The effect of cover crops and P management strategies on soil physical properties and soil organic carbon

by

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Abstract

Cover crops and no-till have been demonstrated to improve soil physical properties and soil organic carbon. However, there has been less research on phosphorus fertilizer timing and placement effects on soil physical properties and soil organic carbon. The Kansas Agricultural Watershed (KAW) field laboratory near Manhattan, Kansas was established in 2014. The soil at the site is mapped as a Smolan silty clay loam with 6-8% slope. The experiment was a 2 × 3 factorial design with two cover crop treatments (cover and no cover) and three phosphorus fertilizer treatments (none, spring injected P, and fall broadcast P). The field lab contains 18 plots about 0.49 hectares each, each containing 3 subplots sampled. It has been hypothesized that cover crops will enhance soil physical properties (increase water stable aggregates, and decrease bulk density), increase soil organic carbon, and assist in the uptake of phosphorus fertilizer. Water stable aggregate samples were collected for the 0 to 5 and 5 to 10 cm depths in 2017, 2018, 2019, and 2022. Bulk density and total carbon were sampled at 0 to 5 cm and 5 to 10 cm in the spring of 2022. Aggregate data showed an overall trend of cover crops increasing aggregation compared to no cover treatments. The size fractions between each year increase in size over time. Bulk density was found to be around 1.1 g cm^{-3} at the surface depth, while the subsurface depth is denser, approximately 1.3 g cm^{-3}, which is less than 1.55 g cm^{-3}, a density that is considered root-restrictive for silty clay loam soil textures. Total carbon results differed with cover crop management, however, there were no differences when converted to a mass per unit area basis (Mg ha^{-1}). Since the site has a pronounced slope, we also tested if the soil texture differed across the slope. Although there were points on the landscape where the clay content differed by ±15%, this difference did not have an impact on any of the variables measured for our treatments. The P management strategies had no effects on the physical soil properties; thus, we conclude that cover cropping is the main factor responsible for enhancing soil physical properties at the KAW field laboratory.

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Chapter 1 - Review of Relevant Literature

Soil Physical Properties

Aggregate stability is an important indicator of soil health (Bissonnais, 1996, Van Eerd et al., 2018) and creates a soil's structure. Soil aggregation is when primary soil particles are bound together stronger than other surrounding soil particles to create a structural unit and are classified into macroaggregates (>250 µm) or microaggregates (<250 µm) (Hartmann & Six, 2022; Kemper & Rosenau, 1986; Totsche et al., 2017; USDA Natural Resources Conservation Service, 1996). Aggregate stability is the ability of a soil aggregate to resist breakdown by outside forces (Kemper & Rosenau, 1986; USDA Natural Resources Conservation Service, 1996).

The formation of aggregates can be influenced by many factors, these can be from external forces, or internal factors (Amézketa, 1999). The internal factors that influence the formation of soil aggregates are the amount of above and below ground biomass, organic matter, the clay content, clay mineralogy, soil texture, and if there are carbonates present in the soil (Chaplot & Cooper, 2015; Hartmann & Six, 2022; USDA Natural Resources Conservation Service, 1996; Van Eerd et al., 2018; Bronick & Lal, 2004). External factors include drying and wetting cycles (Wagner et al., 2007), freeze-thaw cycles (Hartmann and Six, 2022; Six et al., 2004), soil temperature (Amézketa, 1999; Nimmo & Perkins, 2002) and the climate (Amézketa, 1999; Hartmann & Six, 2022). Other external factors that influence the formation of aggregates are management practices. These management practices include tillage (Amézketa, 1999, Mikha & Rice, 2004), manure and compost applications (Amézketa, 1999; Mikha & Rice, 2004), and crop rotations (Amézketa, 1999; Bronick & Lal, 2004).

Bulk density is an indicator of soil quality and an indicator of soil compaction (Blanco-Canqui et al., 2015; Haruna et al., 2020; NRCS, 2019; Rabot et al., 2018; USDA Natural Resources Conservation Service, 2008). This measure of soil quality also shows the soil's function of structural support, root growth, water movement and aeration (USDA Natural Resources Conservation Service, 2008). Bulk density is calculated as the ratio of the mass of dry solids to the bulk volume of the soil (Blake & Hartge, 1986). Bulk density is influenced by natural and human factors. Natural factors include soil texture (Haruna et al., 2020; NRCS, 2019; USDA Natural Resources Conservation Service, 2008), soil organic matter (Blanco-Canqui et al., 2015; NRCS, 2019; USDA Natural Resources Conservation Service, 2008), soil mineralogy (Haruna et al., 2020), and the arrangement of soil particles in the soil (NRCS, 2019; USDA Natural Resources Conservation Service, 2008). Human activities that govern bulk density are crop and land management (Haruna et al., 2020; USDA Natural Resources Conservation Service, 2008), which include: cultivation, implementation of cover crops, organic matter input (NRCS, 2019; USDA Natural Resources Conservation Service, 2008) and equipment traffic on wet soil (USDA Natural Resources Conservation Service, 2008). Practices that improve soil structure generally decrease bulk density (USDA Natural Resources Conservation Service, 2008). A high bulk density indicates a low porosity and a higher amount of soil compaction (NRCS, 2019; USDA Natural Resources Conservation Service, 2008), the reverse is that a lower bulk density value represents a low amount of compaction and high porosity.

Water Stable Aggregates

Blanco-Canqui et al. (2011) conducted a long-term study in Hesston, KS that evaluated the effects of cover crops on soil physical properties under a no-till system on a Geary silt loam (fine-silty, mixed, superactive, mesic Udic Argiustoll). They used three cover crops (sunn hemp

(*Crotalaria juncea* L.*)* (SH), hairy vetch (*Vicia villosa* Roth*)* (HV), late maturing soybeans (*Glycine max* L.) (LMS), and no cover crop) and different nitrogen (N) rates over the 16 years for a combination of 12 treatments. They found that under cover crops surface macroaggregates increased while microaggregates decreased, which suggests that cover crops added to a no-till system can improve soil structure and potentially reduce erosion. The cover crops were also found to decrease Proctor maximum compactibility and increase wet aggregate stability and soil organic carbon (SOC) concentrations compared with the no cover crop plots (Blanco-Canqui et al., 2011).

Davis et al. (2022) conducted a study at two research sites in Kansas over three years examined the impact of conservation systems on soil properties. They looked at eight treatments, one with tillage twice a year with no cover crops, and the other seven being tillage once a year with cover crops on two different soil types: a Kennebec silt loam soil (fine-silty, mixed superactive, mesic Cumulic Hapludoll) and a Canadian-Waldeck find sandy loam soil (coarse-loamy, mixed, superactive, thermic Fluvaquentic Haplustoll). Between the two locations of this study, they found that under cover crops there were more aggregates in the >4.75 mm size class. The control treatment was found to have more aggregates in the 1-2 mm, 0.5-1 mm, 0.25-0.5 mm and <0.25 mm size class at both locations. Overall water stable aggregates were found to be improved after adding cover crops and reduced tillage to a pumpkin (*Cucurbita pepo* L.) patch in just two years.

Simon et al. (2022) evaluated the effect of long-term cover crop management on soil physical properties in Garden City, KS on a Ulysses silt loam (fine-silty, mixed, superactive, mesic Torriorthentic Haplustolls). This study was conducted using a winter wheat *(Triticum aestivum* L.)-fallow rotation, then modified to a three-year no-till winter wheat-grain sorghum

(Sorghum bicolor L.)-fallow cropping system to replicate practices done by producers in the area. They found that in 2018 mean weight diameter was greater under cover crops but not significantly different from fallow, but there were differences in aggregate size fractions. In 2019 they observed differences in mean weight diameter of water stable aggregates, mean weight diameter for dry aggregates, and wind erodible fraction indicating that the long-term management of cover crops have a long-term effect on soil physical properties.

Bulk Density

Bagnall et al. (2022) conducted a study examining differences of soil hydraulic functions depending on tillage, cover crops, organic nutrient sources, cash crop count, residue retention, and rotation diversity from many different sites across Canada, Mexico, and the United States, with soils of these studies being located in Utisols, Alfisols, Mollisols, Vertisols, Aridisols, Inceptisols, and Entisols. They sampled bulk density using rings 7.65 cm in diameter and 0 to 7.65 cm deep. This study found that bulk density is not a direct function of soil hydraulic functions and decreased with reductions in tillage. The authors also found that bulk density responded to multiple management practices, which makes it an appropriate measure for soil health.

Lazicki et al. (2021) conducted a study in northern California that analyzed the sensitivity of soil health indicators in two different systems, organic and conventional on two different soil types: a Rincon silty clay loam soil (fine, smectitic, thermic Mollic Haploxeralfs) and a Yolo silt loam (fine-silty, mixed, superactive, nonacid, thermic Mollic Xerofluvents). The conventional management treatments consisted of synthetic fertilizer and winter fallow, and the organic management treatments consisted of composted poultry manure and a winter legume cover crop. The rotation and management practice implemented were designed to reflect local practices.

They found that the bulk density did not significantly differ between the two treatments. Bulk density samples were taken only from the surface layer (0 to 15 cm) and the lack of difference between the two systems indicates that surface compaction is similar between the two treatments.

Villamil et al. (2006) evaluated bulk density in a no-till corn *(Zea mays* L.)/soybean system in Urbana, IL on a Flanagan silt loam (fine, smectitic, mesic, Aquic Argiudoll). The three combinations of cover crops used were rye *(Secale cereale*), hairy vetch, and a combination of rye and vetch drilled into soybean stubble. Results found consisted of bulk density increasing with depth in all cover crop treatments. They found that the drop in bulk density with the use of a winter cover crop is due to the extra amount of residue in the soils compared to winter fallow periods. Winter cover crops decreased bulk density which increases soil porosity. This study observed that the winter cover crops reduced bulk density due to the increased residue.

Soil Organic Carbon

Soil organic carbon is an important part of agroecosystem sustainability (Tautges et al., 2019). It influences soil structure, nutrient cycling, and microbial activity (Tautges et al., 2019) and is formed from the decomposition of organic matter (Cotrufo et al., 2015). Increasing SOC enhances soil physical, chemical, and biological properties of a soil (Blanco-Canqui et al., 2013), and increases water holding capacity, reduces the risk of erosion, and increases nutrient retainment in soils (Buck & Palumbo-Compton, 2022). Added SOC can reduce contaminant uptake in crops (Lehmann & Kleber, 2015). The amount of SOC that can be sequestered depends on management, soil type, precipitation, irrigation, soil temperature regime, soil moisture regime, drainage and among other factors. Management systems which increase SOC sequestration add biomass to the soil, cause minimal disturbance, conserve water, and improve soil structure (Lal, 2004). The ability of these practices to be successful depends on the soil texture (Haruna et al., 2020; Lal, 2004) crop production (McVay et al., 2006; Stewart et al., 2007) organic matter additions, tillage, fertilizer, and irrigation (Stewart et al., 2007).

Tautges et al. (2019) examined the effect of two different management strategies on soil carbon sequestration in surface and subsurface soils in California's Central Valley near the University of California, Davis. This was conducted on two soil types: a Rincon silty clay loam soil (fine, smectitic, thermic Mollic Haploxeralfs) and a Yolo silt loam (fine-silty, mixed, superactive, nonacid, thermic Mollic Xerofluvents). The two practices studied at this location included: a conventional maize system with tomatoes *(Solanum lycopersicum* L.), synthetic fertilizer, pesticides, and a winter fallow; certified organic maize system with tomatoes, composted poultry manure and a winter cover crop; and a mixture of the two with synthetic fertilizer, pesticides, and a winter cover crop. They found that the organic treatments had the highest amount of aboveground C input, where the hybrid system had lower C inputs but had more C inputs compared to the conventional system. The SOC levels were found to greatly increase in the organic system in the surface layer (0 to 15 cm) and throughout the soil profile.

Simon et al. (2022) conducted a long-term cover crop study in Garden City, KS that evaluated the effect of cover crops on SOC on a silt loam Luvisol. The authors used a winter wheat-fallow rotation and a three-year no-till winter wheat-grain sorghum-fallow cropping system to assess the SOC content in the soil. They found that in 2012 SOC was not significantly different between CC treatments. In 2018 and 2019 CC treatments were not greater than the fallow treatment but increased from winter wheat-fallow system to a winter wheat-grain sorghum-fallow system. Some treatments used in this study were also hayed, and some were not. It was observed that SOC did not differ between hayed treatments and standing CCs. The authors found that the residue input left from the cover crops significantly contributed to the amount of SOC in the soil.

Clay Content

Soils are made up of a mixture of three soil particle sizes (sand, silt and clay), inorganic matter, organic matter and other materials. Clay is fine-textured and is made up of particles that are less than 0.002 mm in diameter (Tucker, 1999). Out of the three soil particles clay is the most reactive due to its specific surface area, and surfaces charges, which enhance interactions between ions, mineral particles, and organic matter (Fernández-Ugalde et al., 2013). Clay particles are important because they play a vital role in nutrient and water content by influencing a soils cation exchange capacity, water-holding capacity, buffering capacity, provides elasticity, reduces leaching, and acts as a binding agent between soil particles (Tucker, 1999). Clay particles dictate soil texture. Clay content in soils is a strong driver of carbon and aggregate properties (Büchi et al., 2022). It acts as a binding agent for soil particles, creating aggregates in the soil (Amézketa, 1999; Besalatpour et al., 2013; Bronick & Lal, 2004; Fernández-Ugalde et al., 2013; Hartmann & Six, 2022; Tisdall & Oades, 1982; Tucker, 1999). Higher clay content in a soil has been shown to increase aggregation (Amézketa, 1999; Hartmann & Six, 2022; Ozlu & Arriaga, 2021). The amount of clay in a soil influences the amount of SOC in the soil (Blanco-Canqui et al., 2013; Haruna et al., 2020).

