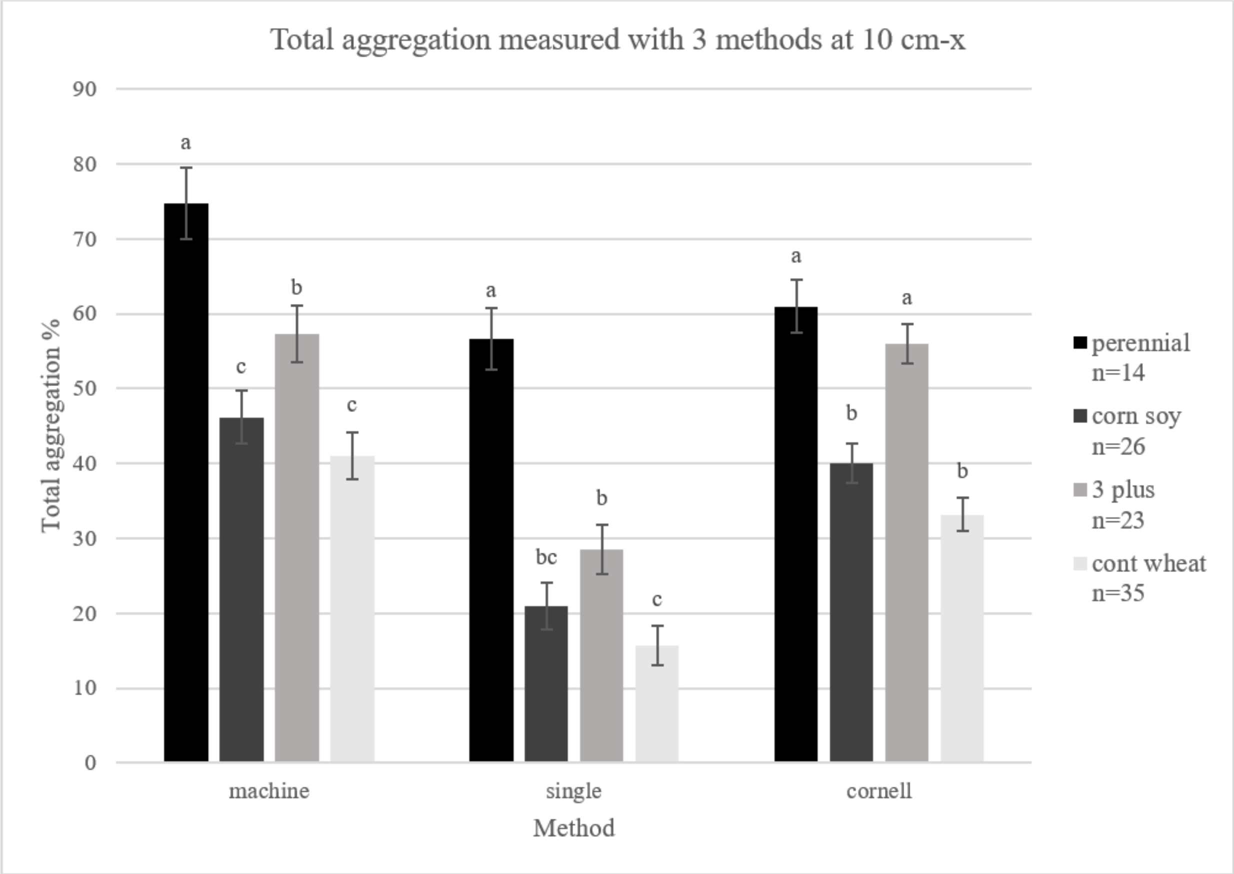

Figure 5. Total aggregation measured at 10 cm to the end of the soil horizon (10 cm-x) for each cropping system with machine ($p < 0.001$), single-sieve ($p < 0.001$), and Cornell ($p < 0.001$) methods. Letters show differences by method between cropping systems. Means sharing a letter indicate no statistical difference. Means separated at $p < 0.05$. Error bars are standard error from SAS.

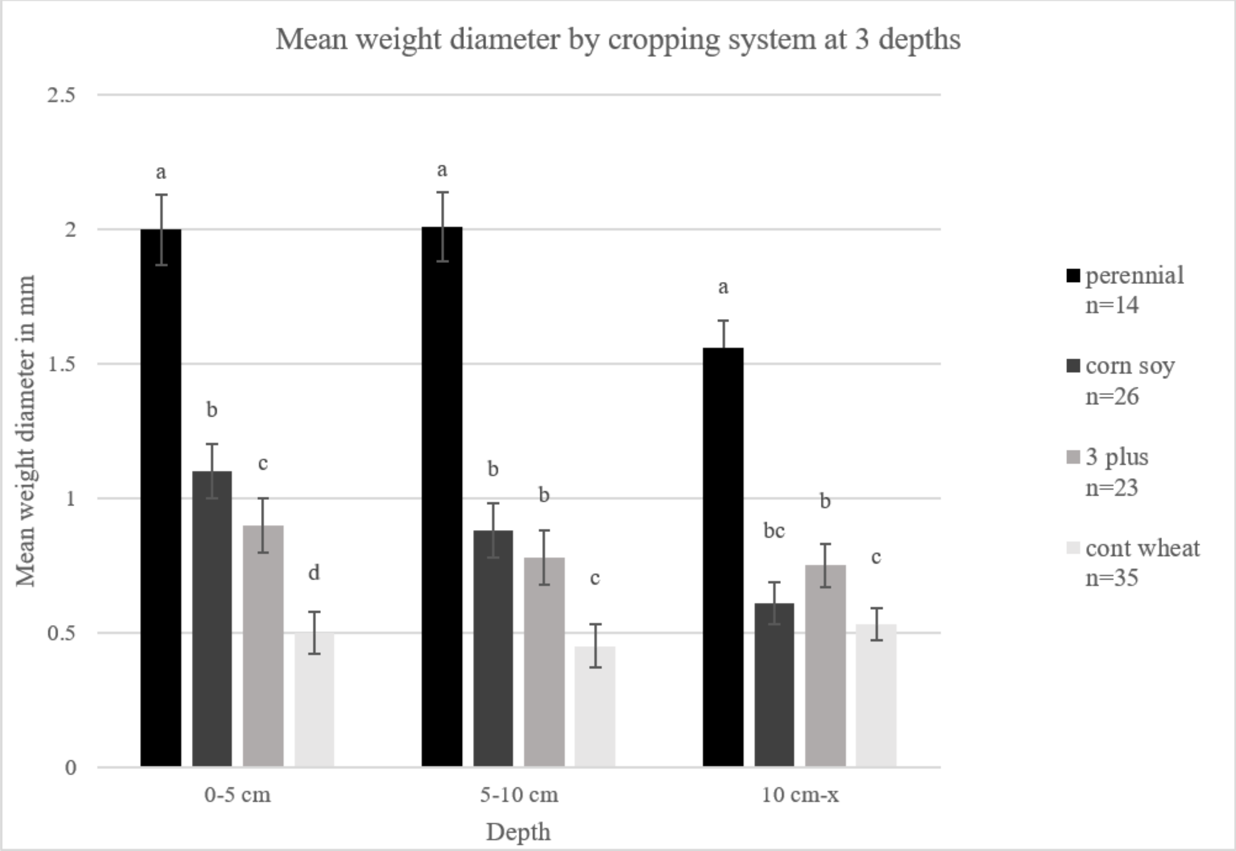

Figure 6. Mean weight diameter (mm) measured at 0-5 cm ($p < 0.001$), 5-10 cm ($p < 0.001$), and 10 cm to the end of the horizon ($p < 0.001$). Letters show differences by depth between cropping systems. Means sharing a letter indicate no statistical difference. Means separated at $p < 0.05$. Error bars are standard error from SAS.

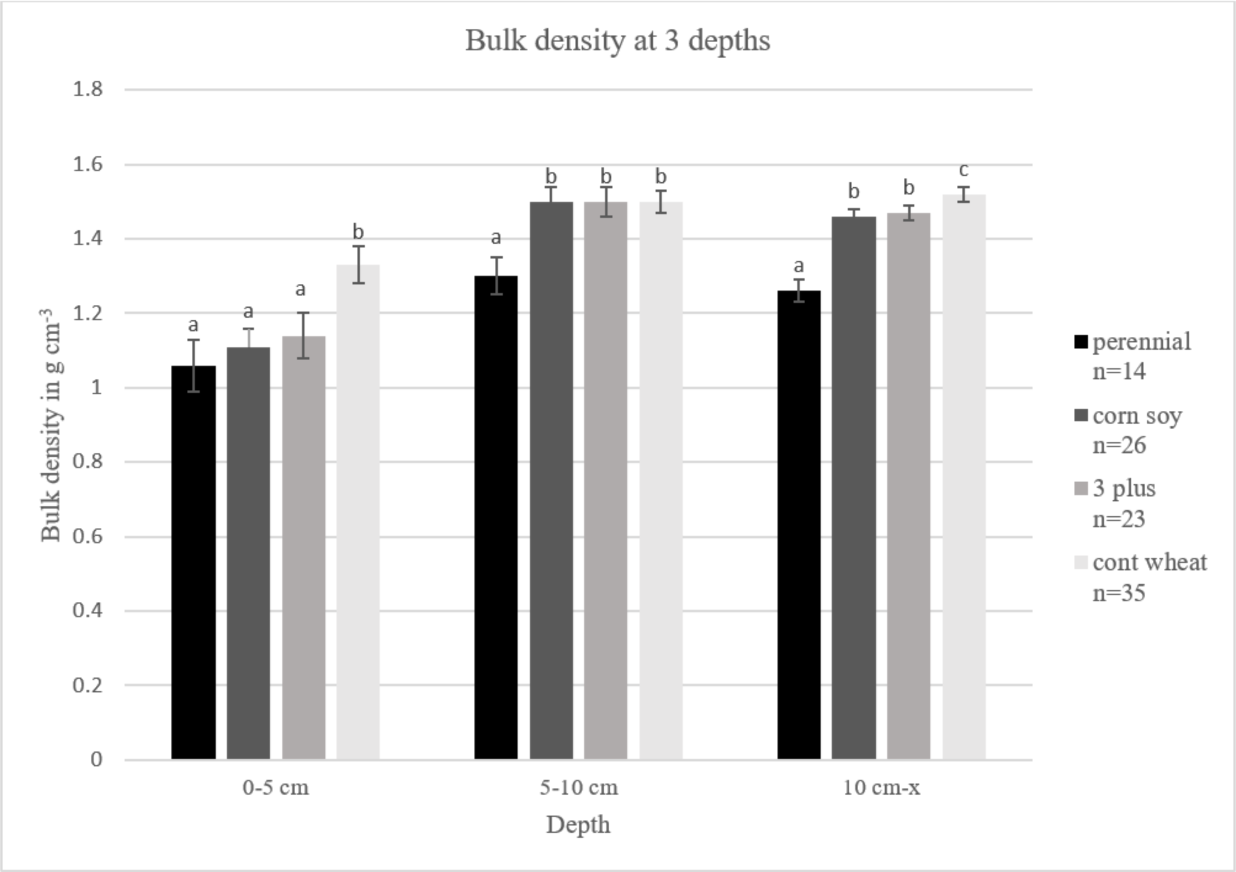

Figure 7. Bulk Density (g cm^{-3}) measured at 0-5 cm ($p = 0.0076$), 5-10 cm ($p < 0.0062$), and 10 cm to the end of the horizon ($p < 0.001$). Letters show differences by depth between cropping systems. Means sharing a letter indicate no statistical difference. Means separated at $p < 0.05$. Error bars are standard error from SAS.

Chapter 4 - Conclusions

The first hypothesis of this study was that aggregate stability methods and SOC would be strongly correlated. With the limited SOC data available at this time, this was not shown to be the case. There were no significant correlations between any of the aggregate stability methods and SOC at 0-5 cm, 5-10 cm, or 10 cm-x.

The next hypothesis for this study was that increased crop diversity and decreased tillage would result in better soil health outcomes as signified by the methods used. This hypothesis proved more difficult to test and ultimately was not directly tested. Separating out tillage from crop planted was a major issue. To start, the continuous wheat fields all were on a continuous tillage regime which left no continuous wheat fields in a NT regime to test against. Moving to the other cropping systems, many of the corn soy or 3 plus fields had somewhere around 5 out of 11 years of tillage, and within that the tillage events were scattered throughout the total 11 years in varying ways. This is ultimately what led us to divide the fields into cropping systems that attempted to take the combined effects of crop and tillage both into account to some extent. In the case of continuous wheat there was no choice. Within the corn soy and 3 plus systems they would not have had great representation of NT or continuous till had we tried to separate them, but would have mostly landed somewhere in between.

When the results are looked at in the context of the available literature there is a case to be made that tillage very likely was shown to have detrimental effects on soil health indicators. The continuous wheat fields overall had the least stable aggregates regardless of method, the lowest amount of POXC at the only depth that the method found effects (0-5 cm), and the lowest PLFA group biomass across all groups except fungi (all systems except perennial had nonsignificant differences in fungi biomass) at 0-5 cm.

The literature indicates that in the northern Great Plains soil health indicators are positively affected by NT continuous wheat, and in some cases the highest tested among more diverse cropping systems. This suggests that it is very likely that the tillage component of the continuous wheat system in this study is to blame for the poor performance amongst the listed indicators. There is a possibility that burning could also contribute to poor performance amongst indicators, although quantification of that effect was not possible within this study as the data regarding burning and burn timing was not available. Parsing out the differences between corn soy and 3 plus cropping systems proved even more difficult and inconsistent. There was not a consistent difference between the two systems across indicators, with the two of them commonly being statistically undifferentiated. In order to more effectively detect a potential difference here would likely require a larger sample size and more consistent differences between tillage regimes, or to eliminate differences in tillage regime entirely.

Lastly was the hypothesis that the single sieve method of aggregate stability analysis would have the weakest correlation to other aggregate stability methods, likely due to the amount of human interaction and involvement with the methodology. This proved to not be the case. The single sieve method had strong correlation to MWD and the machine method of determining total aggregation. There is a strong argument that this method proved the most useful in that it had the mentioned strong correlations, but requires the least equipment to complete. The smartphone application SLAKES did prove to have the lowest correlations with other methods and was least capable of detecting management differences, implying that it was the least sensitive of the methods tested.

Outside of SLAKES the aggregate stability methods all picked up on many management differences and had moderate to strong correlations with each other. POXC proved to be the one method unable to detect any differences in management at both 5-10 cm, and 10 cm-x, suggesting it was the least sensitive. This is mostly contradictory to the literature, as POXC is commonly one of the most sensitive methods. Even so, the literature does make a strong case against the further use of this method as a soil health indicator for active carbon based on the likelihood that it is at best not accurate, and at worst measuring something approximating the opposite of what it claims to be measuring. Differences in management were detectable with ACEP and it had moderate correlations with most of the other indicators. It seems most effective, based on this study and the broader literature, at relatively shallow depths (0-10 cm), similar to many of the other methods. Similar to POXC, the scientific literature questions the accuracy of ACEP as a measurement of protein based mostly on the concern of coextracted humic substances, suggesting that more research should be aimed toward verifying the accuracy of the method prior to continual use as a method of estimating protein content.

References

Abdalla, Khatab, Macdex Mutema, and Trevor Hill. “Soil and Organic Carbon Losses from Varying Land Uses: A Global Meta-Analysis.” *Geographical Research* 58, no. 2 (2020): 167–85. https://doi.org/10.1111/1745-5871.12389.

Augustin, Christopher, and Larry J. Cihacek. “Relationships Between Soil Carbon and Soil Texture in the Northern Great Plains.” *Soil Science* 181, no. 8 (August 2016): 386. https://doi.org/10.1097/SS.0000000000000173.

Bagnall, Dianna K., and Cristine L. S. Morgan. “SLAKES and 3D Scans Characterize Management Effects on Soil Structure in Farm Fields.” *Soil and Tillage Research* 208 (April 1, 2021): 104893. https://doi.org/10.1016/j.still.2020.104893.

Benjamin, J. G., M. Mikha, D. C. Nielsen, M. F. Vigil, F. Calderón, and W. B. Henry. “Cropping Intensity Effects on Physical Properties of a No-till Silt Loam.” *Soil Science Society of America Journal* 71, no. 4 (August 2007): 1160–65.

Bhowmik, Arnab, Ann-Marie Fortuna, Larry J. Cihacek, Andy I. Bary, Patrick M. Carr, and Craig G. Cogger. “Potential Carbon Sequestration and Nitrogen Cycling in Long-Term Organic Management Systems.” *Renewable Agriculture and Food Systems* 32, no. 6 (December 2017): 498–510. https://doi.org/10.1017/S1742170516000429.

Blair, G., R Lefroy, and L Lisle. “Soil Carbon Fractions Based on Their Degree of Oxidation, and the Development of a Carbon Management Index for Agricultural Systems.” *Australian Journal of Agricultural Research* 46, no. 7 (1995): 1459. https://doi.org/10.1071/AR9951459.

Blanco-Canqui, Humberto. “No-till Technology Has Limited Potential to Store Carbon: How Can We Enhance Such Potential?” *Agriculture, Ecosystems & Environment* 313 (June 15, 2021): 107352. https://doi.org/10.1016/j.agee.2021.107352.

Blanco-Canqui, Humberto, Charles Shapiro, Paul Jasa, and Javed Iqbal. “No-till and Carbon Stocks: Is Deep Soil Sampling Necessary? Insights from Long-Term Experiments.” *Soil and Tillage Research* 206 (February 1, 2021): 104840. https://doi.org/10.1016/j.still.2020.104840.

Blanco-Canqui, Humberto, L. R. Stone, and P. W. Stahlman. “Soil Response to Long-Term Cropping Systems on an Argiustoll in the Central Great Plains.” *Soil Science Society of America Journal* 74, no. 2 (April 2010): 602–11.

Bronick, C. J., and R. Lal. “Soil Structure and Management: A Review.” *Geoderma* 124, no. 1 (January 1, 2005): 3–22. https://doi.org/10.1016/j.geoderma.2004.03.005.

Buyer, Jeffrey S., and Myron Sasser. “High Throughput Phospholipid Fatty Acid Analysis of Soils.” *Applied Soil Ecology*, Microorganisms and the Sustainable Management of Soil, 61 (October 1, 2012): 127–30. https://doi.org/10.1016/j.apsoil.2012.06.005.

Calderón, Francisco J., Louise E. Jackson, Kate M. Scow, and Dennis E. Rolston. “Short-Term Dynamics of Nitrogen, Microbial Activity, and Phospholipid Fatty Acids after Tillage.” *Soil Science Society of America Journal* 65, no. 1 (2001): 118–26. https://doi.org/10.2136/sssaj2001.651118x.

Christy, Isabel, Amber Moore, David Myrold, and Markus Kleber. “A Mechanistic Inquiry into the Applicability of Permanganate Oxidizable Carbon as a Soil Health Indicator.” *Soil Science Society of America Journal* n/a, no. n/a. Accessed August 3, 2023. https://doi.org/10.1002/saj2.20569.

Culman, Steve W., Sieglinde S. Snapp, John M. Green, and Lowell E. Gentry. “Short- and Long-Term Labile Soil Carbon and Nitrogen Dynamics Reflect Management and Predict Corn Agronomic Performance.” *Agronomy Journal* 105, no. 2 (March 2013): 493–502.

Dalzell, Brent J., Cinzia Fissore, and Edward A. Nater. “Topography and Land Use Impact Erosion and Soil Organic Carbon Burial over Decadal Timescales.” *CATENA* 218 (November 1, 2022): 106578. https://doi.org/10.1016/j.catena.2022.106578.

Fajardo, Mario, Alex. B. McBratney, Damien J. Field, and Budiman Minasny. “Soil Slaking Assessment Using Image Recognition.” *Soil and Tillage Research* 163 (November 1, 2016): 119–29. https://doi.org/10.1016/j.still.2016.05.018.

Feng, Y., A. C. Motta, D. W. Reeves, C. H. Burmester, E. van Santen, and J. A. Osborne. “Soil Microbial Communities under Conventional-till and No-till Continuous Cotton Systems.” *Soil Biology and Biochemistry* 35, no. 12 (December 1, 2003): 1693–1703. https://doi.org/10.1016/j.soilbio.2003.08.016.

Frostegård, Åsa, Anders Tunlid, and Erland Bååth. “Use and Misuse of PLFA Measurements in Soils.” *Soil Biology and Biochemistry* 43, no. 8 (August 1, 2011): 1621–25. https://doi.org/10.1016/j.soilbio.2010.11.021.

Garcia, Glenn Arthur, Jason G. Warren, Sergio Abit, Chime Garcia, and Grace Flusche Ogden. “Sample Processing Impacts on Single Wet Sieve Aggregate Stability Analysis.” *Agricultural & Environmental Letters* 7, no. 2 (2022): e20094. https://doi.org/10.1002/ael2.20094.

Geisseler, Daniel, Kenneth Miller, Michelle Leinfelder-Miles, and Rob Wilson. “Use of Soil Protein Pools as Indicators of Soil Nitrogen Mineralization Potential.” *Soil Science Society of America Journal* 83, no. 4 (2019): 1236–43. https://doi.org/10.2136/sssaj2019.01.0012.

Gross, Cole D., and Robert B. Harrison. “Quantifying and Comparing Soil Carbon Stocks: Underestimation with the Core Sampling Method.” *Soil Science Society of America Journal* 82, no. 4 (2018): 949–59. https://doi.org/10.2136/sssaj2018.01.0015.

Gruver, Joel. “Evaluating the Sensitivity and Linearity of a Permanganate-Oxidizable Carbon Method.” *Communications in Soil Science and Plant Analysis* 46, no. 4 (February 21, 2015): 490–510. https://doi.org/10.1080/00103624.2014.997387.

Hartemink, Alfred E., and International Union of Soil Sciences, eds. *The Future of Soil Science*. Wageningen: International Union of Soil Sciences, 2006.

Helgason, Bobbi L., Fran L. Walley, and James J. Germida. “Fungal and Bacterial Abundance in Long-Term No-Till and Intensive-Till Soils of the Northern Great Plains.” *Soil Science Society of America Journal* 73, no. 1 (February 2009): 120–27.

Huang, X., E.L. Skidmore, and G.L. Tibke. "Soil quality of two Kansas soils as influenced by the Conservation Reserve Program." *Journal of Soil and Water Conservation* 57, no. 6 (2002): 344+.

Huang, Yanzhang, Zhongbao Xin, Lishan Ran, Yunbin Qin, and Mengfan Cai. “Topsoil Carbon Sequestration of Vegetation Restoration on the Loess Plateau.” *Ecological Engineering* 177 (April 1, 2022): 106570. https://doi.org/10.1016/j.ecoleng.2022.106570.

Hurisso, Tunsisa T., Steve W. Culman, William R. Horwath, Jordon Wade, Deandra Cass, Joshua W. Beniston, Timothy M. Bowles, et al. “Comparison of Permanganate-Oxidizable Carbon and Mineralizable Carbon for Assessment of Organic Matter Stabilization and Mineralization.” *Soil Science Society of America Journal* 80, no. 5 (2016): 1352–64. https://doi.org/10.2136/sssaj2016.04.0106.

Hurisso, Tunsisa T., Dan J. Moebius-Clune, Steve W. Culman, Bianca N. Moebius-Clune, Janice E. Thies, and Harold M. van Es. “Soil Protein as a Rapid Soil Health Indicator of Potentially

Available Organic Nitrogen.” *Agricultural & Environmental Letters* 3, no. 1 (2018): 180006er. https://doi.org/10.2134/ael2018.02.0006er.

Jiménez, Juan J., Rattan Lal, Humberto A. Leblanc, Ricardo O. Russo, and Yogendra Raut. “The Soil C Pool in Different Agroecosystems Derived from the Dry Tropical Forest of Guanacaste, Costa Rica.” *Ecological Engineering*, Ecological management and sustainable development in the humid tropics of Costa Rica, 34, no. 4 (November 5, 2008): 289–99. https://doi.org/10.1016/j.ecoleng.2008.04.016.

Karlen, D. L., M. J. Mausbach, J. W. Doran, R. G. Cline, R. F. Harris, and G. E. Schuman. “Soil Quality: A Concept, Definition, and Framework for Evaluation (A Guest Editorial).” *Soil Science Society of America Journal* 61, no. 1 (1997): 4–10. https://doi.org/10.2136/sssaj1997.03615995006100010001x.

Karlen, Douglas L., Craig A. Ditzler, and Susan S. Andrews. “Soil Quality: Why and How?” *Geoderma*, The assessment of soil quality, 114, no. 3 (June 1, 2003): 145–56. https://doi.org/10.1016/S0016-7061(03)00039-9.

Karlen, Douglas L., and Charles W. Rice. “Soil Degradation: Will Humankind Ever Learn?” *Sustainability* 7, no. 9 (September 2015): 12490–501. https://doi.org/10.3390/su70912490.

Karlen, Douglas L., Brian J. Wienhold, Shujiang Kang, Ted M. Zobeck, and Susan S. Andrews. “Indices for Soil Management Decisions.” In *Soil Management: Building a Stable Base for Agriculture*, edited by Jerry L. Hatfield and Thomas J. Sauer, 39–50. Madison, WI, USA: Soil Science Society of America, 2015. https://doi.org/10.2136/2011.soilmanagement.c3.

Keen, N., and M. Legrand. “Surface glycoproteins : evidence that they may function as the race specific phytoalexin elicitors of Phytophthora megasperma f.sp. glycinea.” *Physiological Plant Pathology*., 17(2), (1980) 175–192. https://doi.org/10.1016/0048-4059(80)90050-8

Kemper, W. D. and Rosenau, R.C. “Aggregate stability and size distribution.” In: Klute, A. Ed., *Methods of soil analysis*. Part 1. Agronomy Monograph 9. 2nd ed. (1986): 425-442.

Kemper, W. D., Russell Rosenau, and Sheldon Nelson. “Gas Displacement and Aggregate Stability of Soils.” *Soil Science Society of America Journal* 49, no. 1 (1985): 25–28. https://doi.org/10.2136/sssaj1985.03615995004900010004x.

Kenney, Ian, Humberto Blanco-Canqui, Deann R. Presley, Charles W. Rice, Keith Janssen, and Brian Olson. “Soil and Crop Response to Stover Removal from Rainfed and Irrigated Corn.” *Global Change Biology. Bioenergy* 7, no. 2 (March 2015): 219–30. https://doi.org/10.1111/gcbb.12128.

Lal, Rattan. “Digging Deeper: A Holistic Perspective of Factors Affecting Soil Organic Carbon Sequestration in Agroecosystems.” *Global Change Biology* 24, no. 8 (2018): 3285–3301. https://doi.org/10.1111/gcb.14054.

Lal, Rattan. “Soil Health and Carbon Management.” *Food and Energy Security* 5, no. 4 (2016): 212–22. https://doi.org/10.1002/fes3.96.

Lehmann, Johannes, Deborah A. Bossio, Ingrid Kögel-Knabner, and Matthias C. Rillig. “The Concept and Future Prospects of Soil Health.” *Nature Reviews. Earth & Environment* 1, no. 10 (October 2020): 544–53. https://doi.org/10.1038/s43017-020-0080-8.

Lenka, Sangeeta, A. K. Singh, and N. K. Lenka. “Soil Aggregation and Organic Carbon as Affected by Different Irrigation and Nitrogen Levels in the Maize-Wheat Cropping System.” *Experimental Agriculture* 50, no. 2 (April 2014): 216–28. https://doi.org/10.1017/S0014479713000501.

Lin, James S., Marcos V. Sarto, Tiffany L. Carter, Dallas E. Peterson, Colleen Gura, Laura Mino, Megan Rohrs, Hallie Lucas, Jamie Clark, and Charles W. Rice. “Soil Organic Carbon, Aggregation and Fungi Community after 44 Years of No-till and Cropping Systems in the

Central Great Plains, USA." *Archives of Microbiology* 205, no. 3 (2023). https://doi.org/10.1007/s00203-023-03421-2.

Loginow, W., Gonet, S., and Ciescinska, B. Fractionation of organic carbon based on susceptibility to oxidation. *Polish Journal of Soil Science* 20 (1987) 47–52.

Maharjan, Bijesh, Saurav Das, and Bharat Sharma Acharya. "Soil Health Gap: A Concept to Establish a Benchmark for Soil Health Management." *Global Ecology and Conservation* 23 (September 1, 2020): e01116. https://doi.org/10.1016/j.gecco.2020.e01116.

Márquez, C. O., V. J. Garcia, C. A. Cambardella, R. C. Schultz, and T. M. Isenhart. "Aggregate-Size Stability Distribution and Soil Stability." *Soil Science Society of America Journal* 68, no. 3 (2004): 725–35. https://doi.org/10.2136/sssaj2004.7250.

Mathew, Reji P., Yucheng Feng, Leonard Githinji, Ramble Ankumah, and Kipling S. Balkcom. "Impact of No-Tillage and Conventional Tillage Systems on Soil Microbial Communities." *Applied and Environmental Soil Science* (2012): 1–10. https://doi.org/10.1155/2012/548620.

McCulley, R. L., and I. C. Burke. "Microbial Community Composition across the Great Plains: Landscape versus Regional Variability." *Soil Science Society of America Journal* 68, no. 1 (February 2004): 106–15.

McGranahan, Devan Allen, Carissa L. Wonkka, Sadikshya Dangi, Jonathan W. Spiess, and Benjamin Geaumont. "Mineral Nitrogen and Microbial Responses to Soil Heating in Burned Grassland." *Geoderma* 424 (October 15, 2022): 116023. https://doi.org/10.1016/j.geoderma.2022.116023.

McVay, K. A., J. A. Budde, K. Fabrizzi, M. M. Mikha, and et al. "Management Effects on Soil Physical Properties in Long-Term Tillage Studies in Kansas." Soil Science Society of America Journal 70, no. 2 (April 2006): 434–38.

Moebius, Bianca N., Harold M. van Es, Robert R. Schindelbeck, Omololu J. Idowu, Daniel J. Clune, and Janice E. Thies. "Evaluation of Laboratory-Measured Soil Properties as Indicators of Soil Physical Quality." *Soil Science* 172, no. 11 (November 2007): 895. https://doi.org/10.1097/ss.0b013e318154b520.

Moebius-Clune, Bianca N., Harold M. van Es, Omololu J. Ido, Robert R. Schindelbeck, Daniel J. Moebius-Clune, David W. Wolfe, George S. Abawi, Janice E. Thies, Beth K. Gugino, and Robert Lucey. "Long-Term Effects of Harvesting Maize Stover and Tillage on Soil Quality." *Soil Science Society of America Journal* 72, no. 4 (August 2008): 960–69.

Ogden, C. B., H. M. van Es, and R. R. Schindelbeck. "Miniature Rain Simulator for Field Measurement of Soil Infiltration." *Soil Science Society of America Journal* 61, no. 4 (1997): 1041–43. https://doi.org/10.2136/sssaj1997.03615995006100040008x.

Pacini, Lorenza, Felipe Yunta, Arwyn Jones, Luca Montanarella, Pierre Barrè, Sergio Saia, Songchao Chen, and Calogero Schillaci. "Fine Earth Soil Bulk Density at 0.2 m Depth from Land Use and Coverage Area Frame Survey (LUCAS) Soil 2018." *European Journal of Soil Science* 74, no. 4 (2023): e13391. https://doi.org/10.1111/ejss.13391.

Poeplau, Christopher, and Axel Don. "Sensitivity of Soil Organic Carbon Stocks and Fractions to Different Land-Use Changes across Europe." *Geoderma* 192 (January 1, 2013): 189–201. https://doi.org/10.1016/j.geoderma.2012.08.003.

Prairie, Aaron M., Alison E. King, and M. Francesca Cotrufo. "Restoring Particulate and Mineral-Associated Organic Carbon through Regenerative Agriculture." *Proceedings of the National Academy of Sciences* 120, no. 21 (May 23, 2023): e2217481120. https://doi.org/10.1073/pnas.2217481120.

Presley, DeAnn R., Aaron J. Sindelar, Meghan E. Buckley, and David B. Mengel. “Long-Term Nitrogen and Tillage Effects on Soil Physical Properties under Continuous Grain Sorghum.” Agronomy Journal 104, no. 3 (May 2012): 749–55.

Ramsey, Philip W., Matthias C. Rillig, Kevin P. Feris, William E. Holben, and James E. Gannon. “Choice of Methods for Soil Microbial Community Analysis: PLFA Maximizes Power Compared to CLPP and PCR-Based Approaches.” *Pedobiologia* 50, no. 3 (July 3, 2006): 275–80. https://doi.org/10.1016/j.pedobi.2006.03.003.

Rieke, Elizabeth L., Dianna K. Bagnall, Cristine L. S. Morgan, Kade D. Flynn, Julie A. Howe, Kelsey L. H. Greub, G. Mac Bean, et al. “Evaluation of Aggregate Stability Methods for Soil Health.” *Geoderma* 428 (December 15, 2022): 116156. https://doi.org/10.1016/j.geoderma.2022.116156.

Rinot, Oshri, Guy J. Levy, Yosef Steinberger, Tal Svoray, and Gil Eshel. “Soil Health Assessment: A Critical Review of Current Methodologies and a Proposed New Approach.” *Science of The Total Environment* 648 (January 15, 2019): 1484–91. https://doi.org/10.1016/j.scitotenv.2018.08.259.

Roberts, Paula, and David L. Jones. “Critical Evaluation of Methods for Determining Total Protein in Soil Solution.” *Soil Biology and Biochemistry*, Special Section: Functional Microbial Ecology: Molecular Approaches to Microbial Ecology and Microbial Habitats, 40, no. 6 (June 1, 2008): 1485–95. https://doi.org/10.1016/j.soilbio.2008.01.001.

Rocci, Katherine S., Jocelyn M. Lavallee, Catherine E. Stewart, and M. Francesca Cotrufo. “Soil Organic Carbon Response to Global Environmental Change Depends on Its Distribution between Mineral-Associated and Particulate Organic Matter: A Meta-Analysis.” *Science of The Total Environment* 793 (November 1, 2021): 148569. https://doi.org/10.1016/j.scitotenv.2021.148569.

Romero, Carlos M., Richard E. Engel, Juliana D’Andrilli, Chengci Chen, Catherine Zabinski, Perry R. Miller, and Roseann Wallander. “Patterns of Change in Permanganate Oxidizable Soil

Organic Matter from Semiarid Drylands Reflected by Absorbance Spectroscopy and Fourier Transform Ion Cyclotron Resonance Mass Spectrometry." *Organic Geochemistry* 120 (June 1, 2018): 19–30. https://doi.org/10.1016/j.orggeochem.2018.03.005.

Sainju, Upendra M., Brett A. Allen, Thecan Caesar-TonThat, and Andrew W. Lenssen. "Dryland Soil Carbon and Nitrogen after Thirty Years of Tillage and Cropping Sequence Combination." *Agronomy Journal* 107, no. 5 (2015): 1822–30. https://doi.org/10.2134/agronj15.0106.

Sainju, Upendra M., Daniel Liptzin, Sadikshya Dangi, and Rajan Ghimire. "Soil Health Indicators and Crop Yield in Response to Long-Term Cropping Sequence and Nitrogen Fertilization." *Applied Soil Ecology* 168 (December 1, 2021): 104182. https://doi.org/10.1016/j.apsoil.2021.104182.

Sainju, Upendra M., Daniel Liptzin, and William B. Stevens. "How Soil Carbon Fractions Relate to Soil Properties and Crop Yields in Dryland Cropping Systems?" *Soil Science Society of America Journal* 86, no. 3 (2022): 795–809. https://doi.org/10.1002/saj2.20399.

Sanderman, Jonathan, Tomislav Hengl, and Gregory J. Fiske. "Soil Carbon Debt of 12,000 Years of Human Land Use." *Proceedings of the National Academy of Sciences* 114, no. 36 (September 5, 2017): 9575–80. https://doi.org/10.1073/pnas.1706103114.

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. "Field book for describing and sampling soils, Version 3.0." Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE (2012).

Schwartz, Robert C, Steven R Evett, and Paul W Unger. "Soil Hydraulic Properties of Cropland Compared with Reestablished and Native Grassland." *Geoderma*, Quantifying agricultural management effects on soil properties and processes, 116, no. 1 (September 1, 2003): 47–60. https://doi.org/10.1016/S0016-7061(03)00093-4.

Schwenke, G. D., M. K. McLeod, S. R. Murphy, S. Harden, A. L. Cowie, and V. E. Lonergan. "The Potential for Sown Tropical Perennial Grass Pastures to Improve Soil Organic Carbon in the North-West Slopes and Plains of New South Wales." *Soil Research* 51, no. 7–8 (October 1, 2013): 726–38. https://doi.org/10.1071/SR13200.

Serri, Dannae L., Carolina Pérez-Brandan, José M. Meriles, Fernando Salvagiotti, Silvina Bacigaluppo, Alberto Malmantile, and Silvina Vargas-Gil. "Development of a Soil Quality Index for Sequences with Different Levels of Land Occupation Using Soil Chemical, Physical and Microbiological Properties." *Applied Soil Ecology* 180 (December 1, 2022): 104621. https://doi.org/10.1016/j.apsoil.2022.104621.

Slessarev, Eric W., Allegra Mayer, Courtland Kelly, Katerina Georgiou, Jennifer Pett-Ridge, and Erin E. Nuccio. "Initial Soil Organic Carbon Stocks Govern Changes in Soil Carbon: Reality or Artifact?" *Global Change Biology* 29, no. 5 (2023): 1239–47. https://doi.org/10.1111/gcb.16491.

Stott, D.E. 2019. Recommended Soil Health Indicators and Associated Laboratory Procedures. Soil Health Technical Note No. 450-03. U.S. Department of Agriculture, Natural Resources Conservation Service.

Tao, Feng, Yuanyuan Huang, Bruce A. Hungate, Stefano Manzoni, Serita D. Frey, Michael W. I. Schmidt, Markus Reichstein, et al. "Microbial Carbon Use Efficiency Promotes Global Soil Carbon Storage." *Nature* 618, no. 7967 (June 2023): 981–85. https://doi.org/10.1038/s41586-023-06042-3.

Teague, W. R., S. L. Dowhower, S. A. Baker, N. Haile, P. B. DeLaune, and D. M. Conover. "Grazing Management Impacts on Vegetation, Soil Biota and Soil Chemical, Physical and Hydrological Properties in Tall Grass Prairie." *Agriculture, Ecosystems & Environment* 141, no. 3 (May 1, 2011): 310–22. https://doi.org/10.1016/j.agee.2011.03.009.

Unger, Paul W, and Ordie R Jones. “Long-Term Tillage and Cropping Systems Affect Bulk Density and Penetration Resistance of Soil Cropped to Dryland Wheat and Grain Sorghum.” *Soil and Tillage Research* 45, no. 1–2 (1998): 39–57. https://doi.org/10.1016/s0167-1987(97)00068-8.