Fernández-Ugalde et al. (2013) conducted a study in conducted at an agricultural research site in France in 2013 and aimed to determine if clay mineralogy is different in the aggregate-size classes. The particle size distribution was compared between two treatments: a grassland system and an organic cropping system. Their results showed that the aggregate-size distribution was not influenced by clay content in the two different management systems, but the distribution of the clay fraction was different between the organic cropping system and the grassland system. The authors found that the clay fraction was biggest in macroaggregates in the grassland system samples and the clay fraction was biggest in the microaggregates in the organic cropping system samples. Overall, Fernández-Ugalde et al. (2013) found that the subtle differences in clay mineralogy can influence the formation of soil structure, and that clay minerals have different efficiencies for aggregation

Wagner et al. (2007) conducted a study in southeastern Australia to observe clay content influences on soil aggregate formation. To carry out this study the authors collected soil samples that consisted of Delvawood clay, and then brought them back to the laboratory to create controlled wet-dry cycles after creating four mixtures with grey bentonite clay and quartz sand and various amounts of straw. They found that aggregate size increases with clay content, and that stable aggregates occurred with clay-rich soils compared to sandier soils. They also found that the mean weight diameter of clay soils increased after six wet-dry cycles. Overall, repeated wetting and drying of a soil reduces the ability of aggregates to resist the forces imposed by wetting but a higher clay content can resist wetting compared to lower clay.

A study performed in Alabama analyzed the clay mineralogy and dispersibility of soils in long-term conservation vs. tillage management system. The four treatments included in this study were no-till without a cover crop, no-till with a cereal rye cover crop, no-till with a cereal rye cover crop and subsoiling, and conventional tillage management on a fine, kaolinitic, thermic Rhodic Paleudult. They found that the conventional tillage system had a higher amount of clay in the soil compared to the no-till system. The authors state that their data shows that the water dispersible clay was related to the percentage of water stable aggregates in a soil (Shaw et al., 2003). The study also concluded that there is a clear relationship between clay dispersibility and aggregation.

Objectives and Hypotheses

There are missing pieces of information from all of the studies currently done: how does cover crops and P management strategies affect soil physical properties and SOC? This study evaluates how soil physical properties are impacted and how SOC is impacted. Clay content is also an important part of our soils. We look at how important clay is in soil physical properties and soil organic matter as well.

There are five objectives in this study: 1) determine if phosphorus management strategies impact soil physical properties and SOC; 2) determine cover crop impacts on near-surface aggregate stability for the depths 0 to 5 and 5 to 10 cm; 3) determine cover crop impacts on bulk density for the 0 to 5 cm and 5 to 10 cm depths; 4) determine clay content impacts on soil physical properties; 5) determine differences in SOC content in cover and no cover plots. Our first null hypothesis in this study is that there will be no effect of phosphorus management strategies on soil physical properties and soil organic matter. The second and third hypotheses are that cover crop plots will have higher aggregation and a lower bulk density, respectively. The fourth hypothesis is that clay content will increase aggregate stability and increase bulk density. Soil organic carbon content will increase for cover crop plots compared to treatments without cover crops is the fifth hypothesis in this study.

Chapter 2 - Methods and Materials

Description of sites and management

This field study took place at the Kansas Agricultural Watershed (KAW) field laboratory, located near Manhattan, Kansas (39°07'46.5"N 96°38'45.0"W). The KAW was established in 2014 as a no-till corn and soybean rotation. The site is an upland terraced agricultural field with 18 watershed units, each being approximately 0.4 ha (Figure 1). The soil type is mapped as Smolan silty clay loam (fine, smectitic, mesic Pachic Argiustoll), with an average of 29.8% clay, 56.3% silt, and 13.9% sand in the surface depth, and a slope of 6 to 8%.

The study evaluates the effects of six treatments. These treatments were structured in a 2 × 3 factorial, randomized complete block design. From 2014-2019 there were two cover crop treatments: cover crop (CC) and no cover crop (NC). The cover crops used between 2014 and 2019 were combinations of winter wheat *(Triticum aestivum*), rapeseed *(Brassica napus*), and triticale *(× Triticosecale*). In the same five-year block, there were three phosphorus (P) treatments: no P control (NP), fall broadcast (FB, 61 kg P_2O_5 ha^{-1}), and spring subsurface injection (SI, 61 kg P_2O_5 ha^{-1}). Each combination of P treatment and cover crop treatment was replicated three times in a randomized complete block design. In 2020 the site management changed to include two different P management strategies and change the type of CC grown. The cover crop changed to be only cereal rye *(Secale cereale*) and the three P treatments were: no P control (NP), build and maintain (BAM, 21.8 kg P_2O_5 ha^{-1}), and sufficiency (SUF, 0 kg P_2O_5 ha^{-1}). The plots with NP from the first study remained NP for the second phase, the plots with SI from the first phase were BAM in the second phase, and the plots with FB in the first phase were SUF in the second phase. The BAM strategy builds P in the soil to a specific level over an extended. Once the desired level is reached, the P is monitored to stay at that level, and fertilizer is added when needed. The SUF management strategy is adding enough fertilizer to the soil to maximize yield of that given year. The amount of fertilizer added to the soil is dependent upon a soil test. Phosphorus fertilizer was not added to the SUF treatments in 2020, 2021, or 2022.

Soil samples were taken in the field laboratory at three georeferenced positions in each plot after cover crops were terminated, but before the cash crop was planted in the spring. Care was taken to ensure the samples were not pulled from visible wheel tracks, not in the row but near them, at approximately 10 cm from the row.

Soil Physical Properties

Water Stable Aggregates

Water stable aggregate (WSA) soil samples were collected in the spring of 2017, 2018, 2019, and 2022. Approximately 2 kg of soil was collected with a flat shovel at three georeferenced points within each plot. The sample was separated into 0 to 5 cm and 5 to 10 cm depths. Samples were then placed in a breathable cloth bag and allowed to air-dry before being sieved into aggregates ≥ 4.75 and < 8 mm in size. Gravimetric water content was measured by taking a 40 g sample and drying it at 105°C for 48 hours. Aggregate samples were processed to find water-stable aggregates according to the Kemper & Rosenau (1986) wet method which 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 five sieves that were 127 mm in diameter and 40 mm deep with the following screen openings: 4.75 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm (Newark Wire Cloth Company, Clifton, NJ).

A 50 g sample of air-dried aggregates was placed on the top sieve (4.75 mm) and saturated with water for 10 minutes. After the allotted time, the sieves were mechanically oscillated at 30 cycle min^{-1} for another ten minutes. Following oscillation, the sieves are placed on an aluminum dish, and dried at 105°C for 48 hours. To find the sand and coarse fragment corrections, the oven-dried samples are placed in a 13.9 g L^{-1} sodium hexametaphosphate solution for 24 hours to assist in the separation of soil particles and coarse fragments. After this time frame, the samples are then rinsed to ensure that the coarse fragments and sand particles are separated from the clay particles, then dried for another 24 hours. The particles in each sieve are then weighed to find the coarse fragment corrections.

Total aggregation is found through the sum of aggregates retained on the five sieves after oscillation and drying.

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

$$MWD = \sum (I=1, \text{ to } 6)\ (w_i / m_a)\ x_i$$

where w_i represents the dry mass of aggregates (w_1 through w_5) determined for each of the five sieve sizes (aggregates and fragments after sieving [mm] minus fragments on the same sieve after dispersion [m_f]) and dry mass (w_6) of material passing through the sieve with 0.21-mm openings during sieving (Kemper and Rosenau, 1986), x_i represents mean diameter of each of the six size fractions (size of smallest fraction [x_6] was calculated as 0.21 mm/2), and m_a is total dry mass of aggregates (sum of w_1 through w_6). The MWD is a calculation that shows an estimate of the average size of all the soil aggregates (van Bavel, 1950) and is easy for most individuals to understand (Kemper & Rosenau, 1986).

Bulk Density

Bulk density samples were taken in the spring of 2022 at 0 to 5 cm and 5 to 10 cm depths at the same three georeferenced points in each plot. We used the core method from Blake & Hartge (1986). The rings were pushed into the soil surface with the help of a sledgehammer and wooden block and then placed into an autoclaveable plastic bag to be dried at 105°C for 48 hours. Once the allotted time was done, bulk density was calculated as shown:

$$\rho_b = W_{ods}/V_s$$

Where ρ_b is the dry bulk density (g cm^{-3}), W_{ods} is the weight of oven-dry soil (g), and V_s is the total volume of soil (cm^3).

Soil Organic Carbon

Total carbon (TC) was sampled in the spring of 2022 at the 0 to 5 cm and 5 to 10 cm depth. Twelve cores were pulled around each of the three georeferenced points in each plot. The samples were air-dried, and ground then given to Kansas State University Soil Testing Laboratory to analyze with a LECO CN 828 (LECO Corporation, St. Joseph, MI) to analyze these samples with methods from LECO Corp. (2006) to determine the total carbon content. Since the samples contained no calcium carbonate for the 0 to 5 and 5 to 10 cm depth intervals, TC equals SOC for these depths.

To calculate the SOC (Mg ha^{-1}) from SOC percentage we used the following equation:

SOC * Bulk Density * Depth = SOC stocks

Clay Content

Soil samples were taken in 2017 at each of the three points within each plot at the 0 to 5 cm depth. Particle size distribution was determined using the pipet method of Kilmer & Alexander (1949) and method 3A1 from the Soil Survey Laboratory Staff (1996).

Statistical Analysis

The data was analyzed by year and by depth, rather than across years and depths in SAS (version 9.4; Cary, NC). We left the P treatment in the analysis of variance by year in order to get a p-value by year.

A correlation between SOC, and clay, MWD, TA, 4.75 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm aggregate size fractions was done to observe if there is a positive or negative correlation between the measurements.

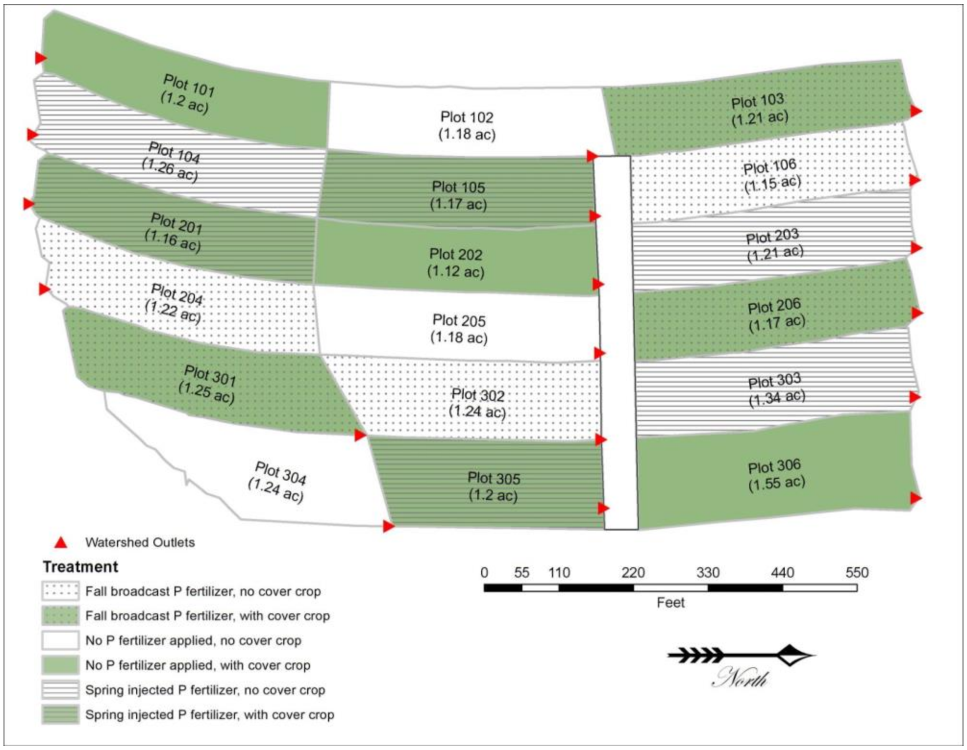


Figure 1. Map of KAW field laboratory with cover crop and P management.

Chapter 3 - Results and Discussion

The P fertilizer treatments were found to not be significant as a main effect in any year but one which will be discussed later. There are a few instances where there was a significant P fertilizer by cover crop treatment interaction and that will be discussed in this chapter. The results discussed are of the cover main effect on MWD, TA, and the five aggregate sizes. Total aggregation, MWD and each of the size fractions were evaluated in SAS using the percentage of sand free water stable aggregates. The results are presented in percentages.

All p-values can be found in Table 1 for the 0 to 5 cm sampling depth and Table 2 for the 5 to 10 cm sampling depth.

Soil Physical Properties

Water Stable Aggregates

Mean Weight Diameter

Mean weight diameter in 2017, 2018, 2019 and 2022 all had a significant effect of cover compared to no cover crop plots in the surface depth (0 to 5 cm) (Figure 2). In 2017 at the 0 to 5 cm depth the CC treatment was greater than the NC treatment with a difference in means of approximately 0.4 mm. The difference between means in the cover treatments in 2018 was approximately 1.2 mm ($p=<0.0001$). In 2019 there was a significant difference between means of approximately 0.5 mm. The 0 to 5 cm depth in 2022 had a difference in means of approximately 1.6 mm. The MWD results for the subsurface depth (5 to 10 cm) showed the same results: every year analyzed had a significant effect of cover (Figure 3), with 2017 having a difference in means of approximately 0.5 mm, 2018 having a difference in means of approximately 1.5 mm, 2019 having a difference in means of approximately 0.4 mm and 2022 having a difference in means of approximately 1 mm. The consistent effect of cover on MWD shows the average aggregate size increased under cover crops compared to plots without cover crops. This result would be expected since the CC plots would have more protection from the left-over crop residue and cover crop biomass and roots compared to the no cover plots that would only have crop residue left on the surface.