Vendig, Isaac, Aidee Guzman, Gisel De La Cerda, Kenzo Esquivel, Allegra C. Mayer, Lauren Ponisio, and Timothy M. Bowles. “Quantifying Direct Yield Benefits of Soil Carbon Increases from Cover Cropping.” *Nature Sustainability*, May 29, 2023, 1–10. https://doi.org/10.1038/s41893-023-01131-7.

Wade, Jordon, Chongyang Li, Mirjam M. Pulleman, Grace Trankina, Skye A. Wills, and Andrew J. Margenot. “To Standardize by Mass of Soil or Organic Carbon? A Comparison of Permanganate Oxidizable Carbon (POXC) Assay Methods.” *Geoderma* 404 (December 15, 2021): 115392. https://doi.org/10.1016/j.geoderma.2021.115392.

Weil, Ray R., Kandikar R. Islam, Melissa A. Stine, Joel B. Gruver, and Susan E. Samson-Liebig. “Estimating Active Carbon for Soil Quality Assessment: A Simplified Method for Laboratory and Field Use.” *American Journal of Alternative Agriculture* 18, no. 1 (2003): 3–17.

West, Tristram O., and Wilfred M. Post. “Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation.” *Soil Science Society of America Journal* 66, no. 6 (2002): 1930–46. https://doi.org/10.2136/sssaj2002.1930.

White, Paul M., and Charles W. Rice. “Tillage Effects on Microbial and Carbon Dynamics during Plant Residue Decomposition.” *Soil Science Society of America Journal* 73, no. 1 (2009): 138–45. https://doi.org/10.2136/sssaj2007.0384.

Wienhold, B, S. Andrews, and D. Karlen. “Soil Quality: A Review of the Science and Experiences in the USA.” *Environmental Geochemistry and Health* 26, no. 2 (June 2004): 89–95. https://doi.org/10.1023/B:EGAH.0000039571.59640.3c.

Williams, Ryan J., Stephen W. Hallgren, Gail W. T. Wilson, and Michael W. Palmer. "*Juniperus virginiana* Encroachment into Upland Oak Forests Alters Arbuscular Mycorrhizal Abundance and Litter Chemistry." *Applied Soil Ecology* 65 (March 1, 2013): 23–30. https://doi.org/10.1016/j.apsoil.2012.12.020.

Woodings, Finnleigh S., and Andrew J. Margenot. "Revisiting the Permanganate Oxidizable Carbon (POXC) Assay Assumptions: POXC Is Lignin Sensitive." *Agricultural & Environmental Letters* 8, no. 1 (2023): e20108. https://doi.org/10.1002/ael2.20108.

Wright, S. F., and R. L. Anderson. "Aggregate Stability and Glomalin in Alternative Crop Rotations for the Central Great Plains." *Biology and Fertility of Soils* 31, no. 3 (June 1, 2000): 249–53. https://doi.org/10.1007/s003740050653.

Wright, S. F., V. S. Green, and M. A. Cavigelli. "Glomalin in Aggregate Size Classes from Three Different Farming Systems." *Soil and Tillage Research* 94, no. 2 (June 1, 2007): 546–49. https://doi.org/10.1016/j.still.2006.08.003.

Wright, Sf, and A. Upadhyaya. "A Survey of Soils for Aggregate Stability and Glomalin, a Glycoprotein Produced by Hyphae of Arbuscular Mycorrhizal Fungi." *Plant and Soil* 198, no. 1 (January 1998): 97–107. https://doi.org/10.1023/A:1004347701584.

Wright, Sf, and A. Upadhyaya. "Extraction of an Abundant and Unusual Protein from Soil and Comparison with Hyphal Protein of Arbuscular Mycorrhizal Fungi." *Soil Science* 161, no. 9 (1996): 575–86. https://doi.org/10.1097/00010694-199609000-00003.

Wuest, Stewart B., John D. Williams, and Hero T. Gollany. "Tillage and Perennial Grass Effects on Ponded Infiltration for Seven Semi-Arid Loess Soils." Journal of Soil and Water Conservation 61, no. 4 (August 2006): 218–23.

Yoder, Robert E. “A Direct Method of Aggregate Analysis of Soils and a Study of the Physical Nature of Erosion Losses [1].” *Agronomy Journal* 28, no. 5 (May 1936): 337–51. https://doi.org/10.2134/agronj1936.00021962002800050001x.

Yudina, Anna, and Yakov Kuzyakov. “Dual Nature of Soil Structure: The Unity of Aggregates and Pores.” *Geoderma* 434 (June 1, 2023): 116478. https://doi.org/10.1016/j.geoderma.2023.116478.

Appendix A - Statistical Code

Cropping system statistical analysis code

```
data bycroppingsystem05;
input  cropsys $  prtn slks mwd mchn sngl cnl actvcrbn totlPLFA BD amfg gneg euk fungi gpos
actn;
datalines;
.
.
.
;
proc glimmix data=bycroppingsystem05 ;
class cropsys;
model (input) =cropsys / solution  ;
lsmeans cropsys / lines cl pdiff;
run;
```

Irrigation statistical analysis code

```
        data irrigation05;

        input  irrigation $  prtn slks mwd mchn sngl cnl actvcrbn totlPLFA BD amfg gneg euk

fungi gpos actn;

        datalines;

        .

        .

        .
```

```
;


proc glimmix data=irrigation05 ;

class irrigation;

model (input)=irrigation / solution  ;

lsmeans irrigation / lines cl pdiff;

run;
```

Correlation statistical analysis code

```
data allcorr05;

input prtn slks mwd mchn sngl cnl actvcrbn totlPLFA BD ;

datalines;

.

.

.

;


proc corr plots=matrix;

var prtn slks mwd mchn sngl cnl actvcrbn totlPLFA BD  ;

run;
```

Appendix B – Raw Data

Aggregate stability and POXC data for 0-5 cm, 5-10 cm, and 10 cm-x

SLAKES (slaking coefficient), MWD (mm), machine (% total aggregation), single sieve (% total aggregation), Cornell (% total aggregation) and POXC (mg POXC kg^{-1} soil)

lab ID	SLAKES	MWD	mchn %	single %	Cornell %	POXC
2185	1.2	0.78	53	24	40	181.8
2186	1.2	1.12	65	39	59	144.9
2187	2.7	0.77	68	41	37	30.9
2191	2.4	0.52	38	16	44	.
2192	1.9	0.73	59	21	40	.
2193	2.7	0.79	55	17	27	.
2197	0.1	1.43	54	56	34	355.0
2198	0.7	1.68	69	57	41	390.4
2199	4.4	0.93	61	37	44	316.3
2203	0.2	1.33	51	53	39	388.6
2204	1.1	1.48	67	57	41	160.3
2205	5	0.78	64	48	49	.
2209	0.8	1.85	65	54	35	538.0
2210	1.2	0.49	29	31	28	290.2
2211	4.2	0.58	47	19	27	127.6
2215	1.8	1.53	62	66	66	465.7
2216	2.1	0.84	50	49	35	578.7
2217	5.5	0.51	38	28	37	135.3
2221	1.1	2.92	88	60	48	.
2222	0.1	.	.	45	37	109.4
2223	4.5	0.76	60	15	47	185.5
2227	1	1.30	.	.	.	.
2228	1.1	0.91	56	39	41	129.3
2229	3.1	0.56	42	19	45	.
2233	2.3	0.60	43	20	32	.
2234	2.8	0.75	53	14	33	226.1
2235	3.1	0.45	33	3	23	289.1
2239	0.8	1.66	74	48	47	173.1
2240	2.4	1.02	60	26	40	327.3

2241	2.2	0.61	48	3	22	.
2245	0.2	1.44	56	43	37	297.9
2246	0.9	1.37	61	26	34	94.6
2247	5.3	0.65	51	26	46	245.5
2251	0.3	1.81	59	42	33	.
2252	3.1	0.90	43	27	32	236.1
2253	2.3	0.84	69	46	52	54.0
2257	2.9	1.01	62	33	34	.
2258	4.4	0.83	61	23	39	309.4
2259	4.4	0.72	60	35	43	55.9
2263	0.9	2.00	64	60	37	.
2264	1.4	1.60	73	41	46	442.5
2265	3.5	1.09	83	48	51	.
2269	1	0.90	.	.	.	262.7
2270	0.8	0.36	20	13	20	134.4
2271	3.1	0.34	22	3	32	191.7
2275	2.8	0.69	30	33	35	218.5
2276	2.7	0.26	10	3	20	196.7
2280	0.5	1.21	47	42	37	238.9
2281	1.6	1.23	58	41	40	247.2
2282	0.8	0.57	42	13	30	88.2
2285	0.5	1.75	61	38	40	215.8
2286	2.8	0.67	33	20	28	59.0
2287	9.2	0.53	38	17	33	194.5
2291	0.6	0.57	27	46	26	261.9
2292	1.2	0.50	31	38	25	187.3
2293	3.7	0.54	40	19	32	36.9
2297	0.3	1.08	40	53	26	253.9
2298	1.3	0.69	32	46	28	107.8
2299	2.6	0.65	51	30	36	219.2
2303	3	0.60	41	29	25	222.3
2304	3.1	0.45	33	8	34	299.5
2305	2.8	0.24	11	1	27	147.5
2309	1.3	1.15	76	65	50	455.8
2310	2.3	1.06	65	22	42	175.0
2311	2.8	0.50	37	8	32	103.3
2315	3.6	0.38	23	8	31	285.2
2316	1.6	0.53	37	6	33	83.2
2317	5.5	0.51	38	10	28	.
2321	3.1	0.36	20	13	26	240.6
2322	1.9	0.33	18	15	37	37.1

2323	3.6	0.24	10	14	23	.
2327	0.5	1.55	64	59	54	.
2328	0.7	0.98	53	31	37	46.3
2329	2	0.90	72	32	50	21.7
2333	0.6	1.89	81	74	62	383.1
2334	1.2	1.45	76	63	49	263.9
2335	1.5	1.00	79	59	61	95.2
2339	0.8	2.38	74	89	72	710.5
2340	0.5	2.48	84	86	77	302.2
2341	2.1	1.53	78	71	66	154.0
2345	0.2	2.07	73	92	71	796.0
2346	0.8	2.42	86	92	70	375.6
2347	0.6	1.66	78	57	48	131.5
2350	1.8	0.64	35	26	21	170.5
2351	2.4	0.46	35	21	22	45.7
2352	3.3	0.50	39	19	15	.
2357	1.1	0.97	63	60	70	589.3
2358	1.9	1.23	88	63	75	499.0
2359	2.7	1.05	88	63	68	266.5
2363	0.2	.	.	95	76	874.4
2364	1.8	.	.	91	77	433.8
2365	1.6	1.45	85	58	67	354.7
2368	1	0.57	30	11	21	295.9
2369	2.9	0.33	18	12	25	.
2370	2.9	0.34	23	27	55	191.1
2373	3	0.06	22	11	29	241.1
2374	1.4	0.44	29	12	42	209.4
2375	3.3	0.97	75	28	63	198.2
2379	3.5	0.40	24	7	41	347.2
2380	3.1	0.31	19	2	19	332.1
2381	3.4	0.54	43	6	27	154.9
2385	1.4	1.13	46	16	29	331.1
2386	1.5	0.30	6	5	27	307.9
2387	1.9	0.38	27	.	21	147.5
2391	2	0.61	34	14	29	365.0
2392	1.9	0.66	37	12	31	182.3
2393	4.7	0.54	39	6	15	181.9
2397	13.5	0.32	17	10	18	320.7
2398	3.1	0.33	16	4	15	278.8
2399	7.3	0.31	17	7	14	196.6
2403	0.2	3.01	91	87	72	756.2

2404	0.1	2.93	83	67	62	395.6
2405	1	2.60	86	66	66	315.7
2409	1.7	0.64	32	9	28	488.6
2410	4	0.57	32	6	32	477.1
2411	2.8	0.32	21	2	21	132.7
2415	0.8	0.46	28	8	36	520.8
2416	3.3	0.09	.	5	39	450.7
2417	3.2	0.35	23	3	35	300.9
2421	2	0.29	14	11	24	243.1
2422	2.8	0.31	14	2	19	236.4
2423	3.1	0.50	37	29	29	162.9
2427	1.7	0.50	26	5	20	296.5
2428	2.6	0.26	13	3	13	249.8
2429	5.9	0.35	23	5	21	193.5
2434	3.5	0.29	15	6	17	270.4
2435	2.2	0.26	14	3	16	234.2
2436	4	0.61	45	11	27	173.8
2440	3.1	0.20	9	8	22	380.7
2441	3.1	0.34	20	4	31	231.3
2442	3.3	0.51	39	12	28	93.4
2446	2.4	0.36	20	9	29	480.8
2447	1.8	0.42	28	6	37	399.0
2448	2	0.72	62	21	45	180.1
2452	0.7	0.65	31	26	32	472.6
2453	2.2	0.40	25	10	43	168.9
2454	3.9	0.56	44	17	38	315.5
2458	0.7	1.57	85	74	67	456.4
2459	1.9	1.00	80	62	62	253.3
2460	4.2	0.94	84	65	65	208.2
2465	3.4	1.23	83	63	64	458.2
2466	2.3	1.02	81	46	60	334.2
2467	3.4	0.95	87	44	68	143.8
2471	0.3	2.96	95	91	82	817.8
2472	0.5	3.34	96	92	84	647.0
2473	1.3	3.37	98	85	80	321.8
2478	0.3	3.33	96	93	83	864.1
2479	0.7	3.45	96	94	89	492.4
2480	1.5	2.76	94	84	80	411.4
2484	0.6	1.10	43	7	35	313.5
2485	2.6	0.36	34	3	25	62.6
2486	3.2	0.67	58	26	34	.

2490	3.9	0.58	27	9	30	345.9
2491	2.6	0.38	26	1	28	195.0
2492	3.1	0.56	45	13	31	174.5
2496	1.5	0.31	17	10	21	252.6
2497	2.1	0.31	18	2	11	161.6
2498	3.4	0.43	31	2	19	160.9
2502	6.2	0.49	33	9	33	316.9
2503	4.6	0.42	28	10	26	278.7
2504	2.9	0.74	64	35	36	82.2
2509	4.6	0.51	32	24	29	497.7
2510	2.4	0.88	42	22	29	339.7
2511	3.9	0.82	62	35	54	197.3
2515	1.1	0.88	.	.	.	440.5
2516	4.3	0.78	39	20	38	403.3
2517	4.2	0.47	33	6	18	269.9
2521	2	0.38	20	5	19	315.2
2522	4.4	0.25	14	2	12	223.1
2523	4.2	0.37	25	2	16	139.6
2528	3	0.46	28	8	18	282.0
2529	4.4	0.31	19	6	14	383.9
2530	3	0.44	32	5	24	296.4
2535	4.6	0.33	17	8	18	301.5
2536	2.5	0.35	24	4	20	283.8
2537	6.4	0.46	35	6	29	204.5
2542	3.1	0.38	24	4	25	243.4
2543	2.9	0.36	24	7	24	257.6
2544	2.7	0.58	48	18	34	330.5
2548	3.7	0.26	14	6	16	365.9
2549	2.5	0.28	16	4	18	443.0
2550	4.1	0.31	19	2	20	97.8
2555	4.8	0.37	21	6	22	344.4
2556	5.7	0.27	15	3	24	464.6
2557	2.9	0.42	31	7	34	325.8
2561	3.7	0.76	29	8	27	246.2
2562	6	0.35	18	3	21	238.3
2563	4.6	0.44	33	5	29	210.7
2567	1.9	0.46	22	9	32	270.1
2568	2.8	0.40	22	4	27	339.7
2569	3	0.64	53	22	50	113.8
2572	5	0.31	18	5	25	383.4
2573	2.2	0.35	23	6	25	333.8

2574	7.5	0.70	60	31	44	36.9
2578	2.2	0.50	27	12	26	406.4
2579	3.7	0.36	20	7	30	462.9
2580	3.7	0.46	35	9	35	198.6
2585	3	0.31	19	7	41	334.1
2586	3.5	0.47	28	7	38	291.9
2587	2.3	0.62	43	12	37	187.1
2591	4.4	0.32	17	6	32	306.9
2592	2.6	0.62	29	9	36	382.7
2593	2.7	0.65	51	22	52	252.3
2597	0.5	1.16	44	48	42	236.8
2598	0.5	1.31	67	62	65	356.4
2599	1.4	1.11	73	49	68	281.5
2603	1.4	1.89	65	69	57	502.3
2604	0.6	2.08	81	65	61	420.8
2605	0.8	1.33	62	55	57	254.7
2610	0.2	2.30	87	91	76	702.8
2611	0.2	2.41	76	87	83	602.2
2612	0.9	1.61	77	64	73	375.2
2616	0.2	2.19	76	84	76	664.2
2617	0.6	2.22	84	80	79	541.7
2618	2.5	1.26	75	65	70	408.8
2622	1.6	1.79	78	43	53	551.4
2623	1	1.99	84	43	60	.
2624	3.4	0.99	85	47	58	297.1
2627	1.9	1.80	83	47	60	521.2
2628	1.3	1.58	86	40	59	363.7
2629	6.2	0.89	72	.	51	283.4
2632	3	0.63	41	16	43	418.4
2633	5.7	0.76	53	21	48	456.0
2634	3.3	0.99	72	32	57	227.1
2637	2	0.77	46	22	34	444.9
2638	2.4	0.64	52	23	48	364.9
2639	2.7	0.73	62	37	55	338.7
2643	1.3	0.78	50	27	58	485.1
2644	3	0.99	54	25	55	304.6
2645	5.9	0.81	60	26	51	271.4
2648	1.7	1.24	70	63	71	724.4
2649	2.6	1.33	83	59	68	360.3
2650	5.3	1.25	82	46	65	308.5
2654	1.3	1.06	60	43	58	708.5

2655	1.4	1.02	66	39	58	451.0
2656	5.6	1.20	74	38	50	346.9
2660	1.1	0.80	58	40	79	.
2661	2.4	0.88	64	39	57	540.5
2662	3.5	0.81	62	36	54	274.2
2666	2.6	0.69	37	25	43	731.8
2667	0.9	0.46	26	13	29	354.9
2668	5	0.60	47	24	55	288.5
2672	1.1	0.53	30	24	50	627.3
2673	2.7	0.52	26	14	20	301.1
2674	3.5	0.48	35	14	46	317.6
2677	2.9	0.81	44	36	52	609.5
2678	2.8	0.85	47	22	50	291.9
2679	4.4	0.91	75	33	61	199.4
2683	4.2	0.82	42	23	43	744.9
2684	2.1	0.59	40	18	48	401.8
2685	7.2	0.60	49	19	50	328.9
2689	2	1.40	65	41	58	514.3
2690	1.9	0.80	58	22	49	269.7
2691	5.1	0.92	65	41	64	239.2
2695	0.7	1.31	51	24	56	368.4
2696	3.5	0.79	48	17	51	239.7
2697	4.5	0.76	62	36	68	226.7
2702	0.7	0.68	37	24	52	467.2
2703	3.4	0.44	29	4	39	209.6
2704	3.1	0.53	40	16	54	266.9
2708	1.7	0.78	36	24	43	590.4
2709	3	0.52	27	12	47	347.3
2710	5.5	0.47	31	6	53	318.4
2715	1.8	0.95	43	18	49	504.4
2716	3.3	0.55	43	15	57	293.8
2717	2.8	0.70	59	24	61	.
2721	0.6	1.21	56	29	65	447.5
2722	2.5	0.69	55	23	62	258.2
2723	4.8	0.69	54	24	66	280.0
2727	1.5	0.71	44	23	49	733.6
2728	3.9	0.71	40	16	44	372.9
2729	2.5	0.63	49	21	54	210.4
2733	1.1	0.41	20	18	48	568.6
2734	3	0.51	39	6	44	297.0
2735	2.3	0.41	26	13	46	249.1

2739	5.8	1.18	42	9	32	597.6
2740	2.2	0.47	28	4	47	470.6
2741	3.1	0.50	37	16	51	317.6
2744	3.8	0.32	19	5	45	391.8
2745	2.2	0.72	38	5	48	363.7
2746	2.7	0.60	41	14	52	309.7
2750	4.1	0.33	17	11	47	511.9
2751	1.4	0.37	23	4	53	380.4
2752	3.1	0.56	42	12	55	274.9
2755	1.8	0.32	19	4	42	437.9
2756	3.3	0.30	18	3	44	326.4
2757	3.2	0.76	61	28	69	250.8
2760	3.3	0.36	19	8	41	476.2
2761	5.3	0.29	17	4	42	381.3
2762	3.3	0.37	25	7	46	319.7
2765	2.2	0.30	14	10	41	526.6
2766	3.5	0.30	17	6	39	413.2
2767	3.9	0.35	24	9	62	342.9
2770	1.7	1.08	.	.	.	312.7
2771	2.4	0.66	35	.	45	605.8
2772	3	0.49	26	.	51	333.2
2773	3.8	0.52	38	.	56	.
2777	1.3	0.35	19	.	51	599.1
2778	1.8	0.44	24	.	32	407.1
2779	3.3	0.60	48	.	62	.

ACEP, PLFA, bulk density, and PLFA groups

ACEP (µg protein g^{-1} soil), total PLFA (pmol g^{-1} soil), bulk density (g cm^3), and all PLFA groups in pmol g^{-1} soil

lab ID	ACEP	total PLFA	BD	AM Fungi	g-	euka-ryote	fungi	g+	actino
2185	5687	73197	1.69	1880	17851	1112	2661	18853	8204
2186	5460	28712	1.7	1567	15231	507	1244	17590	7606
2187	3536	10616	1.68	672	6452	211	635	7265	3954
2188	1760	15265	1.71	192	1713	0	136	1889	1570
2189	.	65129	1.57	224	2144	0	269	2745	2304
2190	649	9873	1.63	102	786	0	0	1478	1093
2191	7293	81568	1.23	1843	19947	938	2555	21039	9274
2192	.	30151	1.59	1152	15676	836	1415	16837	8879
2193	4366	29700	1.73	570	6380	206	285	7085	4509
2194	3690	16828	1.59	442	6978	140	367	7968	5069
2195	2014	61572	1.72	174	3313	0	218	3785	2962
2196	1576	21757	1.65	203	4499	0	899	2881	3048
2197	6549	13094	1.59	2084	19680	756	2013	20207	8858
2198	5792	37291	1.43	1215	14107	702	919	16304	7980
2199	4239	51255	1.44	508	8320	256	412	10730	5379
2200	2654	24363	1.52	450	5616	0	568	7705	5658
2201	1791	23308	1.52	158	2030	0	284	3636	2682
2202	1658	86639	1.47	122	1670	0	165	2837	2137
2203	6155	40784	1.49	1557	16745	679	1635	18438	8297
2204	4996	40128	1.76	1080	12517	647	931	15335	7472
2205	.	.	1.4	.	.	.	.	.	.
2206	1995	75127	1.45	434	4748	81	423	7173	5483
2207	1608	32125	1.63	204	1928	0	99	3589	2641
2208	1386	20475	1.58	182	1325	0	174	2500	1857

2209	6410	77541	1.39	4528	31590	1396	6345	23360	10081
2210	5468	25548	1.47	2582	21916	941	1377	19320	9436
2211	3366	32983	1.46	583	7645	0	186	9339	5781
2212	2162	60573	1.38	416	4237	0	180	6539	5201
2213	1678	39735	1.57	330	2837	0	249	4716	3618
2214	1530	31236	1.48	199	1761	2053	246	3138	2195
2215	5855	81585	1.31	4011	27699	1708	3147	20196	8834
2216	5725	27136	1.53	3140	23023	1623	1209	20161	9568
2217	3606	34656	1.43	713	7976	153	187	9506	5536
2218	2424	48434	1.37	470	6252	0	177	8474	6574
2219	1907	24617	1.5	354	3165	0	124	5047	4213
2220	1624	22806	1.47	180	1481	1348	187	2585	2137
2221	6176	62099	0.72	1419	15580	2472	1451	16136	8148
2222	5448	28170	0.97	1137	13489	713	718	13317	6651
2223	3487	25162	1.37	489	8095	299	204	11407	6386
2224	2866	54683	1.41	469	6780	0	355	10110	7218
2225	2455	17751	1.33	283	3877	0	188	6248	4668
2226	2702	19615	1.27	226	2931	0	208	5453	3984
2227	5914	58808	0.34	2508	24072	866	2158	20748	10837
2228	5059	33684	1.36	1922	20431	1244	2134	18471	9630
2229	3924	27186	1.34	729	9357	428	528	11572	5800
2230	2814	39301	1.36	544	6705	99	258	10559	7145
2231	2469	20977	1.21	413	4898	0	437	8560	6139
2232	2358	16845	1.14	201	2533	0	315	4916	3678
2233	5083	119281	1.6	3516	25993	1168	1083	17466	8490
2234	5063	62539	1.84	2053	15565	2133	464	14895	7897
2235	3580	19644	1.61	400	5223	124	104	6107	3472
2236	3098	105198	1.56	479	6960	280	142	9028	6467
2237	2985	34817	1.44	508	7074	158	399	9987	7957
2238	2410	30731	1.57	288	4731	0	333	7430	5281

2239	4579	64255	1.12	3574	29232	1569	2106	14596	9588
2240	4285	26535	1.65	1710	12983	877	1015	11019	5447
2241	3160	20227	1.7	394	5172	225	891	5139	2778
2242	2632	21608	1.54	410	6580	116	243	8693	6143
2243	2305	14342	1.4	254	3864	0	190	5742	4717
2244	1913	101500	1.35	229	3165	0	476	4519	3740
2245	5269	57162	1.44	1434	13556	387	1619	14141	7105
2246	4843	33823	1.45	1178	12731	449	1412	13472	7370
2247	3464	63790	1.5	393	5910	0	308	7533	4977
2248	2169	18116	1.48	359	4372	0	282	6392	5026
2249	1958	222290	1.61	181	2666	366	383	3745	3194
2250	1374	114278	1.61	183	2292	1278	383	3606	3153
2251	5032	66862	1.55	1543	13494	495	1246	13840	6661
2252	4514	38713	1.46	1050	8722	137	849	8730	4819
2253	3701	183426	1.53	656	6854	171	663	8755	6255
2254	2601	21000	1.52	381	4452	0	225	6001	4863
2255	1627	282812	1.62	308	2941	0	335	4466	3689
2256	1050	44951	1.59	265	2065	0	251	2790	2336
2257	6467	83702	1.14	3828	36666	1986	4391	28041	15061
2258	5436	43947	1.44	1606	17305	931	756	15659	9135
2259	3547	22260	1.45	522	7103	106	233	7452	5204
2260	2360	111793	1.47	303	3653	0	120	4317	4084
2261	2137	53475	1.42	232	2387	138	469	3721	3135
2262	2109	35296	1.5	177	1879	0	172	3728	2760
2263	7059	38457	1.1	2707	24270	1202	2199	18426	9871
2264	5959	28774	1.38	1562	17677	1140	888	15123	8249
2265	4016	18093	1.38	513	7719	236	404	8301	5211
2266	2688	84147	1.39	462	5574	0	327	7067	5125
2267	1945	49977	1.37	278	2854	0	118	3618	2909
2268	.	36800	1.36	198	2232	0	181	3500	2771

2269	5967	62965	0.55	4086	31678	2741	3853	24206	11247
2270	5416	72057	1.45	1742	16086	1380	1148	15561	8561
2271	3574	24001	1.38	513	7186	138	602	8150	5708
2272	2615	24468	1.55	510	5660	116	194	7686	6074
2273	2301	19124	1.61	319	4234	0	291	5929	4340
2274	1416	17627	1.64	194	3215	0	255	3827	3014
2275	6177	90256	1.25	2872	26170	1716	2828	19966	10520
2276	3908	34021	1.46	554	7465	199	348	8588	5242
2277	3154	40192	1.6	730	8873	0	349	9906	7337
2278	2270	22262	1.54	286	2740	0	242	4963	3274
2279	1597	17079	1.59	135	1980	0	191	3181	3019
2280	6702	85250	0.94	1681	21799	642	3472	18590	9159
2281	5371	68114	1.78	1525	18209	651	954	17431	9417
2282	4058	32641	1.5	621	7071	144	435	8299	5292
2283	2666	38192	1.26	618	6750	0	306	10786	7360
2284	1867	21755	1.34	262	2645	0	226	5167	3985
2285	6416	99397	.	1745	24845	852	4395	22300	11227
2286	5056	57847	.	1297	13880	881	1376	14562	8051
2287	3710	38718	.	870	8024	464	418	10058	5984
2288	2063	34485	.	724	5664	0	254	7965	5828
2289	1751	24079	.	359	2507	227	0	4574	3485
2290	1548	18610	.	252	1777	0	198	2737	1990
2291	4325	96665	1.12	4212	26584	3779	3468	21821	10666
2292	3796	65767	1.41	2397	16979	2186	2366	15772	8116
2293	2817	53744	1.37	1773	13452	1155	1595	13120	8983
2294	1791	35472	1.62	1330	6351	1148	648	7185	6177
2295	1141	20857	1.54	1009	3000	253	469	3950	3353
2296	804	10792	1.65	508	1142	0	188	1734	1404
2297	4885	112641	1.39	4657	32092	3660	6112	25148	12096
2298	4123	70195	1.41	1946	17577	2121	2099	16752	8834

2299	3352	57064	1.44	1581	14483	1220	1478	14153	9379
2300	2113	37343	1.35	1522	7107	715	860	9331	6623
2301	1550	26258	1.4	974	3776	246	488	5597	4109
2302	1169	20595	1.53	511	1871	0	403	3233	2672
2303	5313	95884	1.03	3481	28723	2324	3594	20665	9998
2304	3896	44304	1.89	1142	11610	548	477	10839	5888
2305	3014	24135	1.56	322	5114	131	178	5378	2884
2306	2442	29582	1.46	390	5885	0	120	7948	5629
2307	1882	25990	1.46	376	5034	0	179	5914	4775
2308	1595	22557	1.26	244	4990	0	248	3955	3428
2309	6413	85034	1.25	4493	27948	1587	1684	18614	8219
2310	3108	40713	1.89	1333	10448	708	499	9523	4729
2311	2590	21668	1.55	302	4054	0	190	4672	2341
2312	2172	32041	1.5	335	5163	0	162	6802	5433
2313	1889	28437	1.36	221	2645	0	152	4534	3660
2314	1500	15532	1.43	204	1885	0	186	2592	2066
2315	4325	63027	1.75	1433	13852	645	1589	17588	7109
2316	3890	32423	1.33	1250	13603	920	2125	14270	7013
2317	2929	26944	1.5	618	7430	95	1120	7941	4621
2318	1386	56877	1.55	456	5247	0	732	6764	5293
2319	897	19192	1.6	328	2740	0	239	3822	2829
2320	291	11199	1.57	180	772	0	0	1458	1118
2321	4042	59033	1.54	1299	13180	603	1436	16277	6627
2322	3537	24598	1.37	871	10313	430	1130	12611	5892
2323	2782	34615	1.58	695	5411	293	520	6378	3810
2324	1484	46423	1.49	664	7371	0	466	8515	6270
2325	1065	19873	1.53	200	3329	0	289	4102	3174
2326	418	14997	1.51	154	2253	0	472	3077	1955
2327	7541	89246	1.29	4105	25681	2467	2343	19386	9406
2328	3205	39745	1.55	1091	8891	412	998	8762	4711

2329	2604	25316	1.24	925	9007	399	957	10530	6726
2330	1509	37902	1.47	469	4571	0	297	6661	5373
2331	341	16213	1.53	285	1879	0	157	3042	2235
2332	135	12953	1.57	181	866	0	269	1649	935
2333	4410	82831	1.11	3194	21276	1460	2775	19450	9043
2334	3571	38743	1.23	1775	10909	437	1369	12143	5439
2335	2237	30314	1.21	973	7296	96	1805	9983	6041
2336	764	47031	1.55	729	5188	0	924	7293	4990
2337	314	17322	1.25	351	2959	0	406	4183	2057
2338	118	11789	1.24	125	1045	0	153	1502	737
2339	8039	152481	1.19	5681	46881	2423	4872	31324	17648
2340	5795	85314	1.4	3573	31741	1804	7592	23287	13407
2341	3864	35428	1.29	1783	20107	951	6467	17940	8044
2342	2324	121032	1.55	589	7818	123	1165	8688	6211
2343	734	18454	1.65	451	2588	0	310	2969	2891
2344	406	13015	1.55	209	921	413	232	1316	1136
2345	11118	169762	1.15	6986	54610	2824	5647	33804	18311
2346	5457	60459	1.17	3071	29755	1539	3577	23975	14052
2347	3235	36941	0.97	1270	14075	349	2250	14772	7607
2348	2247	103140	1.35	697	7179	0	970	9454	6134
2349	.	20728	1.59	438	3233	0	363	4772	3579
2350	2979	52321	0.6	1649	12976	988	2108	12436	5394
2351	2892	25656	1.63	1633	10160	788	659	10748	4793
2352	1620	22074	1.44	870	5316	224	418	6503	4081
2353	953	15440	1.4	701	4215	0	655	4983	3893
2354	767	41815	1.43	359	1552	0	354	3124	1812
2355	621	12148	1.56	229	1212	0	176	2308	1238
2356	395	11471	1.55	0	514	0	772	1046	322
2357	3788	108939	1.44	4523	31495	1429	2684	23455	16169
2358	3253	59295	1.3	4327	34660	1378	2384	25571	19675

2359	1827	46389	1.28	1391	14134	158	482	13762	14708
2360	1568	32828	1.36	834	9320	0	305	10763	12246
2361	1593	115608	1.37	544	5638	0	253	7711	8530
2362	1253	25841	1.37	405	4579	0	653	5009	5117
2363	9730	159866	0.81	6262	52314	3944	10384	26687	16768
2364	5897	77175	1.26	2814	28740	1897	7406	18646	10588
2365	4079	36599	1.24	1394	20338	500	4377	17811	9896
2366	2118	100946	1.65	403	7948	0	803	9834	7093
2367	904	16026	1.61	200	2385	0	468	2829	2830
2368	5696	62949	1.44	1488	14862	819	2800	14689	6175
2369	4673	42264	1.35	870	10397	505	1883	9446	4909
2370	2865	51586	1.51	871	11145	198	556	14101	10715
2371	1094	37211	1.6	540	6525	0	500	9228	7161
2372	467	25344	1.57	246	2107	0	415	3938	2212
2373	4883	68151	1.1	1658	15715	874	2473	17592	7347
2374	4721	48948	1.39	1635	19130	1034	10615	18420	8576
2375	2973	38303	1.45	1094	10799	594	552	13608	9840
2376	934	90913	1.61	817	7911	173	307	10289	9030
2377	496	15121	1.64	190	2000	0	124	3282	2320
2378	3464	92172	1.63	1705	19685	1255	6706	20860	9999
2379	4109	67485	0.78	2206	16107	344	3452	14936	7028
2380	3981	38181	1.13	2372	17872	995	1164	14388	7402
2381	2850	51139	1.48	663	8430	145	192	9712	6388
2382	2444	60452	1.47	574	11221	0	2136	10769	7794
2383	1995	29638	1.53	368	5599	263	186	5911	5077
2384	696	25045	1.65	380	3919	0	361	4174	3923
2385	6045	68945	1.49	1647	16078	646	3456	15896	7008
2386	5457	35645	1.59	1362	13449	485	1242	13412	6635
2387	3246	44639	1.4	681	8425	354	311	9125	6334
2388	2215	22390	1.48	664	11165	179	251	12100	9375

2389	1123	52233	1.46	311	3740	0	165	5736	4439
2390	913	19052	1.49	169	2379	0	384	3468	2414
2391	6533	93544	1.01	1946	21449	2781	5014	20818	9624
2392	5659	43842	1.57	2087	23371	979	6047	26025	12695
2393	3436	31450	1.62	728	10161	247	1893	10645	6898
2394	1788	18458	1.61	603	6533	0	266	7538	5717
2395	744	103449	1.73	231	2768	0	263	3438	2116
2396	580	21279	1.55	0	1512	236	498	2780	929
2397	4121	54707	1.38	1099	12335	538	1290	14442	6429
2398	3993	38250	1.67	1036	12577	584	1297	13920	7120
2399	3624	35240	1.56	760	9466	487	665	9286	5411
2400	1945	28543	1.57	620	7877	0	479	9414	7273
2401	840	52315	1.7	348	5730	0	271	6935	6157
2402	511	23398	1.6	251	3143	0	804	4425	2554
2403	9006	146134	0.92	5113	50378	2446	4877	31948	17489
2404	5733	61666	1.35	2762	28463	1578	2010	23261	12231
2405	4225	52574	1.27	1404	17535	694	979	16876	7897
2406	3561	31425	1.33	749	13434	294	923	14483	7243
2407	2466	91676	1.44	374	6900	0	744	7445	5136
2408	1903	20839	1.42	253	3936	0	290	5144	3545
2409	6199	70402	1.22	1241	17524	530	1692	16839	7284
2410	6041	32436	1.67	1120	15926	932	1155	15432	8013
2411	2857	35916	1.57	725	7897	131	169	8161	6266
2412	1709	61201	1.48	440	7207	0	548	8584	6643
2413	728	22885	1.57	233	3676	0	145	4783	4026
2414	499	16485	1.63	129	1882	0	123	3003	2199
2415	5698	53853	1.42	1022	13294	372	1264	12670	5967
2416	5524	35130	1.53	1085	14377	1247	1054	12568	7010
2417	3528	34812	1.43	817	8355	273	178	8055	6345
2418	2149	37648	1.35	594	8407	0	150	8998	5922

2419	1886	54609	1.44	547	7556	0	238	9868	7900
2420	654	21869	1.62	287	3216	0	155	4378	4014
2421	4780	64906	1.55	1278	14297	732	3595	14195	5510
2422	4671	37560	1.52	1238	15095	610	3196	14280	6166
2423	3705	27781	1.49	668	8551	365	511	9862	6447
2424	2208	22406	1.52	369	5487	0	167	7315	6042
2425	1116	63239	1.59	310	4304	0	328	4826	4360
2426	921	17792	1.67	257	2692	0	164	3559	3326
2427	4066	35340	1.17	730	8087	253	747	8888	3911
2428	4336	43110	1.75	951	10760	406	3430	10991	5076
2429	3387	30966	1.48	601	7123	158	4034	8634	5367
2430	1864	20759	1.56	369	5230	0	440	7490	6041
2431	1666	51762	1.64	268	2679	0	235	4536	4230
2432	720	16092	1.69	174	1790	0	121	2802	3110
2433	749	16446	1.89	135	894	1217	153	1461	1220
2434	4325	48728	1.15	999	10750	337	2103	9988	3955
2435	3225	36890	1.84	897	9492	452	717	11710	6331
2436	2470	37321	1.63	708	8431	659	262	9516	6701
2437	1983	24101	1.48	603	7822	0	464	9882	7467
2438	1267	44464	1.6	295	4164	0	160	5763	5218
2439	1221	14698	1.58	157	1161	0	214	2432	2284
2440	4142	69856	1.41	1585	16745	765	1783	17193	7950
2441	3083	40414	1.59	967	10082	483	588	10619	6230
2442	2840	35540	1.64	841	8739	926	304	9888	6800
2443	2219	25535	1.52	605	7134	0	160	8000	6421
2444	1500	42400	1.59	367	4266	0	136	5971	5525
2445	1061	19071	1.64	261	3007	0	143	3604	3477
2446	4566	58695	1.27	1389	16597	374	1179	13055	7355
2447	3630	43622	1.58	1107	11954	397	389	11300	7872
2448	2796	38736	1.5	797	10913	217	305	11663	8522