The CC biomass estimation during the winter months was 1,823 kg ha^{-1} in total in 2017 (Table 5) and the average residue in 2017 after a corn crop was 6,755 kg ha^{-1} (Table 5), showing that there was plenty of residue on the surface to provide protection. The greater effect of cover seen in 2018 and 2022 compared to 2017 and 2019 is attributed to both the CC above ground and below ground biomass and previous crop residue. The seasons of 2018 and 2022 were after corn which produces more crop residue compared to 2017 and 2019 which was after soybeans, which produces considerably less residue which can be seen in Table 5 and the results of this study. Reasons for MWD to also be less in 2017 and 2019 besides residue amounts was that 2017 was a dry year with poor corn yield and growth, and 2019 being a wet year. The 2022 growing season was the greatest yielding corn crop and likely had the greatest residue cover and most root biomass. Overall, MWD was significantly impacted by cover crops. Aggregation increases after multiple wet-dry cycles, and with the more cycles, more aggregation with larger aggregates forming. Wagner et al. (2007) found that MWD in clay soils has increased after multiple wet-dry cycles. Mean Weight Diameter shows the average size of aggregates in a sample, the higher the number, the bigger the aggregates. Mean weight diameter has been found to increase under cover crops over multiple years, indicating that long-term management of cover crops has a long-term effect on soil physical properties (Simon et al., 2022). Multiple other studies have found that cover crops have increased the MWD of soils (Blanco-Canqui, et al., 2011; Blanco-Canqui & Ruis, 2020; Davis, et al., 2022).

Total Aggregation

Total aggregation had a significant effect of cover in the 0 to 5 cm depth three out of the four years (Figure 4). The years sampled that did have a significant effect were 2018 with a difference between treatments of 5.3%, 2019 with a difference in means of approximately 13%, and the year 2022 with a difference in means of approximately 14.5%. The only year that did not have a significant effect of cover was 2017, which was a dry year with poor previous crop growth. In the 5 to 10 cm depth only two of the four years had a significant effect of cover (Figure 5). The two years that were not significant were 2017 and 2019. Where 2017 had a difference between means of 5.3% and 2019 had a difference between means of 14%. The two years that did have a significant effect were 2018 with a difference in means of approximately 11.3%. The other year that was significant was 2022 with a difference in means of approximately 10%. Like the results of MWD, 2017 and 2019 had less of an effect of cover than 2018 and 2022 due to cover crop above and below ground biomass and previous crop residue left on the field. The years following soybeans (2017 and 2019) have less crop residue left on the field to protect the soil from disruptions compared to years following corn (2018 and 2022). The soil texture measured for this study site contained an average of 29% clay and 56% silt, which would allow the soil particles to have more surface area to bind with each other. It is shown that stable aggregates can be found in clay-rich soils (Wagner et al, 2007). Other factors that influence aggregation are the soil texture, organic matter, among others (Chaplot & Cooper, 2015; Hartman & Six, 2022; USDA Natural Resources Conservation Service, 1996; Van Eerd et al, 2018; Bronick & Lal, 2004). Overall, aggregation increased with increasing amounts of CC biomass and previous crop residue. The results of 2022 had a larger effect of cover compared to other years analyzed, thus, changes from cover crops and no-tillage practices might not immediately take place (Davis et al, 2022) since aggregation improves over time (Six et al, 2004). The combined effects of CC and soil texture boost aggregation, and the result of this can be seen in our study. Davis et al. (2022) and Blanco-Canqui & Ruis (2020) found that CC has increased aggregation of soils compared to soils without cover crops. Davis et al. (2022) found that total aggregation was increased by approximately 10% under cover crops, while Blanco-Canqui & Ruis (2020) found aggregation increased by 0.5-22% in a metanalysis of multiple studies.

An interaction of cover by fertilizer was found in the 5 to 10 cm depth for TA in 2018 (Figure 6). The result of this interaction shows that the treatments CC-NP and CC-FB are statistically different from NC-NP with a difference in means of about 22%. This difference between treatments would be expected due to the NP treatments not having fertilizer added to the plots, which would cause the crops to not grow as abundantly as they would if the plots had received the fertilizer. As time goes on, the plots with no fertilizer added will have less amount of P in the soil compared to the other treatments, and we might expect to see a difference between treatments over time.

Aggregate Size Fractions

The previously discussed MWD, and TA are metrics for comparing aggregation, and all are calculated from the aggregate size fraction data. We can take a more detailed look at the aggregate size fraction data by year and depth, and for each individual fraction that was measured as large aggregation increases, we expect to see less of the small aggregates. In 2017 the significant cover effect is similar between aggregate fractions in both depths. In the surface depth, the only aggregate size that has a significant effect of cover is the 4.75 mm size where CC is greater than NC by approximately 6.47 mm (Figure 7). In the subsurface depth the only aggregate size which had a significant effect of cover was 4.75 mm (p=0.0332) (Figure 8). These results show that bigger aggregates are formed under cover crops. This experiment had been ongoing for four years when these samples were taken, which would have given the soil some time for aggregates to form due to the presence of more surface residue during winter as well as continuous living root in the cover crop plots, meaning that CC plots will have bigger sized aggregates, while the NC plots have less big aggregates, and more small aggregates, as seen in the 0.25 mm fraction. Since the experiment site would have been considered somewhat new, it would make sense that the other aggregate sizes would not show a difference between treatments at this time since time influences aggregate stability (Amézketa, 1999). The previous crop in 2017 was corn, and the average biomass was 6,755 kg ha^{-1}. Though this year had less precipitation and slightly higher temperatures that suggest there was a greater water and heat stress (Nelson et al., 2022) the effect of cover significantly affected the aggregate sizes.

The year 2017 also had a significant effect of fertilizer (p=0.0448) found in the 0.25 mm size fraction (Figure 9). The results of this effect show that the SI treatment is statistically greater than the other treatments: FB and NP. This difference makes sense since the fertilizer is placed in the soil in the SI treatment and not on the surface like the FB treatment where it is susceptible to the environment. Since this is the only main effect of fertilizer that is found this could be considered to be a Type I effect. The interaction of cover by fertilizer was found in the 2 mm size fraction (Figure 10) and the 0.25 mm size (Figure 11) in the 0 to 5 depth. The treatments CC-SI, NC-NP, and NC-FB are significantly different from treatment NC-SI for the effect in the 2 mm fraction. This result is unexpected since the treatment NC-NP would be expected to have a lower effect of fertilizer than the NC-SI treatment. The interaction in the 0.25 mm fraction has a result that would have been expected when compared to the interaction of the 2 mm fraction where they were not. The result shows that the treatment NC-SI is statistically greater compared to all other treatments. This treatment could be expected to be greater than the others since it has a fertilizer treatment that is placed directly into the soil but a treatment with CC and a P treatment would have been more expected having the greatest effect of the treatments.

In 2018 the significant cover affected different aggregate fractions in the 0 to 5 cm depth and the 5 to 10 cm depth. The aggregate fractions that have a significant effect of cover in the 0 to 5 cm depth is 4.75 mm, 0.5 mm, and 0.25 mm and the fractions 2 mm and 1 mm have no effect of cover (Figure 12). The 4.75 mm fraction shows that CC is greater than NC by a means of approximately 19.5 mm. The 0.5 mm fraction shows that NC is greater than CC by a means of approximately 1.8 mm. The 0.25 mm fraction shows similar results to the 0.5 mm fraction, where NC is greater than CC by approximately 3 mm. This is encouraging to see; the residue of the CC protects the macroaggregates, as macroaggregates are less stable compared to microaggregates (Amézketa, 1999; Totsche, et al., 2017). The aggregate fractions that have a significant effect of cover in the 5 to 10 cm depth is 4.75 mm, 1 mm, 0.5 mm, and 0.25 mm, leaving the 2 mm fraction to not have a significant effect of cover (Figure 13). The 4.75 mm fraction shows that CC is greater than NC by a means of approximately 25.2 mm. The fractions 1 mm, 0.5 mm and 0.25 mm all show that NC is greater than CC by a means of 3.8 mm, 5.2 mm, and 5.6 mm respectively. Just like in the 0 to 5 cm depth the CCs cover and protect the soil and the larger sized aggregates since they are less stable (Amézketa, 1999; Totsche, et al., 2017). The year 2018 was a year following beans, which would have less previous crop residue (4,895 kg ha^{-1}) but more CC biomass residue (2,391 kg ha^{-1}). The year 2018 had an interaction of cover by fertilizer in the 0.5 mm fraction at the 5 to 10 cm depth (p=0.0341) (Figure 14). The result of this interaction shows that the treatment of NC-SI is significantly greater than the other treatments. Since the same results of this interaction can be seen in 2017 with size fraction 0.25 mm this result is not a surprise. Again, this result could be expected to be greater since the fertilizer is placed in the soil next to the crop but a treatment that has both CC and a P treatment would have been assumed to be the greatest effect compared to others.

In 2019 the significant cover effect is different between depths. In the 0 to 5 cm depth the aggregate fractions that had a significant of cover in all of the aggregate sizes except the 0.25 mm fraction (Figure 15). The 4.75 mm, 2 mm, 1 mm, and 0.5 mm fraction each had a result of CC being greater than NC by a means of approximately 3%, 2.8%, 3.1% and 3.9% respectively. In the 5 to 10 cm depth the 4.75 mm, 2 mm, and 1 mm fractions each had a significant effect of CC being greater than NC with a difference in means of approximately 3.5%, 3.4% and 3.2% respectively (Figure 16). The 0.25 mm size fraction had a result of NC being greater than CC with a difference in means of approximately 2.6% (p=0.0241). There was no significant difference between cover treatments in the 0.5 mm size fraction. The difference in the amount of effect of cover between the aggregate sizes in 2019 compared to 2018 and 2017 is likely due to the low amount of cover crop biomass and the previous crop. Since aggregates are influenced by drying and wetting cycles (Wagner et al., 2007), freeze-thaw cycles (Hartmann & Six, 2022; Six et al., 2004), soil temperature (Amézketa, 1999; Nimmo & Perkins, 2002), not having the protective layer of biomass during the winter causes a breakdown of aggregates, resulting in smaller sizes, and the amount of previous crop residue left on the field also affects the aggregate sizes. The 0 to 5 cm layer is susceptible to intense precipitation events, human activity and other external factors, leading to the soil becoming less aggregated (Portella et al., 2012), without the protection of the cover crop the soil surface is left exposed to these erosive mechanisms. Between plots that have residue on the surface and plots with no residue, it has been observed that more water stable aggregates were found in the plots with residue (Trivedi, et al., 2017).

In 2022 the significant cover effect had different effects on the aggregate size fractions depending on the depth. In the surface depth three of the five aggregate fractions had a significant effect of cover where CC was greater than NC: 4.75 mm, 2 mm, and 0.25 mm (Figure 17). The 4.75 mm fraction had a difference in means of approximately 24.9%, and the 2 mm fraction had a difference in means of approximately 3.2%. The 0.25 mm fraction had a difference in means of approximately 8.1% and the results showed that NC was greater than CC. The 1 mm and 0.5 mm fraction had no significant effect of cover. In the subsurface depth there were only two of the five sizes that had a significant effect of cover (Figure 18). The 4.75 mm fraction had a significant difference between CC and NC where CC was greater than NC by a means of approximately 18.2%. The other significance was found in the 0.5 mm fraction where NC was greater than CC by a difference in means of approximately 5.9%. Overall, there are smaller amounts of large sized aggregates and a larger number of smaller aggregates. Smaller aggregates are just as important as the macroaggregates since the microaggregates are the building blocks of soil structure (Elliott, 1986). These results show that cover crops have more influence on bigger sized aggregates than smaller sizes, even if there are no significant differences found. This result follows the findings of Adetunji et al. (2020), Blanco-Canqui et al. (2011), Blanco-Canqui & Ruis (2020), and Blanco-Canqui et al. (2015), where cover crops improved aggregation.

The increase of near-surface macroaggregate and the reduction of microaggregates under cover crops suggests that there is an improvement of soil structure from addition of cover crops under no-till systems (Blanco-Canqui et al., 2011). After nine years of this study taking place there is a greater effect of cover on the bigger sized aggregates compared to the smaller sized aggregates in 2022 than in 2017. The lower soil disturbance in no-till management may explain the presence of larger aggregates (Presley, et al., 2012). Blanco-Canqui, et al., (2011) has also found that cover crops increase macroaggregates while decreasing microaggregates. Davis et al. (2022) has also found that there are more >4.75 mm aggregates under cover crops compared to other treatments, and overall cover crops and reduced tillage have improved water stable aggregates. Other management practices that have been found to impact aggregation are manure and compost (Amézketa, 1999; Mikha & Rice, 2004), and crop rotations (Amézketa, 1999; Bronick & Lal, 2004). Amézketa (1999), and Mikha & Rice (2004) have both found that no-till systems influence the formation of aggregates.

Larger aggregates in a field increase the amount of macropores in a soil. More macropores leads to a higher amount of infiltration, and a lower amount of runoff in a field. Increasing infiltration and reducing runoff could transfer P fertilizer into the soil to where it can be retained by sorption mechanisms, which would reduce P loss (Carver et al., 2022). Cover crops have been found to decrease runoff and sediment loss (Carver et al., 2022; Nelson et al., 2022). A small amount of cover crop biomass has been found to improve sediment loss and the amount of P loss (Carver et al., 2022).

Bulk Density

Bulk density values depend on the soil texture (Haruna et al., 2020; NRCS, 2019; USDA Natural Resources Conservation Service, 2008), and the arrangement of soil particles in the soil (NRCS, 2019; USDA Natural Resources Conservation Service, 2008), among other factors. The measurements taken at the KAW, 0 to 5 cm and 5 to 10 cm, had no significant main effects of cover or fertilizer, but the 0 to 5 cm depth had an interaction of cover by fertilizer (p=0.0102) (Figure 19), and the 5 to 10 cm depth did not (p=0.2201) (Figure 20). When looking at just the cover crop treatments by depth for bulk density there is no significant differences between cover treatments in either depth (p=0.3993 at 0 to 5 cm, and 0.6172 for 5 to 10 cm) (Figure 21).

The bulk density results show that there is a significant interaction of cover by fertilizer (p=0.0102) in the 0 to 5 cm. The surface depth interaction of cover by fertilizer shows that specific P treatments and cover treatments affect the bulk density of the soil more than others. The results of this interaction show that the CC-SI treatment was statistically significant compared to the other treatments, with the treatment NC-SI having the least interaction. These results make sense due to the CC-SI treatment being the highest interaction. The treatment NC-NP is not a treatment with the lowest interaction, NC-SI is, which would not have been expected since NC-NP would have been expected to be the treatment with the least interaction. Comparing these results to Table 1 in Dallas (2003) it can be determined if there is a root limiting layer. Dallas (2003) states that the ideal bulk density for a silty clay loam texture would be < 1.10g cm^{-3}, the bulk density that may affect root growth for a silty clay loam texture would be 1.55g cm^{-3}, and the bulk density for a silty clay loam texture that would restrict root growth would be >1.65g cm^{-3}. It can be observed that in the surface depth all the treatments are around the light gray line (1.1 g cm^{-3}) which shows that the bulk density is at an ideal level. In the 5 to 10 cm depth there is no interaction of cover by fertilizer. It can be observed that the density levels are different when compared to the surface depth, which can be expected. The measured bulk density is between 1.25 and 1.38 g cm^{-3}, which is all still under the 1.5 g cm^{-3} which is the level at which there could start to be root restriction in the soil.

This study has been in no-tillage management for nine years in 2022. This period of no soil disturbance improves soil structure, and it is known that practices that improve soil structure decrease bulk density (USDA Natural Resources Conservation Service, 2008; Presley, et al., 2012). Though this measurement of soil health decreases with less tillage it still increases with depth. Lazicki et al. (2021) has found the same results in their cover crop study where winter cover crops have decreased bulk density and increased soil porosity. Blanco-Canqui (2022) has found in their analysis that the use of cover crops can help reduce soil bulk density. The lower soil disturbance in no-tillage management may explain the decreased bulk density (Presley et al., 2012). Bulk density also helps to determine whether a soil is compacted or not. Compaction affects the growth of crops and water movement in the soil. Cover crops are able to create root channels that can alleviate the compaction. The next cash crop can use the root channels so they can easily reach water and nutrients.

Total Carbon/Soil Organic Carbon

Total carbon results show the percentage of carbon in the soil by mass. As stated previously, these samples do not contain calcium carbonate so TC equals SOC for the depths sampled. In 2022 at the 0 to 5 cm depth there is a significant effect of cover where CC is greater than NC with a difference in means of approximately 0.16% (Figure 22). There is no main effect of cover in the 5 to 10 cm depth ($p=0.3627$) (Figure 22). Trivedi et al. (2017) found that TC percentage was greater in plots with residue compared to plots without residue. To get the residual amount of SOC (ΔSOC %) we took the SOC from 2022 and subtracted it from the SOC from 2014. The results of this showed that in the surface depth there was a significant effect of cover where CC was greater than NC by a difference in means of approximately 0.2% (Figure 23). There was no effect of cover in the 5 to 10 cm depth ($p=0.4946$). The 0 to 5 cm depth also had an interaction of cover by fertilizer (Figure 24). These results show that the treatment CC-FB is statistically different from the other treatments, with treatments NC-NP and NC-SI having the most difference from this treatment. These results were expected since there has been CC growing in these plots for a total of nine years which would allow the SOC% to increase, resulting in an increase from the beginning of the study.

Today, carbon is discussed using carbon stocks, which are measured and traded as Megagrams per hectare, Mg ha^{-1}. The conversion from SOC% to SOC in mass per unit area balances out different management systems in fields and takes into consideration differences in density (Ellert et al., 2001). It was found that there was a significant main effect of cover in the 0 to 5 cm depth where CC is greater than NC by a difference in means of approximately 0.99% (Figure 25). The 5 to 10 cm depth does not have a significant effect of cover ($p=0.3301$). For SOC to increase, it has been observed that large amounts of cover crop biomass (>2 Mg ha^{-1}) are required to change the amounts of SOC in the soil (Blanco-Canqui, 2022). The amount of carbon and its rate of decomposition changes depending on the temperature, texture, and moisture (Lehmann & Kleber, 2015). Increasing the returns to the soil may increase SOC (Stewart et al., 2007). Time is also needed for SOC to increase (Haruna et al., 2020), as well as a management practice that focuses on returns to the soil (Stewart et al., 2007; Lal, 2004). Soil organic carbon has been found to improve soil physical properties (Blanco-Canqui et al., 2013; Blanco-Canqui & Ruis, 2020), but more specifically, improve aggregation (Blanco-Canqui et al., 2013). Soil organic carbon has been found to act as a binding agent and as a nucleus in the formation of aggregates (Bronick & Lal, 2004). Since SOC is involved with the formation of aggregates, the amount of SOC in the soil is influenced by its association with different aggregate size fractions (Wilpiszeski et al., 2019).

The 2022 SOC data was examined for correlation with the other measurements from 2022 (Table 5). It was found that SOC significantly correlated with MWD, and the 4.75 mm ($p=0.019$), and 0.25 mm fractions. These results make sense since more SOC would mean more binding of bigger aggregates, which would overall increase the average aggregate size, and SOC has been observed to have the most impact on large aggregates (Lehmann & Kleber, 2015). The correlation coefficient of SOC and MWD, and the 4.75 mm size fraction are positive, showing that as one of these increases, so does the other. The 2 mm fraction has a negative correlation, and this shows that as one increases, the other decreases, which again makes sense because SOC binds larger aggregates together, so as more SOC binds large size aggregates, there are less smaller aggregates. Blanco-Canqui et al. (2011) states that WSA strongly correlated with changes in SOC, and that a positive correlation between SOC and aggregate stability suggests that SOC has a significant impact on the formation of soil aggregates. Soil organic carbon sequestration depends on the soil texture (Haruna et al., 2020; Lal, 2004). Cai et al. (2022) has found the no-till management has increased SOC at the soil surface compared to conventional tillage. Some of the benefits of increasing SOC include nutrient building, reduced erosion, and increased water holding capacity (Buck & Palumbo-Compton, 2022), therefore due to these benefits SOC is a valuable natural resource (Lal, 2004).

Clay Content

Soil samples were collected in 2017 and analyzed for texture and clay content at 0 to 5 cm. The clay content was examined for correlation with the other measurements from 2017 (Table 6). It was found that clay content significantly correlated with MWD, TA ($p=<0.0001$), and the 1 mm, 0.5 mm ($p=<0.0001$), and 0.25 mm fractions. All of these significances also have a positive Pearson Correlation Coefficient. The positive results show that as clay content increases, the MWD, TA and the 1 mm, 0.5 mm, and 0.25 mm aggregate sizes increase. Clay content has been found to increase aggregation (Bronick & Lal, 2004; Fernández-Ugalde, et al., 2013; Lehmann & Kleber, 2015, Hartmann & Six, 2022). Clay content is important due to its specific surface area, and surface charges which can increase interactions with ions, mineral particles, organic matter, and can increase flocculation (Fernández-Ugalde, et al., 2013). Small differences within clay mineralogy can influence the formation of the soil's structure (Fernández-Ugalde, et al., 2013). To create a soil aggregate, clay content in the soil is the first step (Tisdall & Oades, 1982). Clay binds small aggregates together since it is made up of mostly soil particles and hyphae, and SOC binds smaller aggregates together forming larger sized aggregates. Aggregates can become protected from decomposition with greater amounts of mineral surfaces in the aggregate (Lehmann & Kleber, 2015).

The only negative correlation coefficient that was found after this analysis was with SOC (Pearson Correlation Coefficient = -0.0417). This shows that as one increases, the other decreases. Blanco-Canqui (2022) has found similar findings where SOC was not significantly correlated with sand, silt or clay content and that the lack of significance shows that particle-size distribution has a limited effect on soil organic carbon. The 4.75 mm and 2 mm fraction do not have a significant correlation with clay, which makes sense due to them being the bigger sized and bind with SOC and not clay.

Table 1. Table of p-values for 2017, 2018, 2019, and 2022 for the 0 to 5 cm depth. P-values shown of the main effects of cover, fertilizer, and an interaction of cover by fertilizer for mean weight diameter (mm) (MWD), total aggregation percentage (TA), and percent sand free aggregate size fractions of 4.75 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm. Means separated at $p < 0.05$.

Effect/Interaction		MWD	TA	4.75 mm	2 mm	1 mm	0.5 mm	0.25 mm
2017	Cover	0.0061	0.1794	0.0019	0.5387	0.966	0.5353	0.3788
	Fertilizer	0.8911	0.5203	0.7646	0.6922	0.9191	0.401	0.0448
	Cover*Fertilizer	0.1209	0.834	0.0985	0.0185	0.8971	0.0926	0.0168
2018	Cover	<0.0001	<0.0001	<0.0001	0.5885	0.0884	0.0277	0.0002
	Fertilizer	0.2913	0.4849	0.4449	0.8579	0.6616	0.3775	0.2143
	Cover*Fertilizer	0.2829	0.0835	0.3805	0.5992	0.2475	0.5847	0.3785
2019	Cover	0.0227	0.003	0.0167	0.0035	0.0069	0.0058	0.8766
	Fertilizer	0.1423	0.1207	0.3054	0.4996	0.3805	0.0967	0.0563
	Cover*Fertilizer	0.6253	0.2617	0.2167	0.3934	0.5905	0.4583	0.0899
2022	Cover	<0.0001	0.0023	0.0002	0.0452	0.3796	0.0545	0.0004
	Fertilizer	0.8196	0.9666	0.8307	0.4335	0.7298	0.4708	0.7294
	Cover*Fertilizer	0.8251	0.8869	0.7422	0.6508	0.6141	0.1315	0.8249

Table 2. Table of P-values for 2017, 2018, 2019 and 2022 for the 5 to 10 cm depth. P-values shown for the main effects of cover, fertilizer, and an interaction of cover by fertilizer of mean weight diameter (mm) (MWD), total aggregation percentage (TA), and percent sand free aggregate size fractions of 4.75 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm. Means separated at p < 0.05.

Effect/ Interaction		MWD	TA	4.75 mm	2 mm	1 mm	0.5 mm	0.25 mm
2017	Cover	0.0322	0.1854	0.0332	0.3362	0.8402	0.9585	0.0791
	Fertilizer	0.8771	0.783	0.8814	0.7949	0.5985	0.2637	0.1786
	Cover*Fertilizer	0.9700	0.4646	0.9677	0.4344	0.3062	0.0923	0.2525
2018	Cover	0.0004	0.0077	0.0005	0.4937	0.0128	0.004	0.003
	Fertilizer	0.9244	0.4265	0.9208	0.786	0.5561	0.1664	0.8238
	Cover*Fertilizer	0.6351	0.0341	0.8111	0.8866	0.1054	0.0267	0.8956
2019	Cover	0.0055	0.0625	0.0174	0.004	0.0143	0.7963	0.0241
	Fertilizer	0.9187	0.4915	0.8632	0.9266	0.8484	0.2298	0.1772
	Cover*Fertilizer	0.1532	0.4736	0.5078	0.494	0.3928	0.3593	0.8518
2022	Cover	0.0315	0.0098	0.024	0.1489	0.7099	0.014	0.0641
	Fertilizer	0.901	0.2833	0.7301	0.1844	0.2623	0.1698	0.8221
	Cover*Fertilizer	0.6821	0.3692	0.5129	0.5115	0.2875	0.1784	0.5897

Table 3. Table of P-values for the 0 to 5 cm depth and 5 to 10 cm depth in 2022. P-values shown for the main effect of cover, fertilizer, and an interaction of cover by fertilizer of Bulk Density (g cm^{-3}), Total Carbon (%), and Soil Organic Carbon (Mg ha^{-1}). Means separated at $p < 0.05$.

Effect/Interaction	Depth	Bulk Density (g cm-3)	Total Carbon (%)	Soil Organic Carbon (Mg ha-1)
Cover	0-5	0.3993	0.0019	0.0017
Fertilizer	0-5	0.5072	0.8039	0.9783
Cover*Fertilizer	0-5	0.0102	0.065	0.1887
Cover	5-10	0.6172	0.3627	0.3301
Fertilizer	5-10	0.214	0.9464	0.8105
Cover*Fertilizer	5-10	0.2201	0.4206	0.2298

Table 4. Averaged cover crop biomass (kg ha-1) and average crop residue (kg ha-1) for 2017, 2018, 2019 and 2022 in all plots. The years that were corn were 2017 and 2019, and the years that were beans were 2018 and 2022.

Year	Average Biomass (kg ha^{-1})	Average Crop Residue (kg ha^{-1})
2017	1,823	6,755
2018	2,391	4,895
2019	312	10,273
2022	1,407	4,177

Table 5. Pearson Correlation Coefficients and p-values for 2022 soil organic carbon (SOC) and mean weight diameter (mm) (MWD), total aggregation percentage (TA), and percent sand free aggregate size fractions 4.75 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm in the 0 to 5 cm depth. Means separated at p < 0.05. Coefficients calculated in SAS.