2449	2237	38762	1.51	549	8249	237	238	10554	8629
2450	1675	45477	1.59	494	6641	2801	436	7980	6920
2451	545	19183	1.7	135	2387	0	0	3230	2764
2452	6140	92480	1.2	2659	24048	1255	6679	20011	8390
2453	4242	60575	1.18	1322	16389	825	3102	13558	7434
2454	3865	39945	1.42	1393	15317	1566	950	15777	8587
2455	2167	33925	1.36	720	9110	419	477	10734	7863
2456	1508	61589	1.45	530	6557	236	556	7660	6651
2457	630	17177	1.65	203	2194	276	218	3536	2632
2458	4941	82042	1.11	2033	23702	807	1422	20552	10265
2459	3662	40284	1.45	1152	13544	863	1377	13643	6825
2460	2396	35070	1.49	758	10293	379	329	9842	7421
2461	1861	52904	1.54	481	7685	0	517	8152	6280
2462	1436	31418	1.54	439	7018	0	250	5492	5017
2463	1055	81952	1.56	215	3022	0	208	3088	2688
2464	764	35994	1.6	151	1681	0	131	1602	1733
2465	4637	32533	1.27	3051	28132	1037	2486	24380	13053
2466	3187	61229	1.58	1334	16193	738	899	17565	10740
2467	2066	22533	1.5	1049	13321	690	657	16235	10680
2468	1687	14272	1.56	666	8003	229	337	7611	6289
2469	550	20372	1.55	301	3473	0	120	3878	3311
2470	496	74049	1.6	182	1720	438	0	1873	1576
2471	7887	30471	1.1	6210	63857	3593	16525	44846	23890
2472	5753	55892	1.46	2888	48140	4830	18141	40274	21145
2473	3656	18473	1.31	1551	26804	697	8207	26485	14948
2474	2192	15160	1.54	724	13579	97	3691	16533	10715
2475	1359	106304	1.67	479	7067	0	2073	8938	5997
2476	804	23669	1.61	280	3882	0	544	5189	3538
2477	843	39284	1.72	572	2543	0	774	2963	2323
2478	9470	27071	0.95	7492	76244	4647	26035	55889	31482

2479	6585	173516	1.05	3395	49760	1876	2531	45192	24538
2480	4385	99052	1.24	1513	24049	1286	1279	29658	16424
2481	2494	59698	1.41	766	13121	0	801	17776	9877
2482	1782	76910	1.46	507	8426	103	1495	10402	7355
2483	1397	25750	1.47	297	4102	0	335	5538	4759
2484	5371	81202	1.65	1192	16621	559	3963	17996	7573
2485	.	48456	1.63	964	12268	183	339	12676	7222
2486	2327	41778	1.41	909	9562	110	197	10458	6816
2487	1308	25725	1.55	476	4386	0	121	6130	5238
2488	529	18439	1.59	262	2780	0	103	3832	3371
2489	361	14359	1.63	150	1538	0	0	2167	1839
2490	5081	64432	2	1099	13676	925	1715	15235	6470
2491	4149	50265	1.54	860	12576	388	860	12031	5673
2492	2352	33867	1.47	570	7608	107	0	8807	6181
2493	1652	32731	1.47	466	6052	0	126	7806	6415
2494	1153	18119	1.57	203	3395	0	0	3358	3541
2495	1064	12433	1.66	127	1276	0	0	1593	1741
2496	5156	63030	1.36	1218	13119	328	1426	14736	6283
2497	4393	24985	1.42	1140	13970	563	2939	16065	7887
2498	3182	40864	1.54	687	9000	178	0	10698	7763
2499	2289	46712	1.49	620	7286	0	107	10131	7713
2500	1731	20424	1.57	364	3426	0	155	5395	4400
2501	1609	91334	1.62	270	1681	0	0	3115	2863
2502	5207	37041	1.16	1525	18700	678	2263	21170	8780
2503	4636	35019	1.6	1278	16983	697	2818	18295	8496
2504	2099	84587	1.48	736	10285	476	508	11993	8334
2505	1564	25653	1.65	572	6805	0	235	8285	6899
2506	475	16573	1.63	366	4365	0	177	5284	4677
2507	305	66307	1.67	213	2561	0	108	3572	3140
2508	154	36383	1.56	149	1389	0	108	1887	1803

2509	.	85266	1.02	2361	25324	483	1976	19213	10619
2510	4099	60241	1.34	1906	16425	420	816	14241	8171
2511	2438	37106	1.6	597	8313	0	155	9780	7174
2512	854	26924	1.43	350	4415	0	174	5656	4660
2513	691	25212	1.63	358	3673	240	288	3853	2969
2514	557	21646	1.65	241	1719	174	401	2367	1265
2515	5662	64423	0.74	2342	17007	506	1412	14372	7204
2516	4900	66494	1.33	2192	18373	346	1338	14965	8611
2517	3699	44053	1.33	1159	10639	289	988	9245	5633
2518	2142	35047	1.43	454	6761	0	750	8992	6804
2519	701	26775	1.28	293	4208	0	269	5550	4755
2520	695	25595	1.5	276	2991	0	528	3975	3231
2521	4216	39531	.	732	9078	254	608	8482	4629
2522	4467	42654	.	776	9736	166	399	10619	5369
2523	3023	31693	.	588	5998	124	295	7228	4324
2524	1855	28029	1.52	477	5410	0	249	7020	5406
2525	1258	33571	.	410	4590	0	245	6488	5123
2526	471	21079	.	256	3261	0	228	5406	3500
2527	327	13726	.	169	1218	0	0	2428	1467
2528	4903	46595	1.14	1030	11907	341	369	11039	6060
2529	4749	37310	.	749	9057	227	224	9284	5195
2530	3702	37377	.	882	7694	173	156	10059	6489
2531	2109	30358	.	464	6690	0	238	7163	4933
2532	1669	22693	.	277	4051	0	162	5082	3866
2533	1266	22628	.	243	3076	0	207	5024	3263
2534	773	14080	.	138	1664	0	129	3131	1997
2535	4224	68001	.	1285	16840	758	1398	15395	7070
2536	4043	70954	.	1040	14443	694	1857	15357	6419
2537	3091	35783	.	714	6836	142	180	7487	4669
2538	1640	46349	.	591	8579	0	481	10664	8435

2539	723	19721	.	445	5015	0	263	5957	5099
2540	463	35240	.	177	1987	0	221	2460	1992
2541	285	18639	.	0	808	0	0	864	473
2542	4003	52285	.	913	11024	317	590	11876	5531
2543	4238	58032	.	991	12861	230	670	13212	6177
2544	3411	38022	.	660	6698	0	0	7645	5073
2545	1417	34509	.	572	7579	0	125	6963	5995
2546	708	26406	.	292	4211	0	0	4381	3758
2547	625	26633	.	214	2086	0	0	2789	2029
2548	4669	60020	.	1197	15402	0	519	13467	7138
2549	4479	61698	1.28	1231	15830	229	763	14511	8007
2550	2504	33688	1.49	640	5928	0	181	5867	4419
2551	1772	36877	1.52	518	5937	1405	146	7441	5977
2552	1116	28866	.	330	4229	0	0	4870	4605
2553	1022	32739	1.63	309	3628	0	0	4681	4190
2554	815	27902	1.62	263	1653	0	0	2801	1732
2555	4999	26605	.	1007	14245	583	2087	12567	6426
2556	5044	21458	1.52	1004	14075	475	1288	13128	6713
2557	2868	40772	1.51	881	8714	176	146	8688	5388
2558	2525	59867	1.44	879	7651	0	157	10048	6977
2559	1020	74329	1.58	307	4542	0	130	4331	4397
2560	634	47409	1.65	148	2199	0	139	2644	2482
2561	5360	42884	.	724	12211	277	1345	10341	4980
2562	5045	27742	.	796	12517	479	1346	12031	5795
2563	3066	21284	.	495	6563	197	191	5669	4264
2564	2220	74375	1.48	489	7160	0	164	7241	6213
2565	1390	42036	1.58	451	5448	0	0	6676	6171
2566	676	36046	.	276	2677	0	0	3599	3592
2567	5315	53835	1.22	1091	14209	671	2310	13531	5975
2568	4890	37899	1.35	905	12364	807	1862	11151	5753

2569	2458	28367	.	435	6141	0	144	6216	4996
2570	1537	23109	1.57	257	3432	0	108	4361	4305
2571	596	30627	.	232	2085	0	0	3032	2672
2572	5301	85832	1.03	996	15312	710	1729	13305	6268
2573	5277	43030	1.5	1034	15622	463	556	13709	6948
2574	2413	31493	1.51	602	7961	0	185	7735	6700
2575	1503	28999	1.56	317	4589	0	108	4727	4904
2576	680	27415	.	256	3180	0	174	3299	3980
2577	597	17996	1.66	190	1492	0	164	2291	1932
2578	6176	81453	.	1037	14381	746	1916	12023	6304
2579	6204	50759	.	1097	15373	838	1012	13596	6698
2580	3510	31268	1.54	534	7500	260	138	6436	4822
2581	2630	32326	1.5	432	6827	0	131	6752	6123
2582	1859	16519	.	310	4475	0	159	4704	4779
2583	1200	24704	1.63	203	2823	0	116	3297	3719
2584	603	14905	1.67	0	1146	0	0	1767	1386
2585	4405	75614	1.09	1649	15913	571	940	9387	5834
2586	4292	40864	.	1305	13951	667	747	9567	6433
2587	3249	37638	1.46	509	7322	140	325	6845	5713
2588	2077	31615	1.31	317	4897	0	153	5263	5218
2589	1359	23281	.	213	3052	0	122	3837	3804
2590	568	25272	1.6	0	919	0	95	1337	1511
2591	3976	16654	.	1194	11810	164	817	6274	4200
2592	4138	75721	.	1347	13359	340	429	8321	5304
2593	3216	35540	1.41	526	9038	118	279	8018	7387
2594	2061	31832	1.47	331	5531	0	121	6545	6003
2595	1503	24297	1.57	149	2245	0	100	2798	2705
2596	700	16635	1.64	0	1051	0	0	1648	1524
2597	3772	95795	1.15	2651	13806	2110	4433	10759	5091
2598	3927	51256	1.33	2304	12484	1821	3606	9931	4876

2599	2644	34668	1.21	973	7260	412	1189	7138	4789
2600	648	38958	1.54	253	1880	0	292	2214	2517
2601	573	23766	1.59	111	433	0	0	917	875
2602	463	25002	1.48	0	148	0	0	136	309
2603	5519	20035	1.05	5453	30430	4183	3443	18994	10253
2604	4621	76505	1.46	3642	16837	3653	4312	12694	6192
2605	3669	35013	1.42	1667	9582	1211	2330	7516	4298
2606	2266	31168	1.48	943	7455	322	786	7488	6461
2607	1967	19108	1.44	338	3088	4952	310	3947	3960
2608	762	21927	1.5	301	2338	137	384	2989	3403
2609	373	77132	1.53	192	488	0	230	980	1030
2610	9905	203327	0.79	7507	57912	4138	19582	38646	20469
2611	6131	153080	1.1	4438	38620	2409	15019	33233	15883
2612	3617	42311	1.24	1581	17359	798	4927	17309	9479
2613	2649	66245	1.31	784	11482	0	1269	14876	9754
2614	1469	39724	1.58	450	5671	0	729	7786	7215
2615	786	31277	1.64	337	3551	0	946	5381	5313
2616	9745	195407	0.92	7365	53867	3464	6638	40823	21224
2617	6154	130785	1.04	4098	33248	2239	7123	28326	13145
2618	3531	37946	1.15	1512	17709	455	3125	15964	9485
2619	1736	30388	1.36	576	8687	0	561	11849	8848
2620	988	44459	1.43	747	6203	0	812	7999	6865
2621	682	20623	1.56	317	2224	0	423	2663	2792
2622	4759	102812	0.88	2304	28838	646	1826	21367	12984
2623	4534	66506	0.94	1569	15412	489	1084	16480	10213
2624	2568	38944	1.45	564	7589	0	289	8531	6378
2625	1315	31873	1.6	397	6099	0	218	5902	5649
2626	344	17604	1.65	165	1910	0	0	2125	2208
2627	5120	104171	1.19	3023	31562	1255	4474	22937	12690
2628	3036	63653	1.35	1592	16033	920	1104	15253	8822

2629	2091	39442	1.41	584	7631	0	245	8164	6060
2630	1316	34020	1.52	357	6537	0	313	6063	5801
2631	280	39419	1.67	180	2608	0	179	2508	2364
2632	3706	83871	1.35	2025	21881	986	1851	18265	10387
2633	3291	62494	1.49	1491	15424	646	613	15027	8831
2634	1996	41402	1.63	718	8954	149	269	9748	7038
2635	1665	43374	1.55	511	7941	0	200	8204	7304
2636	283	25292	1.76	232	3094	0	202	3153	2850
2637	4502	103631	0.94	2911	28076	1641	2180	24875	12416
2638	3538	61814	1.4	1409	15258	799	625	15650	8489
2639	2392	44013	1.5	689	9351	204	342	10460	7126
2640	1503	38845	1.45	456	7528	0	273	8685	7078
2641	284	24762	1.61	184	2909	0	129	3289	3273
2642	182	22927	1.61	0	1658	0	270	2009	1823
2643	3124	87154	0.74	3385	25595	1084	1360	17613	10059
2644	3347	57962	1.46	1476	14247	1109	643	13053	7576
2645	2696	48084	1.5	730	9088	411	301	10341	6414
2646	2615	46852	1.51	570	9506	0	363	10751	8291
2647	658	36225	1.47	360	5520	0	194	5427	5515
2648	3858	104031	0.8	4938	33100	1687	2242	20133	11149
2649	3651	69361	1.36	2065	18062	879	900	15077	8903
2650	2766	52770	1.46	808	11165	3624	298	11929	7694
2651	2566	36591	1.41	410	7754	0	223	8551	6743
2652	592	28593	1.46	285	5367	0	259	5060	4694
2653	426	27671	1.46	154	2937	0	177	3279	2964
2654	4102	94111	1.37	4186	30124	1193	1646	18489	10221
2655	3598	71337	1.13	1878	16410	840	966	15650	9362
2656	2600	43917	1.32	861	9572	331	310	10567	7030
2657	1765	47385	1.45	589	8034	0	206	9741	7673
2658	1574	43827	1.69	550	8094	134	227	9462	7287

2659	406	36932	1.62	402	5915	0	195	5959	5248
2660	2976	17116	1	3491	34277	1352	2157	21101	12293
2661	2879	46350	1.33	1885	18653	919	1402	14575	9239
2662	1952	31531	1.53	658	9747	182	260	11004	7948
2663	1460	21325	1.53	395	7235	0	143	7777	7282
2664	482	19242	1.63	269	3299	0	180	3317	3377
2665	274	81198	1.68	118	1192	0	256	1546	1211
2666	5623	117172	1.09	4847	33899	1856	2653	25333	12424
2667	4006	78902	1.42	2337	23457	1862	1272	18306	10071
2668	1782	45201	1.29	979	11480	454	475	10667	7523
2669	1718	39239	1.28	814	9979	155	226	7504	5888
2670	1306	26988	1.34	435	5675	0	133	5022	4812
2671	486	24841	1.49	223	2782	0	244	2365	2301
2672	5283	127401	0.79	4794	34701	2415	3073	30270	14832
2673	3616	55896	1.25	1249	13020	774	515	12965	7048
2674	2025	60801	1.43	1205	13623	242	412	12557	9909
2675	1071	39303	1.58	0	4107	0	0	5458	4731
2676	515	31493	1.64	221	1886	0	270	2424	2261
2677	4655	113299	0.93	4241	32721	1084	2167	25099	13143
2678	3256	62320	1.41	1340	14390	525	622	12470	7387
2679	2021	46202	1.39	698	9387	0	404	9735	7553
2680	1450	34381	1.59	409	5582	0	226	6218	5324
2681	642	27189	1.57	289	3087	0	271	3153	2633
2682	485	19989	1.63	199	1313	0	216	1551	1125
2683	6399	116575	1.1	4546	33635	1844	4088	27252	13915
2684	3912	66493	1.64	1759	17478	1480	1080	14077	8711
2685	2576	40256	1.41	735	8997	298	296	8224	5994
2686	1703	33080	1.51	427	6433	0	190	5995	6001
2687	566	23859	1.59	212	2834	0	183	2983	2822
2688	307	26413	1.6	0	1047	0	0	1496	665

2689	4888	119171	1.11	2915	32331	1410	2229	30204	15534
2690	2898	53773	1.58	1310	13404	756	541	11929	6735
2691	2135	46232	1.52	1192	10508	361	485	9906	7053
2692	1578	46584	1.53	1149	11019	0	404	10035	6475
2693	477	25944	1.61	727	4223	0	332	4258	3074
2694	222	46040	1.56	220	1307	0	269	1250	970
2695	4117	18012	1.28	1956	20625	894	1478	16347	9056
2696	2604	100066	1.38	986	10410	674	498	10034	5832
2697	2098	63858	1.39	738	8813	388	535	8254	6331
2698	1548	41299	1.47	497	5551	0	290	5999	5456
2699	1159	34737	1.45	406	4503	0	318	4728	4020
2700	517	22651	1.55	452	3582	0	314	3740	3387
2701	308	15832	1.47	320	2539	358	210	2591	1866
2702	4649	38012	1.3	2127	21923	945	1456	16992	8840
2703	3198	35963	1.68	717	9242	582	432	6931	4257
2704	2485	64403	1.44	760	8081	356	306	8622	5760
2705	1877	139071	1.49	559	7098	149	310	7104	6220
2706	1032	74249	1.49	281	4055	1935	998	3955	4109
2707	464	47752	1.66	255	1909	0	154	2505	2467
2708	4717	25370	0.97	3378	29505	1897	1917	22023	11660
2709	3293	18679	1.4	1470	14907	1098	761	12675	6942
2710	2770	32225	1.41	811	8975	1557	289	8128	5547
2711	1824	72938	1.5	835	7985	0	424	9698	7595
2712	1414	32517	1.6	507	3936	0	218	4817	4496
2713	453	39022	1.59	529	3895	0	279	4218	4056
2714	445	36837	1.65	319	2299	0	205	2543	2913
2715	5287	25401	1.13	1929	21064	903	902	18511	9298
2716	3261	17958	1.57	992	9793	491	441	7805	4886
2717	2668	92255	1.44	799	7378	347	678	6948	4661
2718	2222	33980	1.57	519	7242	135	275	7638	6632

2719	1136	57275	1.59	262	3592	0	172	3666	3869
2720	409	36681	1.59	261	2339	0	186	3270	2856
2721	5136	25212	1.2	1744	22238	998	1601	17751	9231
2722	3117	20936	1.27	966	11852	632	638	10311	5302
2723	2742	67939	1.52	707	9641	501	806	8013	5690
2724	1877	45462	1.53	499	6040	121	305	6990	5855
2725	1401	40647	1.6	324	3781	112	574	3742	4012
2726	562	41930	1.65	258	2229	0	172	2304	2302
2727	5140	28417	1.67	5465	45392	723	3140	32401	18985
2728	2380	18305	1.55	2094	19739	273	649	17718	14156
2729	1415	16888	1.62	1074	10911	144	301	10660	9144
2730	674	55239	1.58	494	4601	0	188	4460	3654
2731	406	55162	1.7	273	2268	0	330	1796	1369
2732	447	22337	1.73	0	1141	0	0	386	0
2733	4540	15091	1.25	2140	19941	638	1055	17651	9539
2734	2572	47164	1.55	698	7518	277	167	6969	4136
2735	2216	49816	1.36	710	8838	169	238	9087	6033
2736	1624	26104	1.72	532	7709	0	238	8543	6663
2737	1294	32464	1.64	261	3815	0	162	4511	4142
2738	464	61624	1.69	138	1489	0	0	2065	1689
2739	4997	50026	0.98	2305	25252	1052	4190	19535	10373
2740	4008	27045	1.45	1409	15497	660	503	14091	8365
2741	2555	23444	1.56	733	8688	0	240	9027	7205
2742	1508	58960	1.46	364	4037	0	199	5106	4299
2743	562	57475	1.64	304	2100	0	172	2651	2598
2744	4187	35731	1.36	1588	19191	1013	1854	15951	7921
2745	3488	23680	1.59	928	11269	672	895	11104	5955
2746	2753	18446	1.56	760	9377	356	319	9988	7352
2747	1661	14284	1.58	482	6769	151	294	8540	7215
2748	1406	54835	1.73	266	3041	0	193	4007	4121

2749	501	55814	1.6	306	1880	0	314	2697	2696
2750	4329	27662	1.34	3199	29321	970	5950	24926	11755
2751	3516	28414	1.53	1170	14182	903	893	12185	6729
2752	2581	24341	1.46	861	8765	443	354	8575	6081
2753	2077	18291	1.54	425	4336	0	299	5295	4952
2754	986	17698	1.66	142	1450	0	185	2106	2343
2755	4171	48231	1.15	1954	22853	1184	2730	20837	10283
2756	3253	45965	1.69	932	11331	553	510	10549	6573
2757	2496	29896	1.48	647	8292	209	295	8291	6445
2758	1508	22819	1.51	418	4448	1371	338	4844	4517
2759	597	17871	1.45	242	2370	0	153	3085	3116
2760	3814	12663	1.25	2164	20896	1327	3906	14940	8502
2761	3114	36726	1.56	1246	13101	787	955	9770	6983
2762	2456	42207	1.49	946	10791	172	641	8677	7045
2763	1712	35244	1.57	504	4892	82	285	6674	5290
2764	547	28051	1.53	254	2742	0	209	3411	3402
2765	4525	18945	1.43	1724	20012	1275	5144	14887	7586
2766	3542	14168	1.67	1346	13944	892	937	11930	7775
2767	2478	56473	1.35	927	8347	134	520	7932	6501
2768	1225	50861	1.57	377	4856	0	263	5990	5156
2769	596	34514	1.53	281	2910	0	199	3999	3766
2770	3722	24568	1.69	1422	12911	811	1110	9613	5262
2771	4726	15431	0.83	3101	25101	1466	1768	21258	10866
2772	3691	10093	1.35	1015	11450	510	244	10807	6020
2773	2328	9734	1.49	441	6427	0	120	6899	5061
2774	1997	100118	1.52	273	5530	0	109	5800	5888
2775	1471	71333	1.52	230	4327	0	131	4769	5415
2776	649	42515	1.59	169	2577	0	0	2376	2861
2777	4596	35321	1.48	2830	25503	1246	1154	18375	10700
2778	3669	25255	1.46	1211	13147	606	465	12302	7493

2779	2109	17745	1.48	382	6617	0	149	5944	5120
2780	1439	11242	1.5	305	5576	0	108	6051	5662
2781	781	75483	1.72	144	2416	0	0	2546	2331
2782	594	68760	1.73	0	1432	0	0	871	514

Horizon, depth, pedon number, and soil series

Lab ID	hrzn	Depth	Pedon	Soil Series
2185	Ap	0-5	S22KS079001	Irwin
2186	Ap	5-10.	S22KS079001	Irwin
2187	BA	10-19.	S22KS079001	Irwin
2188	Bt1	19-47	S22KS079001	Irwin
2189	2Bt2	47-84	S22KS079001	Irwin
2190	2Btk	84-100+	S22KS079001	Irwin
2191	Ap	0-5	S22KS079002	Kaski
2192	Ap	5-10.	S22KS079002	Kaski
2193	A1	10-24.	S22KS079002	Kaski
2194	A2	24-43	S22KS079002	Kaski
2195	C1	43-74	S22KS079002	Kaski
2196	C2	74-100+	S22KS079002	Kaski
2197	Ap	0-5	S22KS079003	Geary
2198	Ap	5-10.	S22KS079003	Geary
2199	AB	10-23.	S22KS079003	Geary
2200	Bt1	23-52	S22KS079003	Geary
2201	Bt2	52-77	S22KS079003	Geary
2202	Bt3	77-100+	S22KS079003	Geary
2203	Ap	0-5	S22KS079004	Geary
2204	Ap	5-10.	S22KS079004	Geary

2205	AB	10-29.	S22KS079004	Geary
2206	Bt1	29-50	S22KS079004	Geary
2207	Bt2	50-72	S22KS079004	Geary
2208	Bt3	72-100+	S22KS079004	Geary
2209	Ap	0-5	S22KS079005	Geary
2210	Ap	5-10.	S22KS079005	Geary
2211	AB	10-30.	S22KS079005	Geary
2212	Bt1	30-50	S22KS079005	Geary
2213	Bt2	50-77	S22KS079005	Geary
2214	Bt3	77-100+	S22KS079005	Geary
2215	Ap	0-5	S22KS079006	Geary
2216	Ap	5-10.	S22KS079006	Geary
2217	AB	10-30.	S22KS079006	Geary
2218	Bt1	30-50	S22KS079006	Geary
2219	Bt2	50-74	S22KS079006	Geary
2220	Bt3	74-100+	S22KS079006	Geary
2221	Ap	0-5	S22KS079007	Hobbs
2222	Ap	5-10.	S22KS079007	Hobbs
2223	A1	10-41.	S22KS079007	Hobbs
2224	A2	41-60	S22KS079007	Hobbs
2225	Bw	60-95	S22KS079007	Hobbs
2226	Ab	95-100+	S22KS079007	Hobbs
2227	Ap	0-5	S22KS079008	Hobbs
2228	Ap	5-10.	S22KS079008	Hobbs
2229	A1	10-31.	S22KS079008	Hobbs
2230	A2	32-63	S22KS079008	Hobbs
2231	Bw	63-84	S22KS079008	Hobbs
2232	Ab	84-100+	S22KS079008	Hobbs
2233	Ap	0-5	S22KS079009	Hobbs
2234	Ap	5-10.	S22KS079009	Hobbs

2235	A1	10-31.	S22KS079009	Hobbs
2236	A2	31-59	S22KS079009	Hobbs
2237	Ab	59-82	S22KS079009	Hobbs
2238	Bw	82-100+	S22KS079009	Hobbs
2239	Ap	0-5	S22KS079010	Hobbs
2240	Ap	5-10.	S22KS079010	Hobbs
2241	A1	10-28.	S22KS079010	Hobbs
2242	A2	28-62	S22KS079010	Hobbs
2243	A3	62-82	S22KS079010	Hobbs
2244	Bw	82-100+	S22KS079010	Hobbs
2245	Ap	0-5	S22KS079011	Crete
2246	Ap	5-10.	S22KS079011	Crete
2247	BA	10-29.	S22KS079011	Crete
2248	Bt1	29-59	S22KS079011	Crete
2249	Bt2	59-79	S22KS079011	Crete
2250	Bt3	79-100+	S22KS079011	Crete
2251	Ap	0-5	S22KS079012	Crete
2252	Ap	5-10.	S22KS079012	Crete
2253	BA	10-35.	S22KS079012	Crete
2254	Bt1	35-61	S22KS079012	Crete
2255	Bt2	61-87	S22KS079012	Crete
2256	Bt3	87-100+	S22KS079012	Crete
2257	Ap	0-5	S22KS079013	Hobbs
2258	Ap	5-10.	S22KS079013	Hobbs
2259	A1	10-33.	S22KS079013	Hobbs
2260	A2	33-64	S22KS079013	Hobbs
2261	2A/C	64-93	S22KS079013	Hobbs
2262	3AB	93-100+	S22KS079013	Hobbs
2263	Ap	0-5	S22KS079014	Hobbs
2264	Ap	5-10.	S22KS079014	Hobbs

2265	A1	10-29.	S22KS079014	Hobbs
2266	A2	29-50	S22KS079014	Hobbs
2267	2A/C	50-90	S22KS079014	Hobbs
2268	Ab	90-100+	S22KS079014	Hobbs
2269	Ap	0-5	S22KS079015	Crete
2270	Ap	5-10.	S22KS079015	Crete
2271	BA	10-33.	S22KS079015	Crete
2272	Bt1	33-56	S22KS079015	Crete
2273	Bt2	56-77	S22KS079015	Crete
2274	Bt3	77-100+	S22KS079015	Crete
2275	Ap	0-5	S22KS079016	Crete
2276	AB	10-28.	S22KS079016	Crete
2277	Bt1	28-49	S22KS079016	Crete
2278	Bt2	49-80	S22KS079016	Crete
2279	Bt3	80-100+	S22KS079016	Crete
2280	Ap	0-5	S22KS079017	Hobbs
2281	Ap	5-10.	S22KS079017	Hobbs
2282	A1	10-33.	S22KS079017	Hobbs
2283	A2	33-78	S22KS079017	Hobbs
2284	A3	78-100+	S22KS079017	Hobbs
2285	Ap	0-5	S22KS079018	Hobbs
2286	Ap	5-10.	S22KS079018	Hobbs
2287	A	10-33.	S22KS079018	Hobbs
2288	Bw	33-53	S22KS079018	Hobbs
2289	C1	53-77	S22KS079018	Hobbs
2290	C2	77-100+	S22KS079018	Hobbs
2291	Ap	0-5	S22KS079019	Geary
2292	Ap	5-10.	S22KS079019	Geary
2293	BA	10-25.	S22KS079019	Geary
2294	Bt1	25-49	S22KS079019	Geary

2295	Bt2	49-70	S22KS079019	Geary
2296	Bt3	70-100+	S22KS079019	Geary
2297	Ap	0-5	S22KS079020	Geary
2298	Ap	5-10.	S22KS079020	Geary
2299	BA	10-24.	S22KS079020	Geary
2300	Bt1	24-51	S22KS079020	Geary
2301	Bt2	51-76	S22KS079020	Geary
2302	Bt3	76-100+	S22KS079020	Geary
2303	Ap	0-5	S22KS079021	Nalim-Shellabarger
2304	Ap	5-10.	S22KS079021	Nalim-Shellabarger
2305	BA	10-27.	S22KS079021	Nalim-Shellabarger
2306	Bt1	27-60	S22KS079021	Nalim-Shellabarger
2307	Bt2	60-80	S22KS079021	Nalim-Shellabarger
2308	C	80-100+	S22KS079021	Nalim-Shellabarger
2309	Ap	0-5	S22KS079022	Nalim-Shellabarger
2310	Ap	5-10.	S22KS079022	Nalim-Shellabarger
2311	BA	10-22.	S22KS079022	Nalim-Shellabarger
2312	Bt1	22-52	S22KS079022	Nalim-Shellabarger
2313	Bt2	52-76	S22KS079022	Nalim-Shellabarger
2314	BC	76-100+	S22KS079022	Nalim-Shellabarger
2315	Ap	0-5	S22KS113001	Crete
2316	Ap	5-10.	S22KS113001	Crete
2317	BA	10-15.	S22KS113001	Crete
2318	Bt	15-52	S22KS113001	Crete
2319	Btk	52-87	S22KS113001	Crete
2320	Bt	87-100+	S22KS113001	Crete
2321	Ap	0-5	S22KS113002	Crete
2322	Ap	5-10.		Crete
2323	BA	10-15.		Crete
2324	Bt	15-52		Crete

2325	Btk	52-87		Crete
2326	B't	87-100+		Crete
2327	Ap	0-5	S22KS113003	Crete
2328	Ap	5-10.		Crete
2329	Bt1	10-30.		Crete
2330	Bt2	30-66		Crete
2331	Btk1	66-88		Crete
2332	Btk2	88-100+		Crete
2333	Ap	0-5	S22KS113004	Crete
2334	Ap	5-10.		Crete
2335	Bt1	10-30.		Crete
2336	Bt2	30-66		Crete
2337	Btk1	66-88		Crete
2338	Btk2	88-100+		Crete
2339	A1	0-5	S22KS113005	Crete
2340	Ap	5-10.		Crete
2341	A2	10-28.		Crete
2342	Bt	28-63		Crete
2343	Btk1	63-81		Crete
2344	Btk2	81-100+		Crete
2345	A1	0-5	S22KS113006	Crete
2346	Ap	5-10.		Crete
2347	A2	10-30.		Crete
2348	Bt	30-79		Crete
2349	Btk	79-100+		Crete
2350	Ap	0-5	S22KS113007	Wells
2351	Ap	5-10.		Wells
2352	AB	10-27.		Wells
2353	Btk1	27-48		Wells
2354	Btk2	48-68		Wells

2355	Btk3	68-94		Wells
2356	BC	94-100+		Wells
2357	Ap1	0-5	S22KS113008	Roxbury
2358	Ap	5-10.		Roxbury
2359	Ap2	10-20.		Roxbury
2360	A1	20-49		Roxbury
2361	A2	49-77		Roxbury
2362	C	77-100+		Roxbury
2363	A1	0-5	S22KS113009	Ladysmith
2364	Ap	5-10.		Ladysmith
2365	A2	10-39.		Ladysmith
2366	Btss	39-89		Ladysmith
2367	Btk	89-100+		Ladysmith
2368	Ap	0-5	S22KS113010	Ladysmith
2369	Ap	5-10.		Ladysmith
2370	A	10-40.		Ladysmith
2371	Bt	40-87		Ladysmith
2372	Btk	87-100+		Ladysmith
2373	Ap	0-5	S22KS113011	Ladysmith
2374	Ap	5-10.		Ladysmith
2375	A	10-34.		Ladysmith
2376	Bt	34-71		Ladysmith
2377	Btk1	71-90		Ladysmith
2378	Btk2	90-100+		Ladysmith
2379	Ap	0-5	S22KS113012	Crete
2380	Ap	5-10.		Crete
2381	ABt	10-38.		Crete
2382	Bt1	38-60		Crete
2383	Bt2	60-75		Crete
2384	Btk	75-100+		Crete

2385	Ap1	0-5	S22KS113013	Wells
2386	Ap	5-10.		Wells
2387	Ap2	10-18.		Wells
2388	Bt1	18-28		Wells
2389	Bt2	28-64		Wells
2390	BC	64-100+		Wells
2391	Ap	0-5	S22KS113014	Wells
2392	Ap	5-10.		Wells
2393	BA	10-19.		Wells
2394	Bt	19-40		Wells
2395	2Btk	40-76		Wells
2396	2Btk2	76-100+		Wells
2397	Ap	0-5	S22KS113015	Crete
2398	Ap	5-10.		Crete
2399	Ap	10-15.		Crete
2400	Bt1	15-49		Crete
2401	Bt2	49-68		Crete
2402	Btk	68-100+		Crete
2403	A	0-5	S22KS113016	Wells
2404	A	5-10.		Wells
2405	A	10-22.		Wells
2406	BA	22-39		Wells
2407	Btk	39-53		Wells
2408	BCk	53-100+		Wells
2409	Ap	0-5	S22KS113017	Crete
2410	Ap	5-10.		Crete
2411	BA	10-18.		Crete
2412	Bt1	18-51		Crete
2413	Bt2	51-76		Crete
2414	Btk	76-100+		Crete

2415	Ap	0-5	S22KS113018	Crete
2416	Ap	5-10.		Crete
2417	BA	10-20.		Crete
2418	Bt1	20-31		Crete
2419	Bt2	31-68		Crete
2420	Btk	68-100+		Crete
2421	Ap	0-5	S22KS113019	Crete
2422	Ap	5-10.		Crete
2423	BA	10-21.		Crete
2424	Bt1	21-46		Crete
2425	Bt2	46-67		Crete
2426	Btk	67-100+		Crete
2427	Ap	0-5	S22KS113020	Crete
2428	Ap	5-10.		Crete
2429	BA	10-22.		Crete
2430	Bt1	22-48		Crete
2431	Bt2	48-67		Crete
2432	Bt3	67-94		Crete
2433	Btk	94-100+		Crete
2434	Ap	0-5	S22KS113021	Crete
2435	Ap	5-10.		Crete
2436	BA	10-20.		Crete
2437	Bt1	20-44		Crete
2438	Bt2	44-67		Crete
2439	Btk	67-100+		Crete
2440	Ap	0-5	S22KS113022	Crete
2441	Ap	5-10.		Crete
2442	BA	10-24.		Crete
2443	Bt1	24-49		Crete
2444	Bt2	49-69		Crete

2445	Btk	69-100+		Crete
2446	Ap	0-5	S22KS113023	Crete
2447	Ap	5-10.		Crete
2448	BA	10-20.		Crete
2449	Bt	20-30		Crete
2450	Btss	30-63		Crete
2451	Btk	63-100+		Crete
2452	Ap	0-5	S22KS113024	Crete
2453	Ap	5-10.		Crete
2454	BA	10-14.		Crete
2455	Bt	14-34		Crete
2456	Btss	34-63		Crete
2457	Btk	63-100+		Crete
2458	Ap	0-5	S22KS113025	Goessel
2459	Ap	5-10.		Goessel
2460	BA	10-29.		Goessel
2461	Bt1	29-52		Goessel
2462	Bt2	52-63		Goessel
2463	Btk1	63-88		Goessel
2464	Btk2	88-100+		Goessel
2465	Ap	0-5	S22KS113026	Goessel
2466	Ap	5-10.		Goessel
2467	BA	10-29.		Goessel
2468	Bt	29-46		Goessel
2469	Btk1	46-78		Goessel
2470	Btk2	78-100+		Goessel
2471	A1	0-5	S22KS113027	Goessel
2472	Ap	5-10.		Goessel
2473	A2	10-28.		Goessel
2474	BA	28-44		Goessel