	Pearson Correlation Coefficient	P-value
SOC and Clay	-0.0417	0.7427
SOC and MWD	0.3207	0.0154
SOC and TA	0.22304	0.105
SOC and 4.75 mm	0.31833	0.019
SOC and 2 mm	0.05562	0.6895
SOC and 1 mm	-0.10767	0.4384
SOC and 0.5 mm	-0.249343	0.069
SOC and 0.25 mm	0-0.29343	0.0313

Table 6. Pearson Correlation Coefficients and p-values for 2017 clay and mean weight diameter (mm) (MWD), total aggregation percentage (TA), and percent sand free aggregate size fractions 4.75 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm at the 0 to 5 cm depth. Means separated at p < 0.05. Coefficients calculated in SAS.

	Pearson Correlation Coefficient	P-value
Clay and SOC	-0.0417	0.7427
Clay and MWD	0.32330	0.022
Clay and TA	0.61327	<0.0001
Clay and 4.75 mm	0.20108	0.1599
Clay and 2 mm	0.25898	0.0694
Clay and 1 mm	0.38967	0.0052
Clay and 0.5 mm	0.69884	<0.0001
Clay and 0.25 mm	0.48769	0.0003

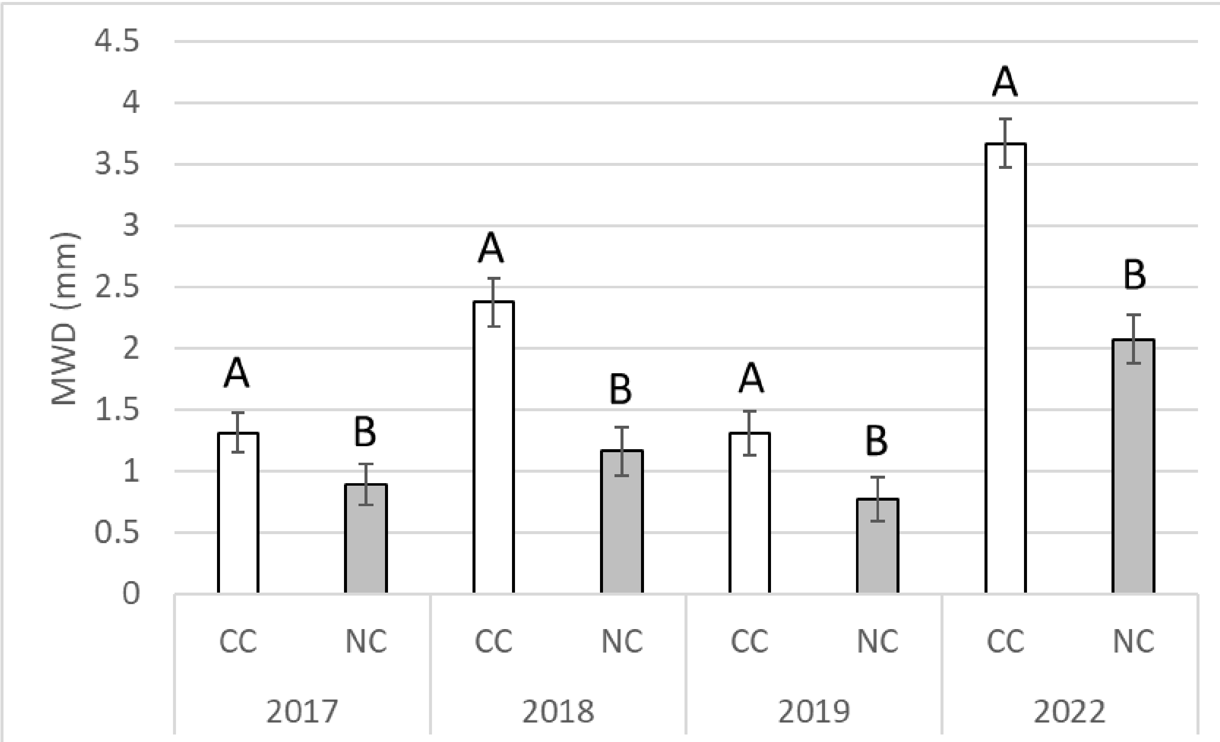


Figure 2. Mean Weight Diameter (MWD) measured for cover crop (CC) and no cover crop (NC) plots in 2017, 2018, 2019 and 2022 at 0 to 5 cm depth. The MWD was analyzed individually within each year. Letters show statistical differences. No letters indicate no statistical difference. P=0.0061 in 2017, p=<0.0001 in 2018, p=0.0227 in 2019, and p=<0.0001 in 2022. Means separated at $p < 0.05$. Error bars are standard error from SAS. Values were determined by SAS.

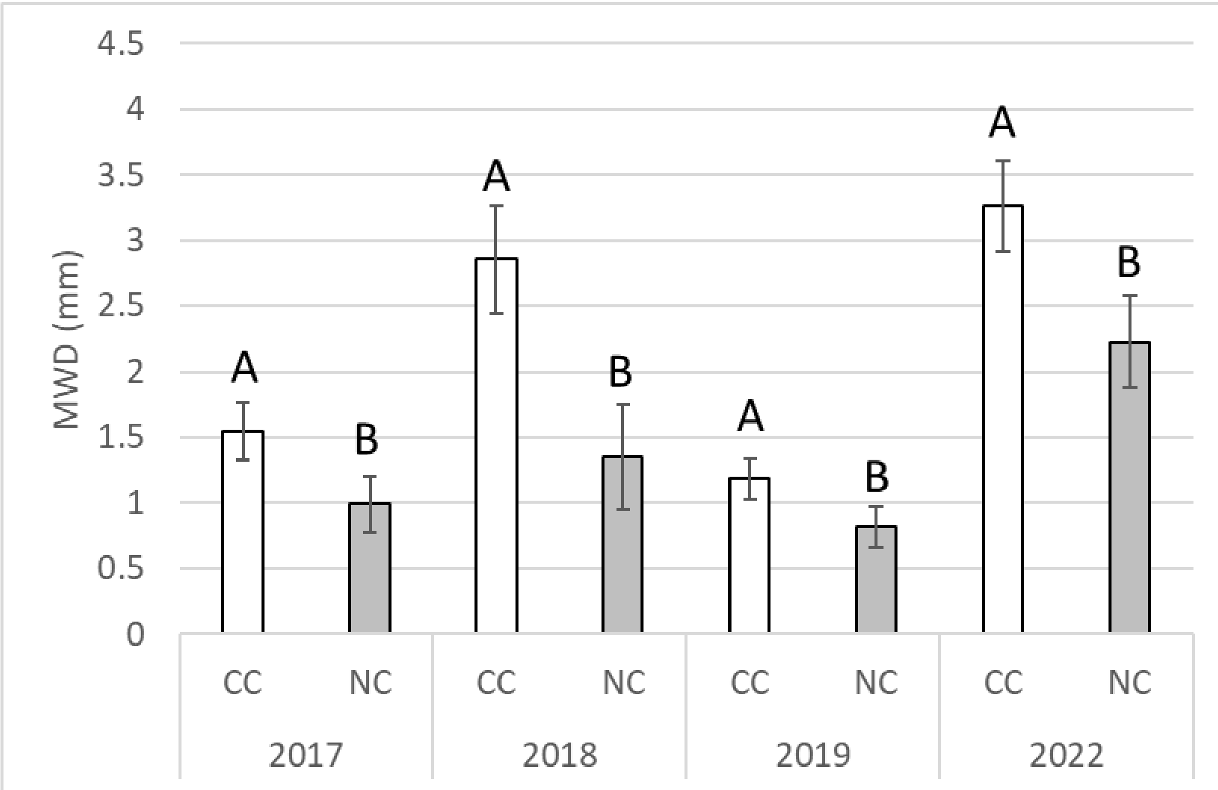


Figure 3. Mean Weight Diameter (MWD) measured for cover crop (CC) and no cover crop (NC) plots in 2017, 2018, 2019 and 2022 at a 5 to 10 cm depth. The MWD was analyzed individually within each year. Letters show statistical differences. No letters indicate no statistical difference. P = 0.0322 in 2017, p=0.0004 in 2018, p=0.0055 in 2019, and p=0.0315 in 2022. Means separated at $p < 0.05$. Error bars are standard error from SAS. Values were determined by SAS.

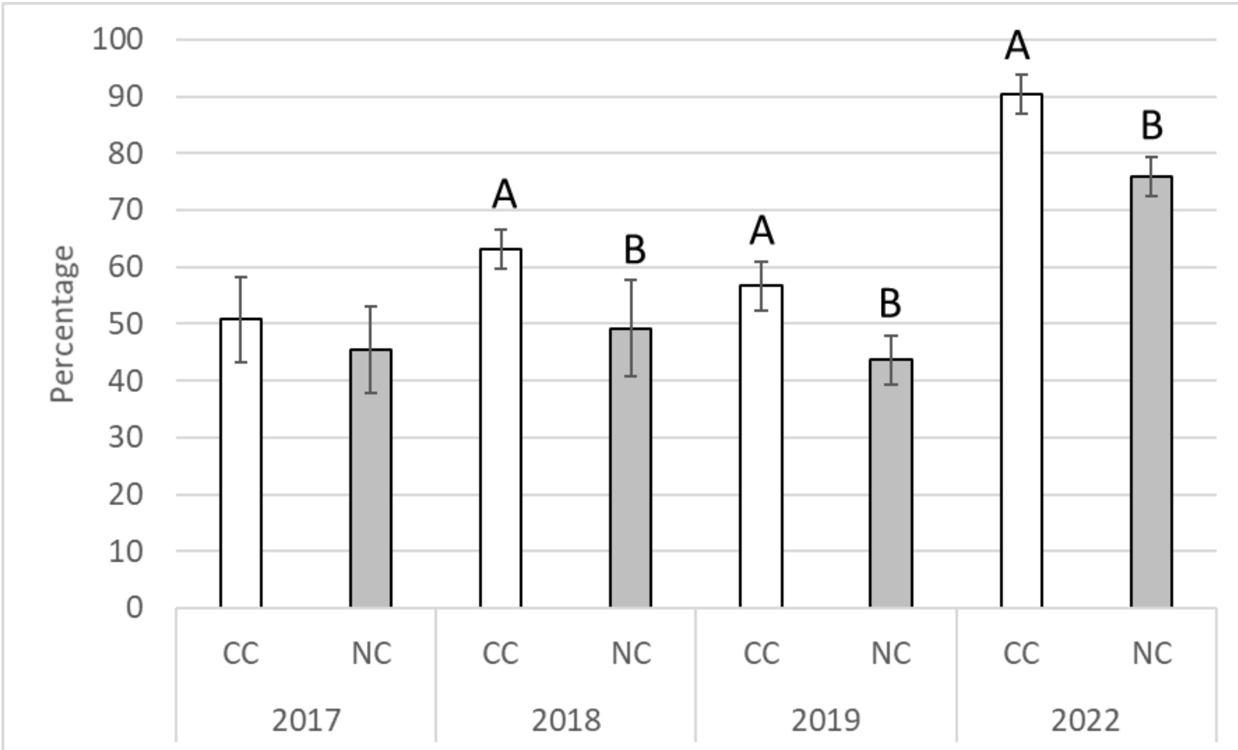


Figure 4. Percent sand free total aggregation (TA) measured for cover crop (CC) and no cover crop (NC) plots for 2017, 2018, 2019, and 2022 at a 0 to 5 cm depth. The TA was analyzed separately by year. Letters show statistical differences. No letters indicate no statistical difference. P = 0.1794 in 2017, p=<0.0001 in 2018, p=0.0003 in 2019, and p=0.003 in 2022. Means separated at $p < 0.05$. Error bars are standard error from SAS. Values were determined by SAS.

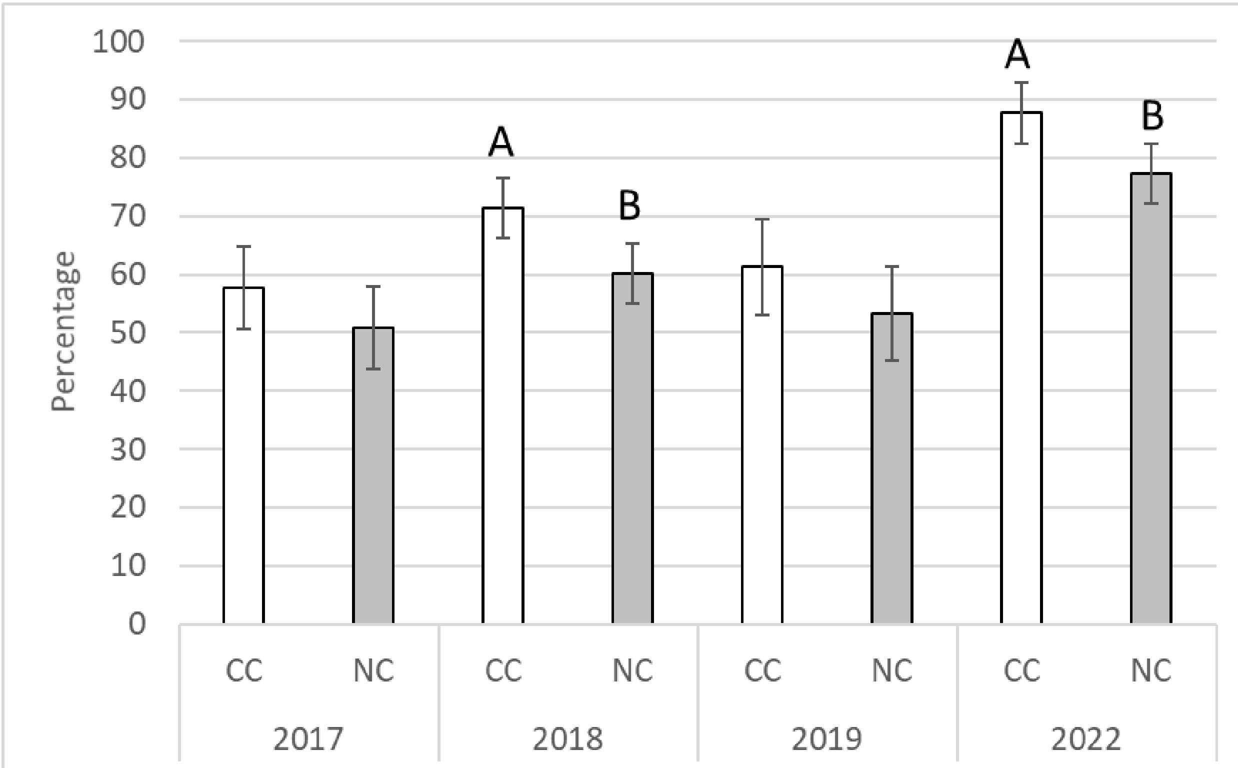


Figure 5. Percent sand free total aggregation (TA) for 2017, 218, 2019, and 2022 at a 5 to 10 cm depth. The TA was analyzed separately by year. Letters show statistical differences. No letters indicate no statistical difference. P=0.1854 in 2017, p=0.0077 in 2018, p=0.0625 in 2019, and p=0.0098 in 2022. Means separated at $p < 0.05$. Error bars are standard error from SAS. Values were determined by SAS.