2475	Btss1	44-72		Goessel
2476	Btss2	72-91		Goessel
2477	Btk	91-100+		Goessel
2478	A1	0-5	S22KS113028	Goessel
2479	A1	5-10.		Goessel
2480	A2	10-33.		Goessel
2481	Bt	33-47		Goessel
2482	Btss1	47-71		Goessel
2483	Btss2	71-100+		Goessel
2484	Ap	0-5	S22KS113029	Crete
2485	Ap	5-10.		Crete
2486	BA	10-24.		Crete
2487	Bt	24-54		Crete
2488	Btk1	54-79		Crete
2489	Btk2	79-100+		Crete
2490	Ap	0-5	S22KS113030	Crete
2491	Ap	5-10.		Crete
2492	BA	10-34.		Crete
2493	Bt1	34-64		Crete
2494	Bt2	64-78		Crete
2495	Btk	78-100+		Crete
2496	Ap	0-5	S22KS113031	Crete
2497	Ap	5-10.		Crete
2498	BA	10-30.		Crete
2499	Bt1	30-54		Crete
2500	Bt2	54-72		Crete
2501	Bt3	72-100+		Crete
2502	Ap	0-5	S22KS113032	Ladysmith
2503	Ap	5-10.		Ladysmith
2504	Bt1	10-28.		Ladysmith

2505	Bt2	28-50		Ladysmith
2506	Bt3	50-71		Ladysmith
2507	Btk1	71-89		Ladysmith
2508	Btk2	89-100+		Ladysmith
2509	Ap	0-5	S22KS113033	Crete
2510	Ap	5-10.		Crete
2511	BA	10-40.		Crete
2512	Bt	40-65		Crete
2513	Btk1	65-81		Crete
2514	Btk2	81-100+		Crete
2515	Ap	0-5	S22KS113034	Crete
2516	Ap	5-10.		Crete
2517	BA	10-24.		Crete
2518	Bt1	24-54		Crete
2519	Bt2	54-74		Crete
2520	Btk	74-100+		Crete
2521	Ap	0-5	S22KS113035	Ladysmith
2522	Ap	5-10.		Ladysmith
2523	BA	10-25.		Ladysmith
2524	Bt1	25-47		Ladysmith
2525	Bt2	47-63		Ladysmith
2526	Btk1	63-80		Ladysmith
2527	Btk2	80-100+		Ladysmith
2528	Ap	0-5	S22KS113036	Ladysmith
2529	Ap	5-10.		Ladysmith
2530	BA	10-23.		Ladysmith
2531	Bt1	23-39		Ladysmith
2532	Bt2	39-56		Ladysmith
2533	Btk1	56-82		Ladysmith
2534	2Btk2	82-100+		Ladysmith

2535	Ap	0-5	S22KS113037	Ladysmith
2536	Ap	5-10.		Ladysmith
2537	BA	10-23.		Ladysmith
2538	Bt1	23-50		Ladysmith
2539	Bt2	50-76		Ladysmith
2540	Btk1	76-89		Ladysmith
2541	2Btk2	89-100+		Ladysmith
2542	Ap	0-5	S22KS113038	Ladysmith
2543	Ap	5-10.		Ladysmith
2544	BA	10-30.		Ladysmith
2545	Bt	30-54		Ladysmith
2546	Btk1	54-73		Ladysmith
2547	Btk2	73-100+		Ladysmith
2548	Ap	0-5	S22KS113039	Crete
2549	Ap	5-10.		Crete
2550	BA	10-21.		Crete
2551	Bt1	21-45		Crete
2552	Bt2	45-70		Crete
2553	Btk1	70-84		Crete
2554	Btk2	84-100+		Crete
2555	Ap	0-5	S22KS113040	Crete
2556	Ap	5-10.		Crete
2557	BA	10-25.		Crete
2558	Bt1	25-47		Crete
2559	Bt2	47-75		Crete
2560	Btk	75-100+		Crete
2561	Ap	0-5	S22KS113041	Crete
2562	Ap	5-10.		Crete
2563	BA	10-21.		Crete
2564	Bt	21-46		Crete

2565	Btss	46-73		Crete
2566	Btk	73-100+		Crete
2567	Ap	0-5	S22KS113042	Crete
2568	Ap	5-10.		Crete
2569	Bt1	10-38.		Crete
2570	Bt2	38-69		Crete
2571	Btk	69-100+		Crete
2572	Ap	0-5	S22KS113043	Crete
2573	Ap	5-10.		Crete
2574	BA	10-22.		Crete
2575	Bt	22-52		Crete
2576	Btk1	52-70		Crete
2577	Btk2	70-100+		Crete
2578	Ap	0-5	S22KS113044	Crete
2579	Ap	5-10.		Crete
2580	BA	10-20.		Crete
2581	Bt1	20-39		Crete
2582	Bt2	39-63		Crete
2583	Btkss	63-87		Crete
2584	Btk	87-100+		Crete
2585	Ap	0-5	S22KS113045	Crete
2586	Ap	5-10.		Crete
2587	BA	10-20.		Crete
2588	Btss1	20-36		Crete
2589	Btss2	36-72		Crete
2590	Btk	72-100+		Crete
2591	Ap	0-5	S22KS113046	Crete
2592	Ap	5-10.		Crete
2593	BA	10-22.		Crete
2594	Btss1	22-43		Crete

2595	Btss2	43-77		Crete
2596	Btss3	77-100+		Crete
2597	Ap	0-5	S22KS113047	Crete
2598	Ap	5-10.		Crete
2599	Bt	10-33.		Crete
2600	Btss	33-67		Crete
2601	Btkss	67-79		Crete
2602	Btk	79-100+		Crete
2603	Ap	0-5	S22KS113048	Crete
2604	Ap	5-10.		Crete
2605	BA	10-20.		Crete
2606	Bt	20-43		Crete
2607	Btss1	43-64		Crete
2608	Btss2	64-89		Crete
2609	Btssk	89-100+		Crete
2610	A1	0-5	S22KS113049	Crete
2611	A1	5-10.		Crete
2612	A2	10-34.		Crete
2613	Bt1	34-64		Crete
2614	Bt2	64-87		Crete
2615	Btk	87-100+		Crete
2616	A1	0-5	S22KS113050	Crete
2617	A1	5-10.		Crete
2618	A2	10-37.		Crete
2619	Bt	37-64		Crete
2620	Btk1	64-85		Crete
2621	Btk2	85-100+		Crete
2622	Ap	0-5	S22KS113051	Goessel
2623	Ap	5-10.		Goessel
2624	Bt1	10-48.		Goessel

2625	Bt2	48-65		Goessel
2626	Btk	65-100+		Goessel
2627	Ap	0-5	S22KS113052	Goessel
2628	Ap	5-10.		Goessel
2629	BA	10-25.		Goessel
2630	Bt	25-56		Goessel
2631	Btk	56-100+		Goessel
2632	Ap	0-5	S22KS113053	Goessel
2633	Ap	5-10.		Goessel
2634	BA	10-24.		Goessel
2635	Bt	24-58		Goessel
2636	Btk	58-100+		Goessel
2637	Ap	0-5	S22KS113054	Goessel
2638	Ap	5-10.		Goessel
2639	BA	10-30.		Goessel
2640	Bt1	30-58		Goessel
2641	Bt2	58-88		Goessel
2642	Btk	88-100+		Goessel
2643	Ap	0-5	S22KS113055	Goessel
2644	Ap	5-10.		Goessel
2645	BA	10-22.		Goessel
2646	Bt	22-54		Goessel
2647	Btk	54-100+		Goessel
2648	Ap	0-5	S22KS113056	Goessel
2649	Ap	5-10.		Goessel
2650	BA	10-34.		Goessel
2651	Bt1	34-52		Goessel
2652	Bt2	52-80		Goessel
2653	Btk	80-100+		Goessel
2654	Ap	0-5	S22KS113057	Ladysmith

2655	Ap	5-10.		Ladysmith
2656	BA	10-24.		Ladysmith
2657	Bt1	24-47		Ladysmith
2658	Bt2	47-55		Ladysmith
2659	Btk	55-100+		Ladysmith
2660	Ap	0-5	S22KS113058	Ladysmith
2661	Ap	5-10.		Ladysmith
2662	Bt1	10-31.		Ladysmith
2663	Bt2	32-48		Ladysmith
2664	Btk1	48-70		Ladysmith
2665	Btk2	70-100+		Ladysmith
2666	Ap	0-5	S22KS113059	Crete
2667	Ap	5-10.		Crete
2668	BA	10-33.		Crete
2669	Bt1	33-51		Crete
2670	Bt2	51-69		Crete
2671	Btk	69-100+		Crete
2672	Ap	0-5	S22KS113060	Crete
2673	Ap	5-10.		Crete
2674	BA	10-34.		Crete
2675	Bt	34-76		Crete
2676	Btk	76-100+		Crete
2677	Ap	0-5	S22KS113061	Crete
2678	Ap	5-10.		Crete
2679	BA	10-27.		Crete
2680	Bt1	27-44		Crete
2681	Bt2	44-67		Crete
2682	Bt3	67-100+		Crete
2683	Ap	0-5	S22KS113062	Crete
2684	Ap	5-10.		Crete

2685	Bt1	10-34.		Crete
2686	Bt2	34-50		Crete
2687	Btk1	50-83		Crete
2688	Btk2	83-100+		Crete
2689	Ap	0-5	S22KS113063	Crete
2690	Ap	5-10.		Crete
2691	BA	10-20.		Crete
2692	Bt	20-43		Crete
2693	Btk1	43-70		Crete
2694	Btk2	70-100+		Crete
2695	Ap	0-5	S22KS113064	Crete
2696	Ap	5-10.		Crete
2697	BA	10-22.		Crete
2698	Bt1	22-37		Crete
2699	Bt2	37-55		Crete
2700	Btk1	55-88		Crete
2701	2Btk2	88-100+		Crete
2702	Ap	0-5	S22KS113065	Crete
2703	Ap	5-10.		Crete
2704	BA	10-25.		Crete
2705	Bt1	25-38		Crete
2706	Bt2	38-73		Crete
2707	Btkss	73-100+		Crete
2708	Ap	0-5	S22KS113066	Crete
2709	Ap	5-10.		Crete
2710	A	10-20.		Crete
2711	Bt1	20-33		Crete
2712	Bt2	33-59		Crete
2713	Bt3	59-75		Crete
2714	Btk	75-100+		Crete

2715	Ap	0-5	S22KS113067	Crete
2716	Ap	5-10.		Crete
2717	BA	10-20.		Crete
2718	Bt1	20-34		Crete
2719	Bt2	34-60		Crete
2720	Btk	60-100+		Crete
2721	Ap	0-5	S22KS113068	Crete
2722	Ap	5-10.		Crete
2723	BA	10-22.		Crete
2724	Bt	22-44		Crete
2725	Btss	44-65		Crete
2726	Btk	65-100+		Crete
2727	Ap	0-5	S22KS113069	Smolan
2728	Ap	5-10.		Smolan
2729	Bt1	10-26.		Smolan
2730	Bt2	26-51		Smolan
2731	Bt3	51-80		Smolan
2732	Bt4	80-100+		Smolan
2733	Ap	0-5	S22KS113070	Smolan
2734	Ap	5-10.		Smolan
2735	BA	10-20.		Smolan
2736	Bt1	20-40		Smolan
2737	Bt2	40-70		Smolan
2738	Btk	70-100+		Smolan
2739	Ap	0-5	S22KS113071	Crete
2740	Ap	5-10.		Crete
2741	BA	10-29.		Crete
2742	Bt	29-67		Crete
2743	Btk	67-100+		Crete
2744	Ap	0-5	S22KS113072	Crete

2745	Ap	5-10.		Crete
2746	BA	10-24.		Crete
2747	Bt1	24-50		Crete
2748	Bt2	50-80		Crete
2749	Btk	80-100+		Crete
2750	Ap	0-5	S22KS113073	Crete
2751	Ap	5-10.		Crete
2752	Bt1	10-35.		Crete
2753	Bt2	35-75		Crete
2754	Btk	75-100+		Crete
2755	Ap	0-5	S22KS113074	Crete
2756	Ap	5-10.		Crete
2757	Bt1	10-45.		Crete
2758	Bt2	45-70		Crete
2759	Btk	70-100+		Crete
2760	Ap	0-5	S22KS113075	Crete
2761	Ap	5-10.		Crete
2762	BA	10-29.		Crete
2763	Bt	29-66		Crete
2764	Btk	66-100+		Crete
2765	Ap	0-5	S22KS113076	Crete
2766	Ap	5-10.		Crete
2767	BA	10-28.		Crete
2768	Bt	28-75		Crete
2769	Btk	75-100+		Crete
2770	Ap	5-10.	S22KS079016	Crete
2771	Ap	0-5	S22KS113077	Crete
2772	Ap	5-10.		Crete
2773	BA	10-28.		Crete
2774	Bt1	28-50		Crete

2775	Bt2	50-78		Crete
2776	Btk	78-100+		Crete
2777	Ap	0-5	S22KS113078	Crete
2778	Ap	5-10.		Crete
2779	BA	10-28.		Crete
2780	Bt	28-58		Crete
2781	Btk1	58-83		Crete
2782	Btk2	83-100+		Crete

Tillage coefficient (0.0=0/11 years tilled) (1.1=11/11 years tilled), irrigation, cropping system, SOC

SOC % only available for Harvey county pedons

Lab ID	tillage coefficient	irr	Cropping System	SOC %
2185	1.1	no	Cont Wheat	1.48
2186	1.1	no	Cont Wheat	1.11
2187	1.1	no	Cont Wheat	0.94
2188	1.1	no	Cont Wheat	0.66
2189	1.1	no	Cont Wheat	0.19
2190	1.1	no	Cont Wheat	0.27
2191	1.1	no	Cont Wheat	1.77
2192	1.1	no	Cont Wheat	1.32
2193	1.1	no	Cont Wheat	1.36
2194	1.1	no	Cont Wheat	1.71
2195	1.1	no	Cont Wheat	0.60
2196	1.1	no	Cont Wheat	0.44
2197	0.8	no	Corn Soy	1.54
2198	0.8	no	Corn Soy	1.49
2199	0.8	no	Corn Soy	1.33
2200	0.8	no	Corn Soy	1.02
2201	0.8	no	Corn Soy	0.50
2202	0.8	no	Corn Soy	0.40
2203	0.8	no	Corn Soy	1.52
2204	0.8	no	Corn Soy	1.32
2205	0.8	no	Corn Soy	1.39
2206	0.8	no	Corn Soy	0.82
2207	0.8	no	Corn Soy	0.59

2208	0.8	no	Corn Soy	0.47
2209	0.8	yes	Corn Soy	1.92
2210	0.8	yes	Corn Soy	1.62
2211	0.8	yes	Corn Soy	1.32
2212	0.8	yes	Corn Soy	0.91
2213	0.8	yes	Corn Soy	0.67
2214	0.8	yes	Corn Soy	0.58
2215	0.8	yes	Corn Soy	1.89
2216	0.8	yes	Corn Soy	1.61
2217	0.8	yes	Corn Soy	1.24
2218	0.8	yes	Corn Soy	1.01
2219	0.8	yes	Corn Soy	0.74
2220	0.8	yes	Corn Soy	0.54
2221	0.8	no	Corn Soy	1.65
2222	0.8	no	Corn Soy	1.27
2223	0.8	no	Corn Soy	1.28
2224	0.8	no	Corn Soy	1.24
2225	0.8	no	Corn Soy	0.94
2226	0.8	no	Corn Soy	1.00
2227	0.8	no	Corn Soy	2.08
2228	0.8	no	Corn Soy	1.40
2229	0.8	no	Corn Soy	1.04
2230	0.8	no	Corn Soy	1.26
2231	0.8	no	Corn Soy	0.92
2232	0.8	no	Corn Soy	1.04
2233	0.8	no	Corn Soy	1.16
2234	0.8	no	Corn Soy	1.01
2235	0.8	no	Corn Soy	0.92
2236	0.8	no	Corn Soy	1.50
2237	0.8	no	Corn Soy	1.82

2238	0.8	no	Corn Soy	0.99
2239	0.8	no	Corn Soy	1.35
2240	0.8	no	Corn Soy	1.15
2241	0.8	no	Corn Soy	0.82
2242	0.8	no	Corn Soy	1.41
2243	0.8	no	Corn Soy	1.07
2244	0.8	no	Corn Soy	0.87
2245	0.7	no	Corn Soy	1.64
2246	0.7	no	Corn Soy	1.36
2247	0.7	no	Corn Soy	1.47
2248	0.7	no	Corn Soy	0.97
2249	0.7	no	Corn Soy	0.64
2250	0.7	no	Corn Soy	0.53
2251	0.7	no	Corn Soy	1.38
2252	0.7	no	Corn Soy	1.30
2253	0.7	no	Corn Soy	1.41
2254	0.7	no	Corn Soy	0.80
2255	0.7	no	Corn Soy	0.79
2256	0.7	no	Corn Soy	0.51
2257	0.7	yes	Corn Soy	2.03
2258	0.7	yes	Corn Soy	1.56
2259	0.7	yes	Corn Soy	1.36
2260	0.7	yes	Corn Soy	0.85
2261	0.7	yes	Corn Soy	0.75
2262	0.7	yes	Corn Soy	0.70
2263	0.7	yes	Corn Soy	2.24
2264	0.7	yes	Corn Soy	1.72
2265	0.7	yes	Corn Soy	1.57
2266	0.7	yes	Corn Soy	1.17
2267	0.7	yes	Corn Soy	0.76

2268	0.7	yes	Corn Soy	0.82
2269	0.7	yes	Corn Soy	1.81
2270	0.7	yes	Corn Soy	1.27
2271	0.7	yes	Corn Soy	1.37
2272	0.7	yes	Corn Soy	1.12
2273	0.7	yes	Corn Soy	0.70
2274	0.7	yes	Corn Soy	0.55
2275	0.7	yes	Corn Soy	1.65
2276	0.7	yes	Corn Soy	1.34
2277	0.7	yes	Corn Soy	1.35
2278	0.7	yes	Corn Soy	0.68
2279	0.7	yes	Corn Soy	0.54
2280	0.7	no	Corn Soy	1.88
2281	0.7	no	Corn Soy	1.44
2282	0.7	no	Corn Soy	1.58
2283	0.7	no	Corn Soy	1.51
2284	0.7	no	Corn Soy	0.81
2285	0.7	no	Corn Soy	1.71
2286	0.7	no	Corn Soy	1.40
2287	0.7	no	Corn Soy	1.47
2288	0.7	no	Corn Soy	0.96
2289	0.7	no	Corn Soy	0.71
2290	0.7	no	Corn Soy	0.57
2291	0.8	no	Perennial	1.60
2292	0.8	no	Perennial	1.30
2293	0.8	no	Perennial	1.11
2294	0.8	no	Perennial	0.62
2295	0.8	no	Perennial	0.38
2296	0.8	no	Perennial	0.31
2297	0.8	no	Perennial	1.60

2298	0.8	no	Perennial	1.31
2299	0.8	no	Perennial	1.45
2300	0.8	no	Perennial	0.90
2301	0.8	no	Perennial	0.55
2302	0.8	no	Perennial	0.42
2303	0.5	no	Corn Soy	1.45
2304	0.5	no	Corn Soy	1.15
2305	0.5	no	Corn Soy	1.08
2306	0.5	no	Corn Soy	1.01
2307	0.5	no	Corn Soy	0.73
2308	0.5	no	Corn Soy	0.68
2309	0.5	no	Corn Soy	2.04
2310	0.5	no	Corn Soy	0.84
2311	0.5	no	Corn Soy	0.66
2312	0.5	no	Corn Soy	0.93
2313	0.5	no	Corn Soy	0.79
2314	0.5	no	Corn Soy	0.59
2315	1.1	no	Cont Wheat	
2316	1.1	no	Cont Wheat	
2317	1.1	no	Cont Wheat	
2318	1.1	no	Cont Wheat	
2319	1.1	no	Cont Wheat	
2320	1.1	no	Cont Wheat	
2321	1.1	no	Cont Wheat	
2322	1.1	no	Cont Wheat	
2323	1.1	no	Cont Wheat	
2324	1.1	no	Cont Wheat	
2325	1.1	no	Cont Wheat	
2326	1.1	no	Cont Wheat	
2327	0	no	Perennial	