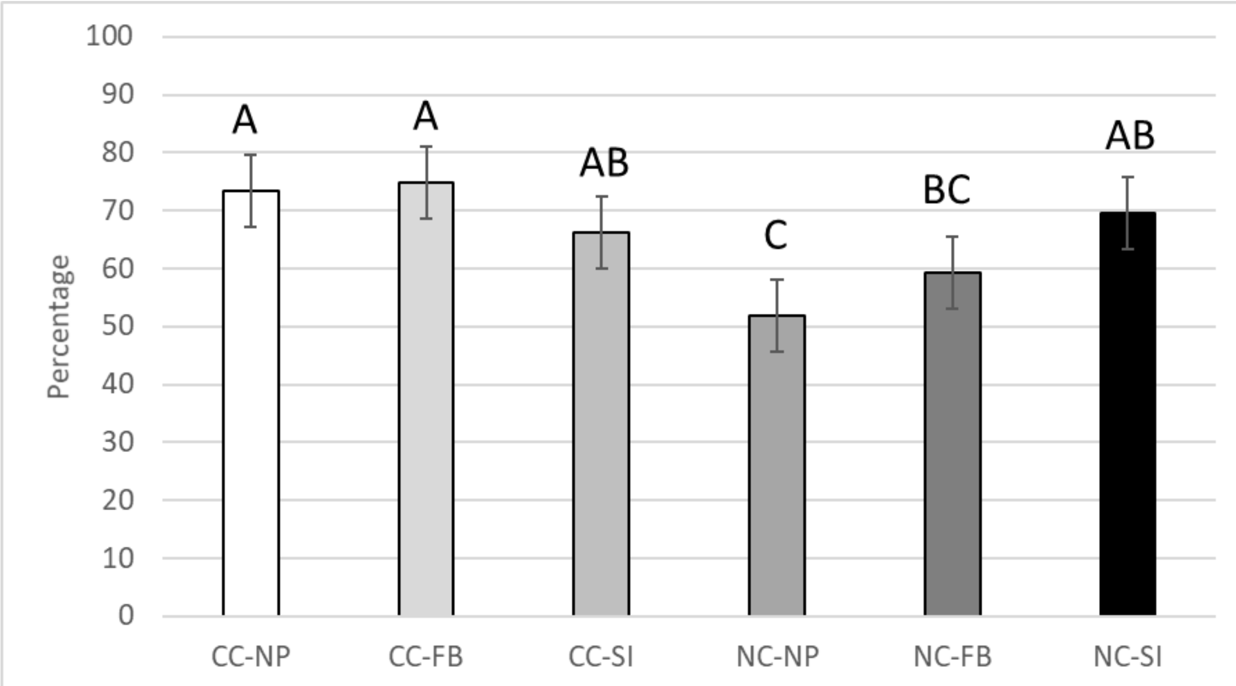


Figure 6. Total aggregation (TA) Cover by fertilizer interaction in the 5 to 10 cm depth in 2018. Letters show statistical differences. Means separated at $p < 0.05$. $P = 0.0341$. Cover treatments were cover crops (CC) and no cover crop (NC). Phosphorus treatments were fall broadcast (FB), spring injection (SI) and no phosphorus (NP). Error bars are standard error from SAS. Values were determined by SAS.

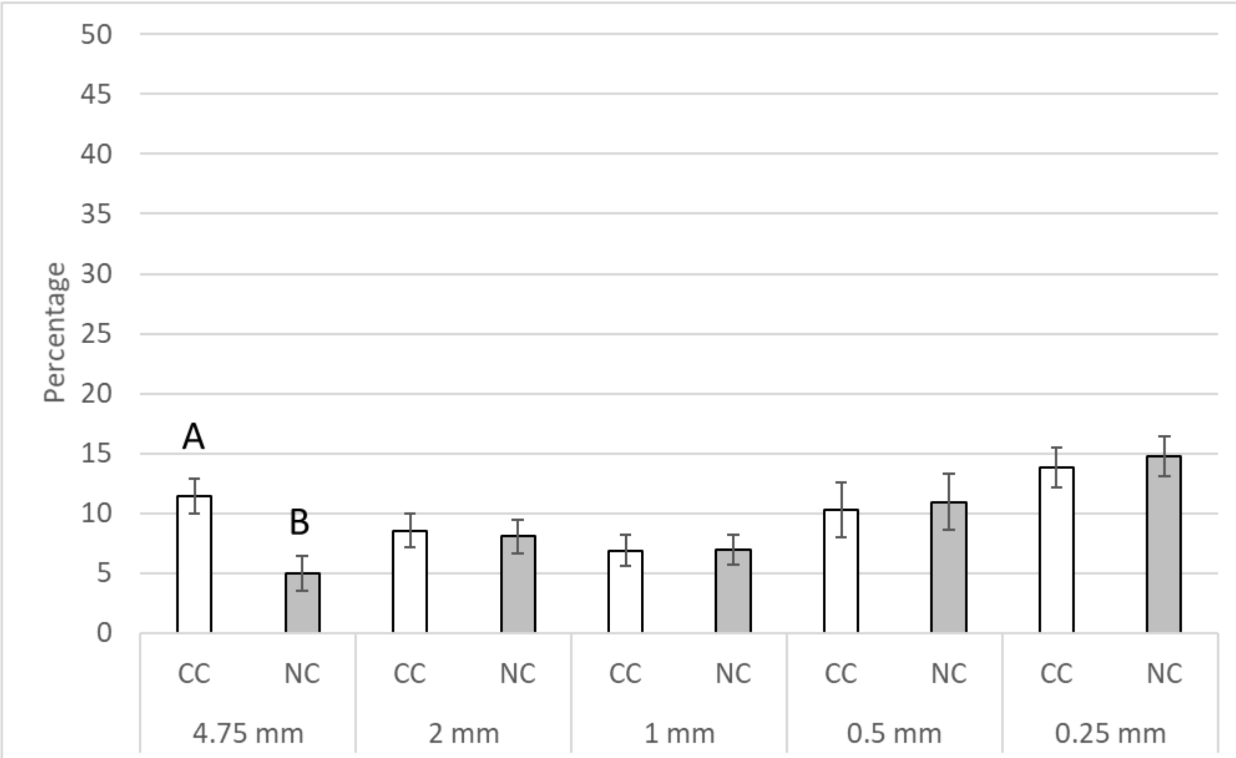


Figure 7. Percent sand free aggregate sizes in 2017 measured for cover crop (CC) and no cover crop (NC) plots at a 0 to 5 cm depth. This figure shows statistical differences; no letters indicate no statistical difference. P=0.0019, 0.5387, 0.9660, 0.5353, and 0.3788 for fraction sizes 4.75 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm respectively. Means separated at $p < 0.05$. Error bars are standard error from SAS. Values were determined by SAS.

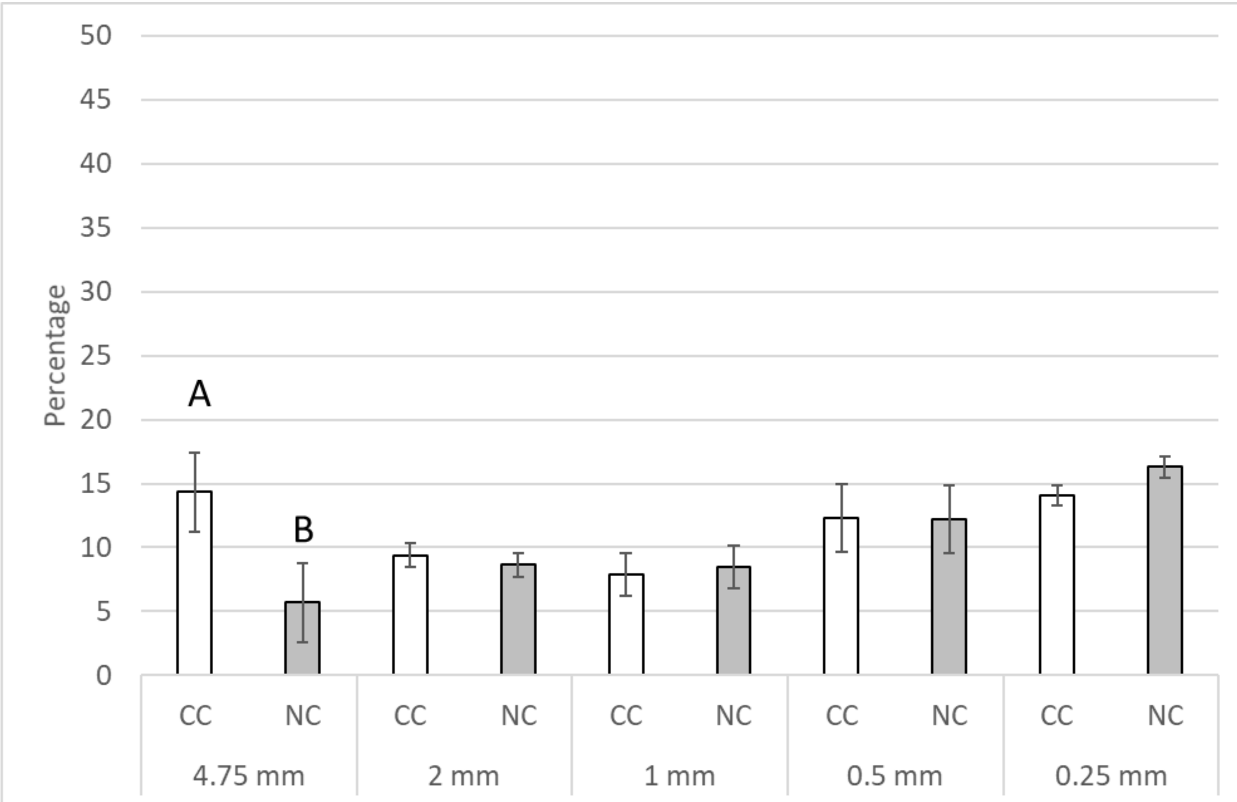


Figure 8. Percent sand free aggregate sizes in 2017 measured for cover crop (CC) and no cover crop (NC) plots at a 5 to 10 cm depth. This figure shows the percentage of soil left on each sieve. Each size was analyzed individually. Letters show statistical differences. No letters indicate no statistical difference. P=0.0337, 0.3362, 0.8402, 0.9585 and 0.0791 for fraction sizes 4.75 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm respectively. Means separated at $p < 0.05$. Error bars are standard error from SAS. Values were determined by SAS.

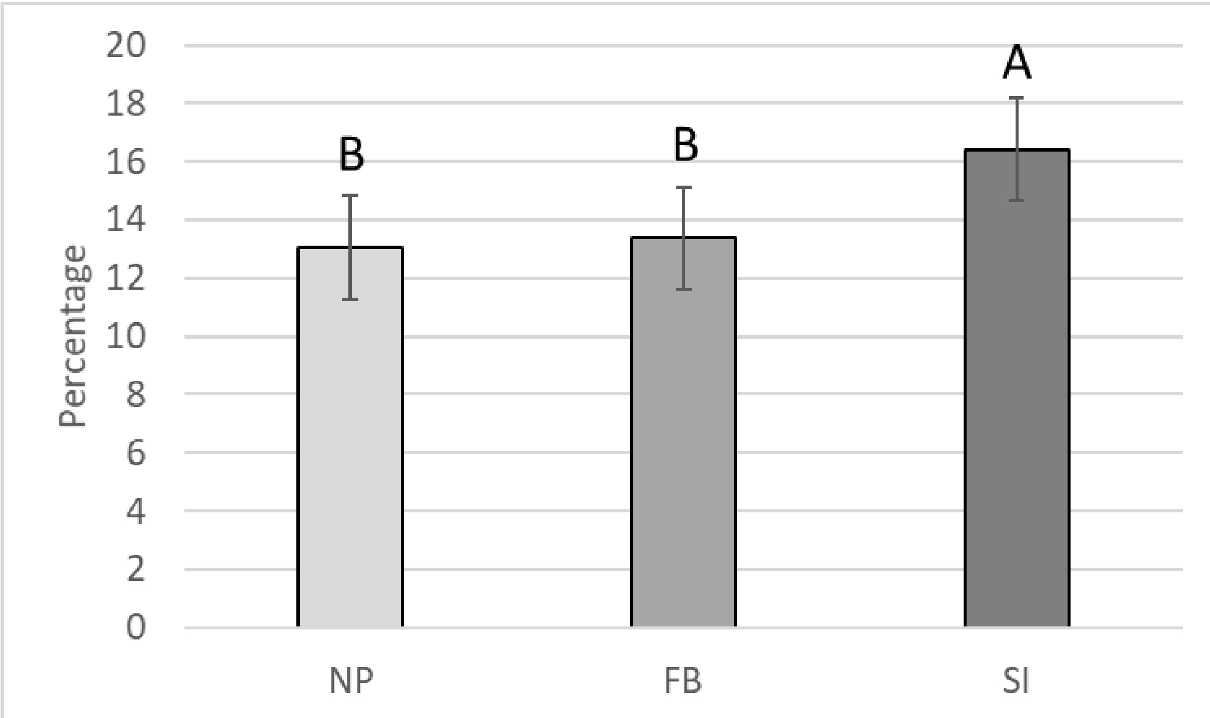


Figure 9. Percent sand free aggregate size 0.25 mm main effect of fertilizer in 2017 at the 0 to 5 cm depth. Fertilizer treatments are No Phosphorus (NP), Fall Broadcast (FB), and Spring Injection (SI). Letters show statistical differences. Means separated at p< 0.05. P = 0.0448. Error bars are standard error from SAS. Values were determined by SAS.