2328	0	no	Perennial	
2329	0	no	Perennial	
2330	0	no	Perennial	
2331	0	no	Perennial	
2332	0	no	Perennial	
2333	0	no	Perennial	
2334	0	no	Perennial	
2335	0	no	Perennial	
2336	0	no	Perennial	
2337	0	no	Perennial	
2338	0	no	Perennial	
2339	0	no	Perennial	
2340	0	no	Perennial	
2341	0	no	Perennial	
2342	0	no	Perennial	
2343	0	no	Perennial	
2344	0	no	Perennial	
2345	0	no	Perennial	
2346	0	no	Perennial	
2347	0	no	Perennial	
2348	0	no	Perennial	
2349	0	no	Perennial	
2350	0.7	no	Corn Soy Wheat	
2351	0.7	no	Corn Soy Wheat	
2352	0.7	no	Corn Soy Wheat	
2353	0.7	no	Corn Soy Wheat	
2354	0.7	no	Corn Soy Wheat	
2355	0.7	no	Corn Soy Wheat	
2356	0.7	no	Corn Soy Wheat	
2357	1.1	no	Cont Wheat	

2358	1.1	no	Cont Wheat	
2359	1.1	no	Cont Wheat	
2360	1.1	no	Cont Wheat	
2361	1.1	no	Cont Wheat	
2362	1.1	no	Cont Wheat	
2363	0	no	Perennial	
2364	0	no	Perennial	
2365	0	no	Perennial	
2366	0	no	Perennial	
2367	0	no	Perennial	
2368	1.1	no	Cont Wheat	
2369	1.1	no	Cont Wheat	
2370	1.1	no	Cont Wheat	
2371	1.1	no	Cont Wheat	
2372	1.1	no	Cont Wheat	
2373	0.8	no	Cont Wheat	
2374	0.8	no	Cont Wheat	
2375	0.8	no	Cont Wheat	
2376	0.8	no	Cont Wheat	
2377	0.8	no	Cont Wheat	
2378	0.8	no	Cont Wheat	
2379	1.1	no	Cont Wheat	
2380	1.1	no	Cont Wheat	
2381	1.1	no	Cont Wheat	
2382	1.1	no	Cont Wheat	
2383	1.1	no	Cont Wheat	
2384	1.1	no	Cont Wheat	
2385	1.1	no	Cont Wheat	
2386	1.1	no	Cont Wheat	
2387	1.1	no	Cont Wheat	

2388	1.1	no	Cont Wheat	
2389	1.1	no	Cont Wheat	
2390	1.1	no	Cont Wheat	
2391	1.1	no	Cont Wheat	
2392	1.1	no	Cont Wheat	
2393	1.1	no	Cont Wheat	
2394	1.1	no	Cont Wheat	
2395	1.1	no	Cont Wheat	
2396	1.1	no	Cont Wheat	
2397	1.1	no	Cont Wheat	
2398	1.1	no	Cont Wheat	
2399	1.1	no	Cont Wheat	
2400	1.1	no	Cont Wheat	
2401	1.1	no	Cont Wheat	
2402	1.1	no	Cont Wheat	
2403	0	no	Perennial	
2404	0	no	Perennial	
2405	0	no	Perennial	
2406	0	no	Perennial	
2407	0	no	Perennial	
2408	0	no	Perennial	
2409	1.1	no	Cont Wheat	
2410	1.1	no	Cont Wheat	
2411	1.1	no	Cont Wheat	
2412	1.1	no	Cont Wheat	
2413	1.1	no	Cont Wheat	
2414	1.1	no	Cont Wheat	
2415	1.1	no	Cont Wheat	
2416	1.1	no	Cont Wheat	
2417	1.1	no	Cont Wheat	

2418	1.1	no	Cont Wheat	
2419	1.1	no	Cont Wheat	
2420	1.1	no	Cont Wheat	
2421	1.1	no	Cont Wheat	
2422	1.1	no	Cont Wheat	
2423	1.1	no	Cont Wheat	
2424	1.1	no	Cont Wheat	
2425	1.1	no	Cont Wheat	
2426	1.1	no	Cont Wheat	
2427	1.1	no	Cont Wheat	
2428	1.1	no	Cont Wheat	
2429	1.1	no	Cont Wheat	
2430	1.1	no	Cont Wheat	
2431	1.1	no	Cont Wheat	
2432	1.1	no	Cont Wheat	
2433	1.1	no	Cont Wheat	
2434	1	no	Cont Wheat	
2435	1	no	Cont Wheat	
2436	1	no	Cont Wheat	
2437	1	no	Cont Wheat	
2438	1	no	Cont Wheat	
2439	1	no	Cont Wheat	
2440	1	no	Cont Wheat	
2441	1	no	Cont Wheat	
2442	1	no	Cont Wheat	
2443	1	no	Cont Wheat	
2444	1	no	Cont Wheat	
2445	1	no	Cont Wheat	
2446	1	no	Cont Wheat	
2447	1	no	Cont Wheat	

2448	1	no	Cont Wheat	
2449	1	no	Cont Wheat	
2450	1	no	Cont Wheat	
2451	1	no	Cont Wheat	
2452	1	no	Cont Wheat	
2453	1	no	Cont Wheat	
2454	1	no	Cont Wheat	
2455	1	no	Cont Wheat	
2456	1	no	Cont Wheat	
2457	1	no	Cont Wheat	
2458	0.1	no	Forages	
2459	0.1	no	Forages	
2460	0.1	no	Forages	
2461	0.1	no	Forages	
2462	0.1	no	Forages	
2463	0.1	no	Forages	
2464	0.1	no	Forages	
2465	0.1	no	Forages	
2466	0.1	no	Forages	
2467	0.1	no	Forages	
2468	0.1	no	Forages	
2469	0.1	no	Forages	
2470	0.1	no	Forages	
2471	0	no	Perennial	
2472	0	no	Perennial	
2473	0	no	Perennial	
2474	0	no	Perennial	
2475	0	no	Perennial	
2476	0	no	Perennial	
2477	0	no	Perennial	

2478	0	no	Perennial	
2479	0	no	Perennial	
2480	0	no	Perennial	
2481	0	no	Perennial	
2482	0	no	Perennial	
2483	0	no	Perennial	
2484	1.1	no	Cont Wheat	
2485	1.1	no	Cont Wheat	
2486	1.1	no	Cont Wheat	
2487	1.1	no	Cont Wheat	
2488	1.1	no	Cont Wheat	
2489	1.1	no	Cont Wheat	
2490	1.1	no	Cont Wheat	
2491	1.1	no	Cont Wheat	
2492	1.1	no	Cont Wheat	
2493	1.1	no	Cont Wheat	
2494	1.1	no	Cont Wheat	
2495	1.1	no	Cont Wheat	
2496	1.1	no	Cont Wheat	
2497	1.1	no	Cont Wheat	
2498	1.1	no	Cont Wheat	
2499	1.1	no	Cont Wheat	
2500	1.1	no	Cont Wheat	
2501	1.1	no	Cont Wheat	
2502	1.1	no	Cont Wheat	
2503	1.1	no	Cont Wheat	
2504	1.1	no	Cont Wheat	
2505	1.1	no	Cont Wheat	
2506	1.1	no	Cont Wheat	
2507	1.1	no	Cont Wheat	

2508	1.1	no	Cont Wheat	
2509	1.1	yes	Corn Soy	
2510	1.1	yes	Corn Soy	
2511	1.1	yes	Corn Soy	
2512	1.1	yes	Corn Soy	
2513	1.1	yes	Corn Soy	
2514	1.1	yes	Corn Soy	
2515	1.1	yes	Corn Soy	
2516	1.1	yes	Corn Soy	
2517	1.1	yes	Corn Soy	
2518	1.1	yes	Corn Soy	
2519	1.1	yes	Corn Soy	
2520	1.1	yes	Corn Soy	
2521	1.1	no	Cont Wheat	
2522	1.1	no	Cont Wheat	
2523	1.1	no	Cont Wheat	
2524	1.1	no	Cont Wheat	
2525	1.1	no	Cont Wheat	
2526	1.1	no	Cont Wheat	
2527	1.1	no	Cont Wheat	
2528	1.1	no	Cont Wheat	
2529	1.1	no	Cont Wheat	
2530	1.1	no	Cont Wheat	
2531	1.1	no	Cont Wheat	
2532	1.1	no	Cont Wheat	
2533	1.1	no	Cont Wheat	
2534	1.1	no	Cont Wheat	
2535	1.1	no	Cont Wheat	
2536	1.1	no	Cont Wheat	
2537	1.1	no	Cont Wheat	

2538	1.1	no	Cont Wheat	
2539	1.1	no	Cont Wheat	
2540	1.1	no	Cont Wheat	
2541	1.1	no	Cont Wheat	
2542	1.1	no	Cont Wheat	
2543	1.1	no	Cont Wheat	
2544	1.1	no	Cont Wheat	
2545	1.1	no	Cont Wheat	
2546	1.1	no	Cont Wheat	
2547	1.1	no	Cont Wheat	
2548	1.1	no	Cont Wheat	
2549	1.1	no	Cont Wheat	
2550	1.1	no	Cont Wheat	
2551	1.1	no	Cont Wheat	
2552	1.1	no	Cont Wheat	
2553	1.1	no	Cont Wheat	
2554	1.1	no	Cont Wheat	
2555	1.1	no	Cont Wheat	
2556	1.1	no	Cont Wheat	
2557	1.1	no	Cont Wheat	
2558	1.1	no	Cont Wheat	
2559	1.1	no	Cont Wheat	
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2561	1.1	no	Cont Wheat	
2562	1.1	no	Cont Wheat	
2563	1.1	no	Cont Wheat	
2564	1.1	no	Cont Wheat	
2565	1.1	no	Cont Wheat	
2566	1.1	no	Cont Wheat	
2567	1.1	no	Cont Wheat	

2568	1.1	no	Cont Wheat	
2569	1.1	no	Cont Wheat	
2570	1.1	no	Cont Wheat	
2571	1.1	no	Cont Wheat	
2572	1.1	no	Cont Wheat	
2573	1.1	no	Cont Wheat	
2574	1.1	no	Cont Wheat	
2575	1.1	no	Cont Wheat	
2576	1.1	no	Cont Wheat	
2577	1.1	no	Cont Wheat	
2578	1.1	no	Cont Wheat	
2579	1.1	no	Cont Wheat	
2580	1.1	no	Cont Wheat	
2581	1.1	no	Cont Wheat	
2582	1.1	no	Cont Wheat	
2583	1.1	no	Cont Wheat	
2584	1.1	no	Cont Wheat	
2585	1.1	no	wheat soy	
2586	1.1	no	wheat soy	
2587	1.1	no	wheat soy	
2588	1.1	no	wheat soy	
2589	1.1	no	wheat soy	
2590	1.1	no	wheat soy	
2591	1.1	no	wheat soy	
2592	1.1	no	wheat soy	
2593	1.1	no	wheat soy	
2594	1.1	no	wheat soy	
2595	1.1	no	wheat soy	
2596	1.1	no	wheat soy	
2597	0	no	Perennial	

2598	0	no	Perennial	
2599	0	no	Perennial	
2600	0	no	Perennial	
2601	0	no	Perennial	
2602	0	no	Perennial	
2603	0	no	Perennial	
2604	0	no	Perennial	
2605	0	no	Perennial	
2606	0	no	Perennial	
2607	0	no	Perennial	
2608	0	no	Perennial	
2609	0	no	Perennial	
2610	0	no	Perennial	
2611	0	no	Perennial	
2612	0	no	Perennial	
2613	0	no	Perennial	
2614	0	no	Perennial	
2615	0	no	Perennial	
2616	0	no	Perennial	
2617	0	no	Perennial	
2618	0	no	Perennial	
2619	0	no	Perennial	
2620	0	no	Perennial	
2621	0	no	Perennial	
2622	0.7	yes	Corn Soy Wheat	
2623	0.7	yes	Corn Soy Wheat	
2624	0.7	yes	Corn Soy Wheat	
2625	0.7	yes	Corn Soy Wheat	
2626	0.7	yes	Corn Soy Wheat	
2627	0.7	yes	Corn Soy Wheat	

2628	0.7	yes	Corn Soy Wheat	
2629	0.7	yes	Corn Soy Wheat	
2630	0.7	yes	Corn Soy Wheat	
2631	0.7	yes	Corn Soy Wheat	
2632	0.7	yes	Corn Soy Wheat	
2633	0.7	yes	Corn Soy Wheat	
2634	0.7	yes	Corn Soy Wheat	
2635	0.7	yes	Corn Soy Wheat	
2636	0.7	yes	Corn Soy Wheat	
2637	0.7	yes	Corn Soy Wheat	
2638	0.7	yes	Corn Soy Wheat	
2639	0.7	yes	Corn Soy Wheat	
2640	0.7	yes	Corn Soy Wheat	
2641	0.7	yes	Corn Soy Wheat	
2642	0.7	yes	Corn Soy Wheat	
2643	0.6	yes	Corn Soy Wheat	
2644	0.6	yes	Corn Soy Wheat	
2645	0.6	yes	Corn Soy Wheat	
2646	0.6	yes	Corn Soy Wheat	
2647	0.6	yes	Corn Soy Wheat	
2648	0.6	yes	Corn Soy Wheat	
2649	0.6	yes	Corn Soy Wheat	
2650	0.6	yes	Corn Soy Wheat	
2651	0.6	yes	Corn Soy Wheat	
2652	0.6	yes	Corn Soy Wheat	
2653	0.6	yes	Corn Soy Wheat	
2654	0.6	yes	Corn Soy Wheat	
2655	0.6	yes	Corn Soy Wheat	
2656	0.6	yes	Corn Soy Wheat	
2657	0.6	yes	Corn Soy Wheat	

2658	0.6	yes	Corn Soy Wheat	
2659	0.6	yes	Corn Soy Wheat	
2660	0.6	yes	Corn Soy Wheat	
2661	0.6	yes	Corn Soy Wheat	
2662	0.6	yes	Corn Soy Wheat	
2663	0.6	yes	Corn Soy Wheat	
2664	0.6	yes	Corn Soy Wheat	
2665	0.6	yes	Corn Soy Wheat	
2666	0.5	no	Corn Soy	
2667	0.5	no	Corn Soy	
2668	0.5	no	Corn Soy	
2669	0.5	no	Corn Soy	
2670	0.5	no	Corn Soy	
2671	0.5	no	Corn Soy	
2672	0.5	no	Corn Soy	
2673	0.5	no	Corn Soy	
2674	0.5	no	Corn Soy	
2675	0.5	no	Corn Soy	
2676	0.5	no	Corn Soy	
2677	0.5	yes	Corn Soy	
2678	0.5	yes	Corn Soy	
2679	0.5	yes	Corn Soy	
2680	0.5	yes	Corn Soy	
2681	0.5	yes	Corn Soy	
2682	0.5	yes	Corn Soy	
2683	0.5	yes	Corn Soy	
2684	0.5	yes	Corn Soy	
2685	0.5	yes	Corn Soy	
2686	0.5	yes	Corn Soy	
2687	0.5	yes	Corn Soy	

2688	0.5	yes	Corn Soy	
2689	0	no	wheat soy sorghum	
2690	0	no	wheat soy sorghum	
2691	0	no	wheat soy sorghum	
2692	0	no	wheat soy sorghum	
2693	0	no	wheat soy sorghum	
2694	0	no	wheat soy sorghum	
2695	0	no	wheat soy sorghum	
2696	0	no	wheat soy sorghum	
2697	0	no	wheat soy sorghum	
2698	0	no	wheat soy sorghum	
2699	0	no	wheat soy sorghum	
2700	0	no	wheat soy sorghum	
2701	0	no	wheat soy sorghum	
2702	0	no	wheat soy sorghum	
2703	0	no	wheat soy sorghum	
2704	0	no	wheat soy sorghum	
2705	0	no	wheat soy sorghum	
2706	0	no	wheat soy sorghum	
2707	0	no	wheat soy sorghum	
2708	0	no	wheat soy sorghum	
2709	0	no	wheat soy sorghum	
2710	0	no	wheat soy sorghum	
2711	0	no	wheat soy sorghum	
2712	0	no	wheat soy sorghum	
2713	0	no	wheat soy sorghum	
2714	0	no	wheat soy sorghum	
2715	0	no	wheat soy sorghum	
2716	0	no	wheat soy sorghum	
2717	0	no	wheat soy sorghum	

2718	0	no	wheat soy sorghum	
2719	0	no	wheat soy sorghum	
2720	0	no	wheat soy sorghum	
2721	0	no	wheat soy sorghum	
2722	0	no	wheat soy sorghum	
2723	0	no	wheat soy sorghum	
2724	0	no	wheat soy sorghum	
2725	0	no	wheat soy sorghum	
2726	0	no	wheat soy sorghum	
2727	0.1	no	Forages	
2728	0.1	no	Forages	
2729	0.1	no	Forages	
2730	0.1	no	Forages	
2731	0.1	no	Forages	
2732	0.1	no	Forages	
2733	0.1	no	Forages	
2734	0.1	no	Forages	
2735	0.1	no	Forages	
2736	0.1	no	Forages	
2737	0.1	no	Forages	
2738	0.1	no	Forages	
2739	1	no	Cont Wheat	
2740	1	no	Cont Wheat	
2741	1	no	Cont Wheat	
2742	1	no	Cont Wheat	
2743	1	no	Cont Wheat	
2744	1	no	Cont Wheat	
2745	1	no	Cont Wheat	
2746	1	no	Cont Wheat	
2747	1	no	Cont Wheat	

2748	1	no	Cont Wheat	
2749	1	no	Cont Wheat	
2750	0.8	no	Corn Soy Wheat	
2751	0.8	no	Corn Soy Wheat	
2752	0.8	no	Corn Soy Wheat	
2753	0.8	no	Corn Soy Wheat	
2754	0.8	no	Corn Soy Wheat	
2755	0.8	no	Corn Soy Wheat	
2756	0.8	no	Corn Soy Wheat	
2757	0.8	no	Corn Soy Wheat	
2758	0.8	no	Corn Soy Wheat	
2759	0.8	no	Corn Soy Wheat	
2760	0.8	no	Corn Soy Wheat	
2761	0.8	no	Corn Soy Wheat	
2762	0.8	no	Corn Soy Wheat	
2763	0.8	no	Corn Soy Wheat	
2764	0.8	no	Corn Soy Wheat	
2765	0.8	no	Corn Soy Wheat	
2766	0.8	no	Corn Soy Wheat	
2767	0.8	no	Corn Soy Wheat	
2768	0.8	no	Corn Soy Wheat	
2769	0.8	no	Corn Soy Wheat	
2770	0.7	yes	Corn Soy	
2771	0.5	yes	Corn Soy	
2772	0.5	yes	Corn Soy	
2773	0.5	yes	Corn Soy	
2774	0.5	yes	Corn Soy	
2775	0.5	yes	Corn Soy	
2776	0.5	yes	Corn Soy	
2777	0.5	yes	Corn Soy	

2778	0.5	yes	Corn Soy	
2779	0.5	yes	Corn Soy	
2780	0.5	yes	Corn Soy	
2781	0.5	yes	Corn Soy	
2782	0.5	yes	Corn Soy	