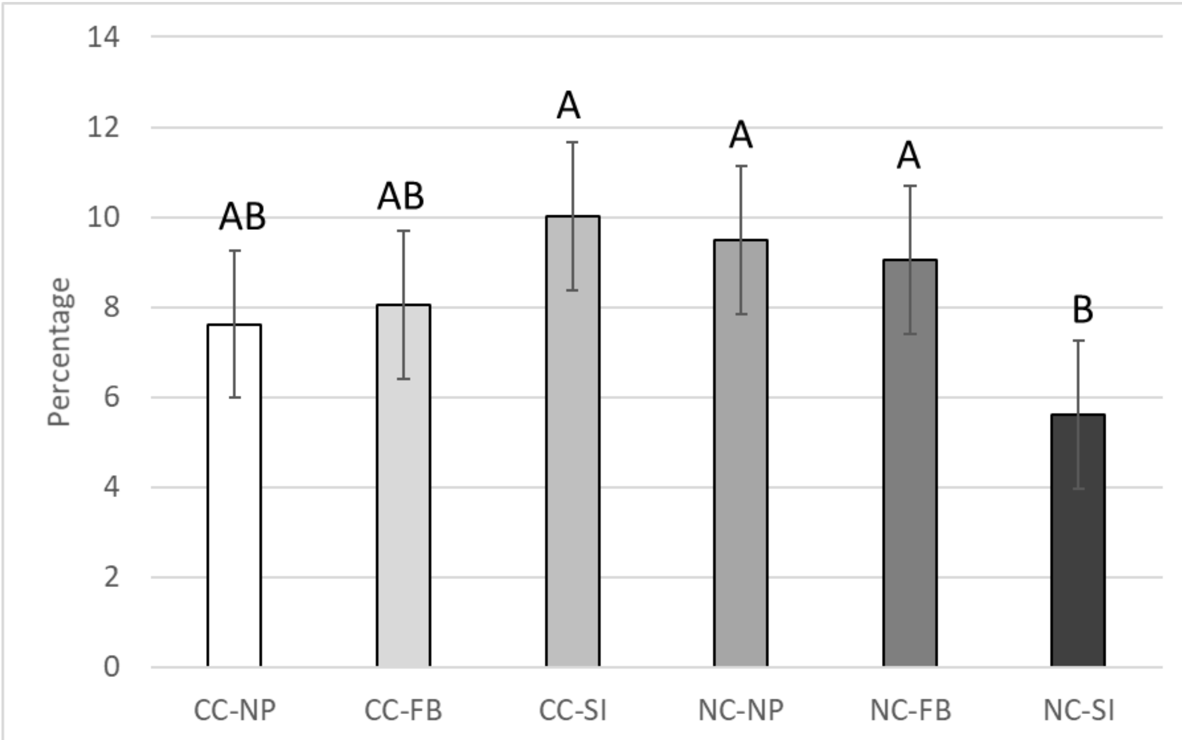


Figure 10. Percent sand free aggregate size 2 mm interaction of cover (cover crop (CC) or no cover crop (NC)) by fertilizer (No Phosphorus (NP), Fall Broadcast (FB), and Spring Injection (S)) in 2017 at the 0 to 5 cm depth. Letters show statistical differences. M Means separated at $p < 0.05$. $P = 0.0185$. Error bars are standard error from SAS. Values were determined by SAS.

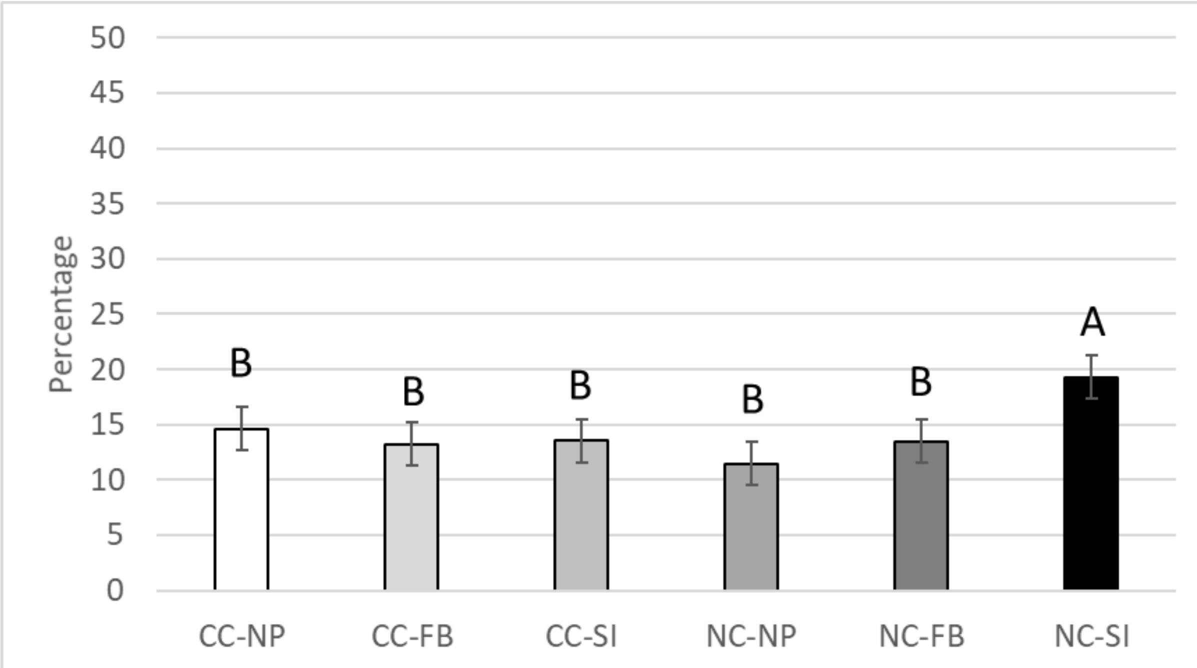


Figure 11. Percent sand free aggregate size 0.25 mm interaction of cover (cover crop (CC) and no cover crop (NC)) by fertilizer (No Phosphorus (NP), Fall Broadcast (FB), and Spring Injection (SI)) in 2017 at the 0 to 5 cm depth. Letters show statistical differences. Means separated at $p < 0.05$. $P = 0.0168$. Error bars are standard error from SAS. Values were determined by SAS.

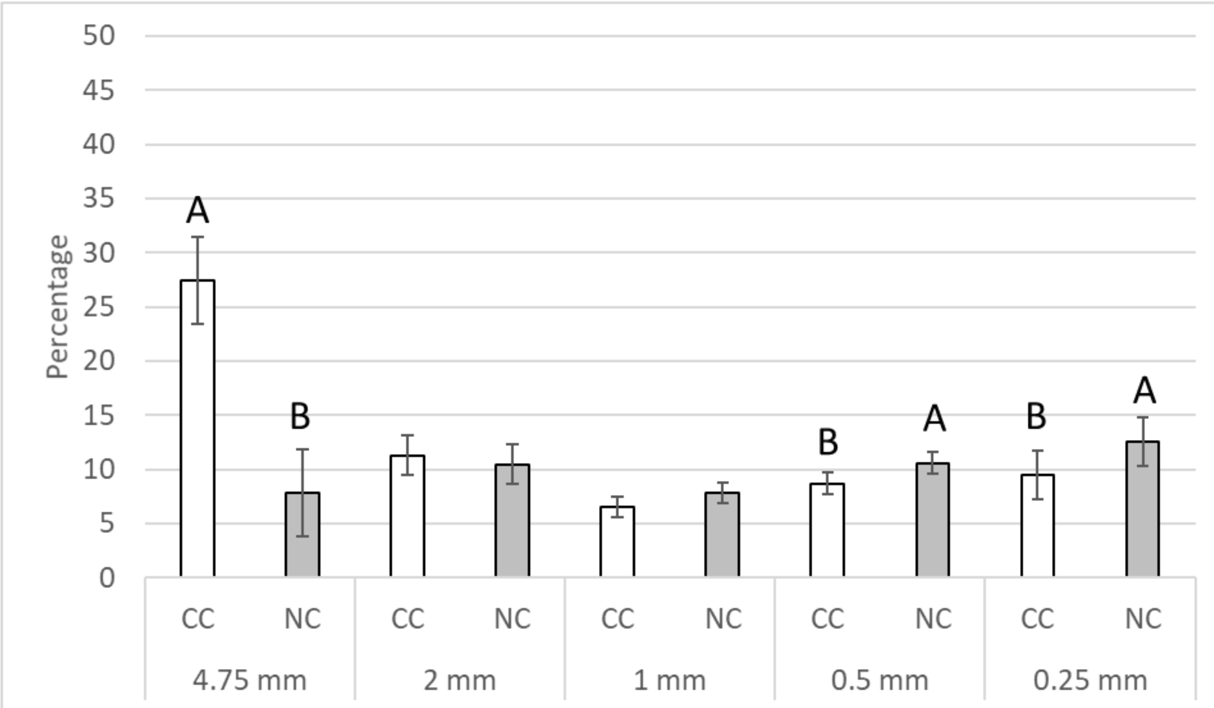


Figure 12. Percent sand free aggregate sizes in 2018 measured for cover crop (CC) and no cover crop (NC) plots at a 0 to 5 cm depth. This figure shows the percentage of soil left on each sieve. Each size was analyzed individually. Letters show statistical difference. No letters indicate no statistical difference. P= <0.0001, 0.5885, 0.0884, 0.0277, and 0.0002 for fraction sizes 4.75 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm, respectively. Means separated by $p < 0.05$. Error bars are standard error from SAS. Values were determined by SAS.

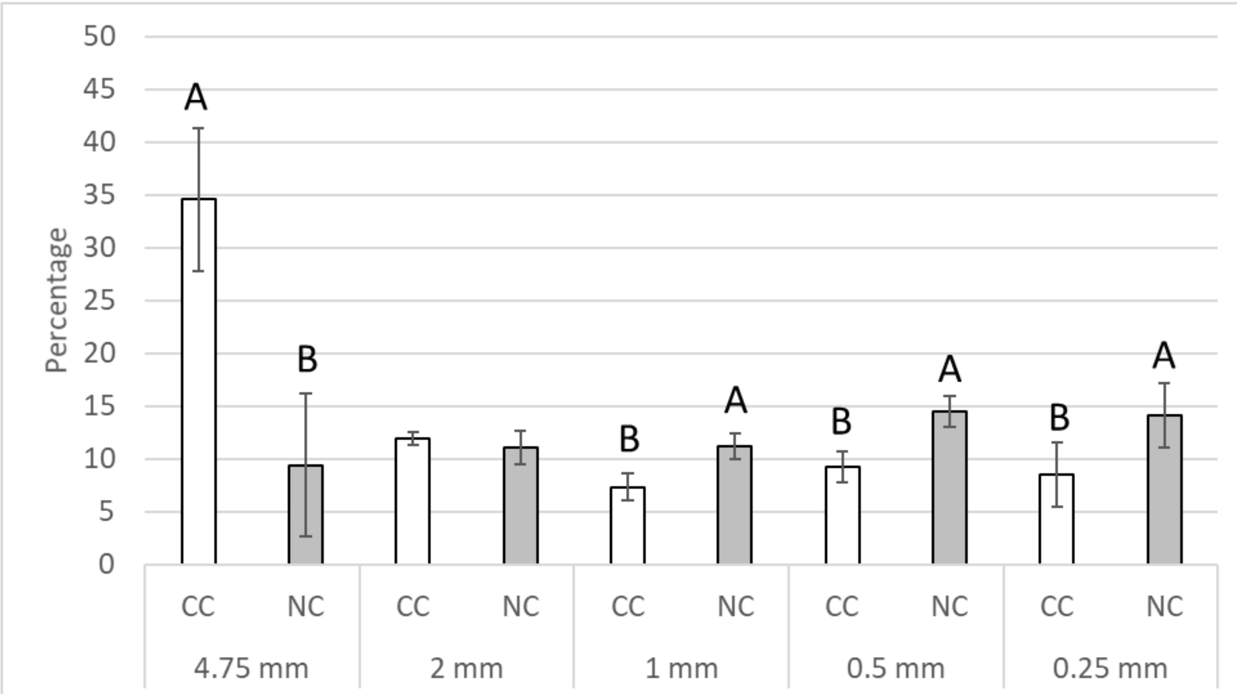


Figure 13. Percent sand free aggregate sizes in 2018 measured for cover crop (CC) and no cover crop (NC) plots at a 5 to 10 cm depth. This figure shows the percentage of soil left on each sieve. Each size was analyzed individually. Letters show statistical differences. No letters indicate no statistical difference. P=0.0005, 0.4937, 0.0128, 0.004, and 0.003 for fraction sizes 4.75 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm, respectively. Means separated at $p < 0.05$. Error bars are standard error from SAS. Values were determined by SAS.

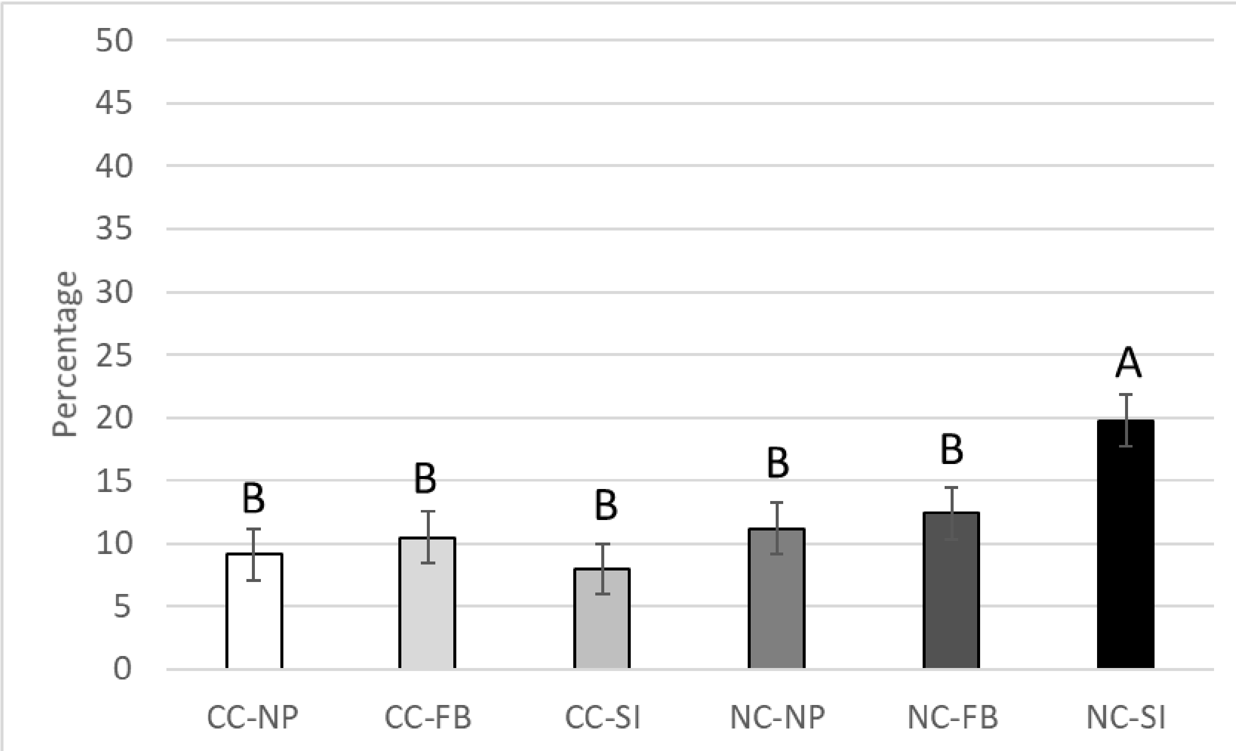


Figure 14. Percent sand free aggregate size 0.5 mm interaction of cover (cover crop (CC) and no cover crop (NC)) by fertilizer (No Phosphorus (NP, Fall Broadcast (FB), and Spring Injection (SI)) in 2018 at the 5 to 10 cm depth. Letters show statistical differences. Means separated at $p < 0.05$. P = 0.0341. Error bars are standard error from SAS. Values were determined by SAS.

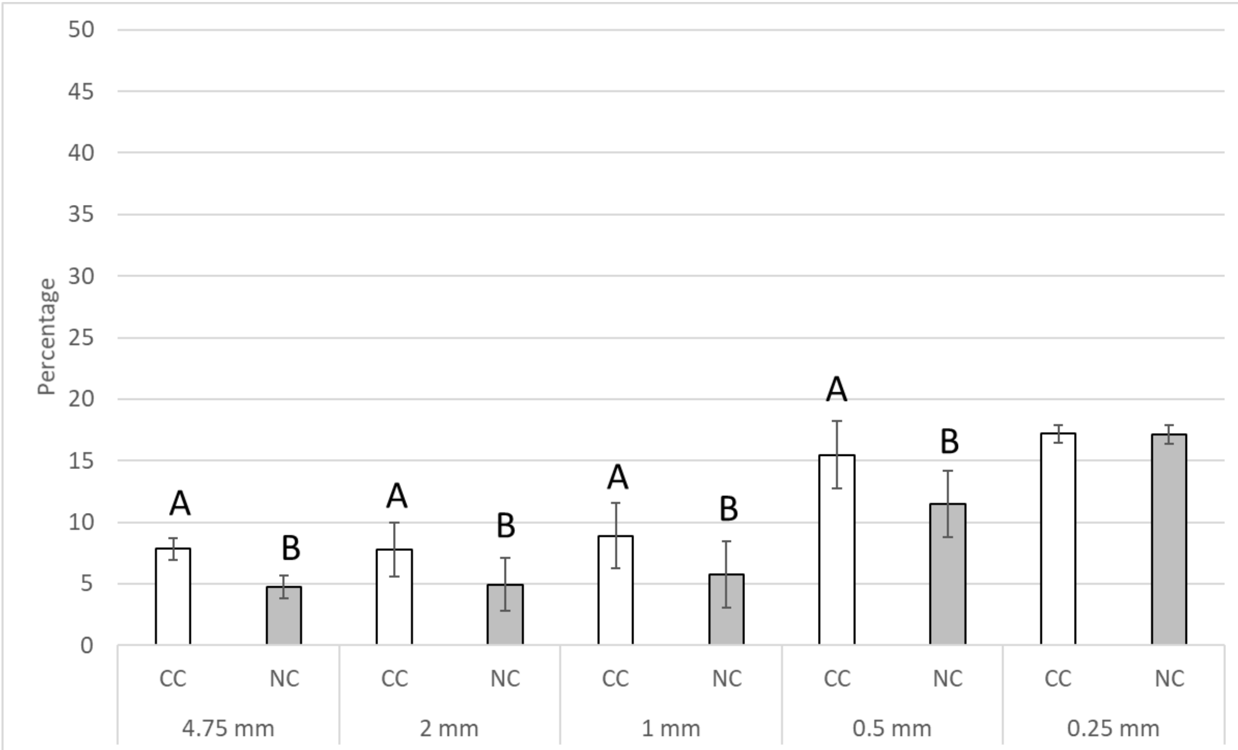


Figure 15. Percent sand free aggregate sizes in 2019 measured for cover (CC) and no cover crop (NC) plots at a 0 to 5 cm depth. This figure shows the percentage of soil left on each sieve. Each size was analyzed individually. Letters show statistical differences. No letters indicate no statistical difference. P=0.0167, 0.0035, 0.0069, 0.0058 and 0.08766 for fraction sizes 4.75 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm, respectively. Means separated at p < 0.05. Error bars are standard error from SAS. Values were determined by SAS.

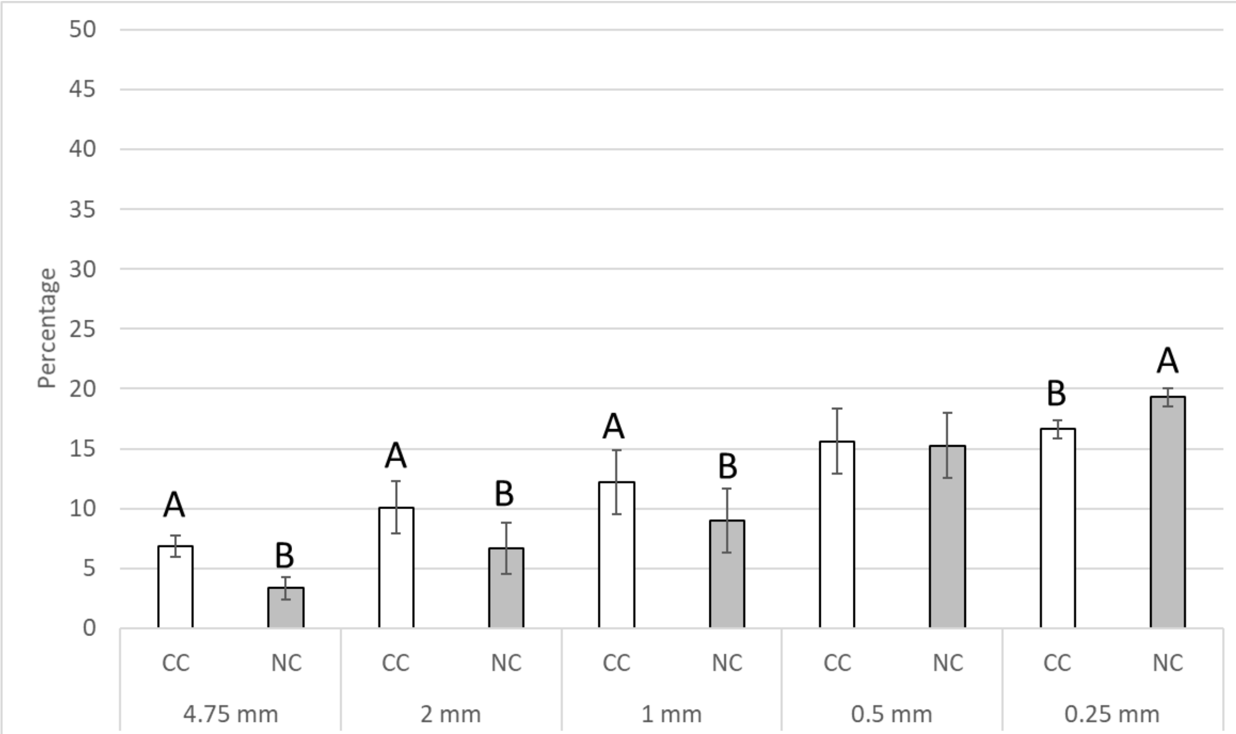


Figure 16. Percent sand free aggregate sizes in 2019 measured for cover crop (CC) and no cover crop (NC) plots at a 5 to 10 cm depth. This figure shows the percentage of soil left on each sieve. Each size was analyzed individually. Letters show statistical differences. No letters indicate no statistical difference. P=0.0174, 0.004, 0.0143, 0.7963 and 0.0241 for fraction sizes 4.75 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm, respectively. Means separated at $p < 0.05$. Error bars are standard error from SAS. Values were determined by SAS.

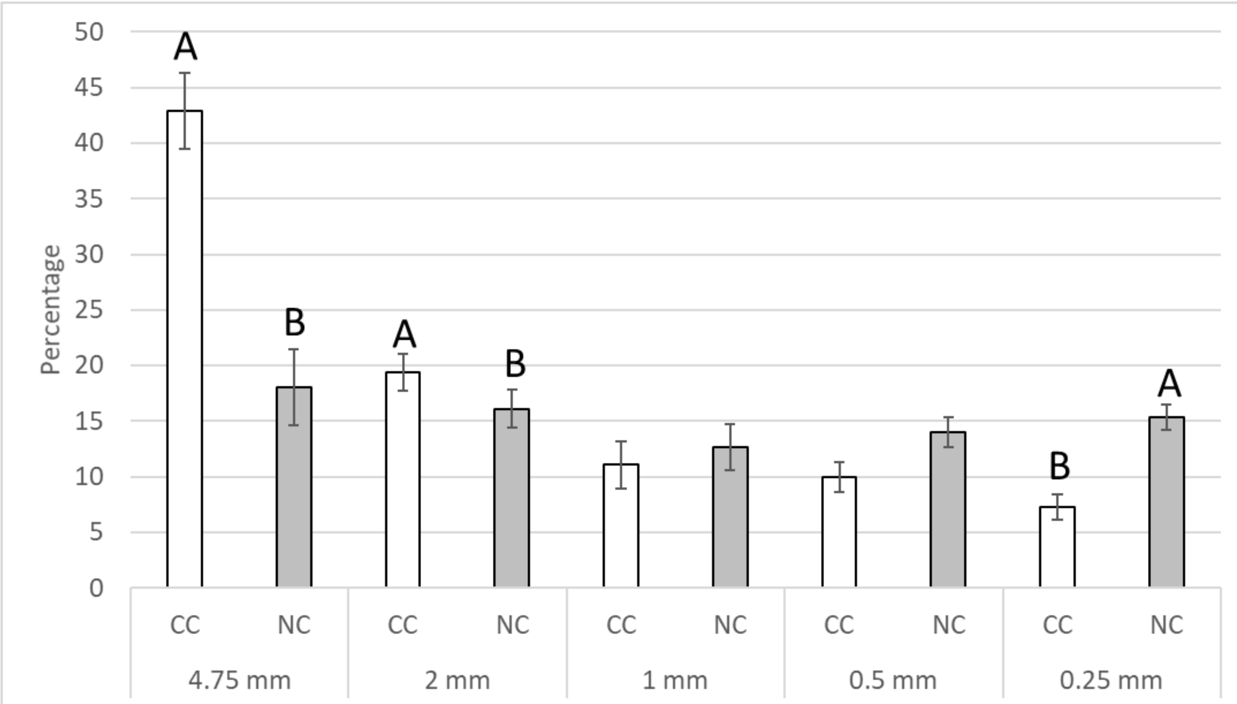


Figure 17. Percent sand free aggregate sizes in 2022 measured for cover crop (CC) and no cover crop (NC) plots at a 0 to 5 cm depth. This figure shows the percentage of soil left on each sieve. Each size was analyzed individually. Letters show statistical difference. No letters indicate no statistical difference. P+ 0.0002, 0.0452, 0.3796, 0.0545, and 0.0004 for fraction sizes 4.75 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm, respectively. Means separated at $p < 0.05$. Error bars are standard error from SAS. Values were determined by SAS.

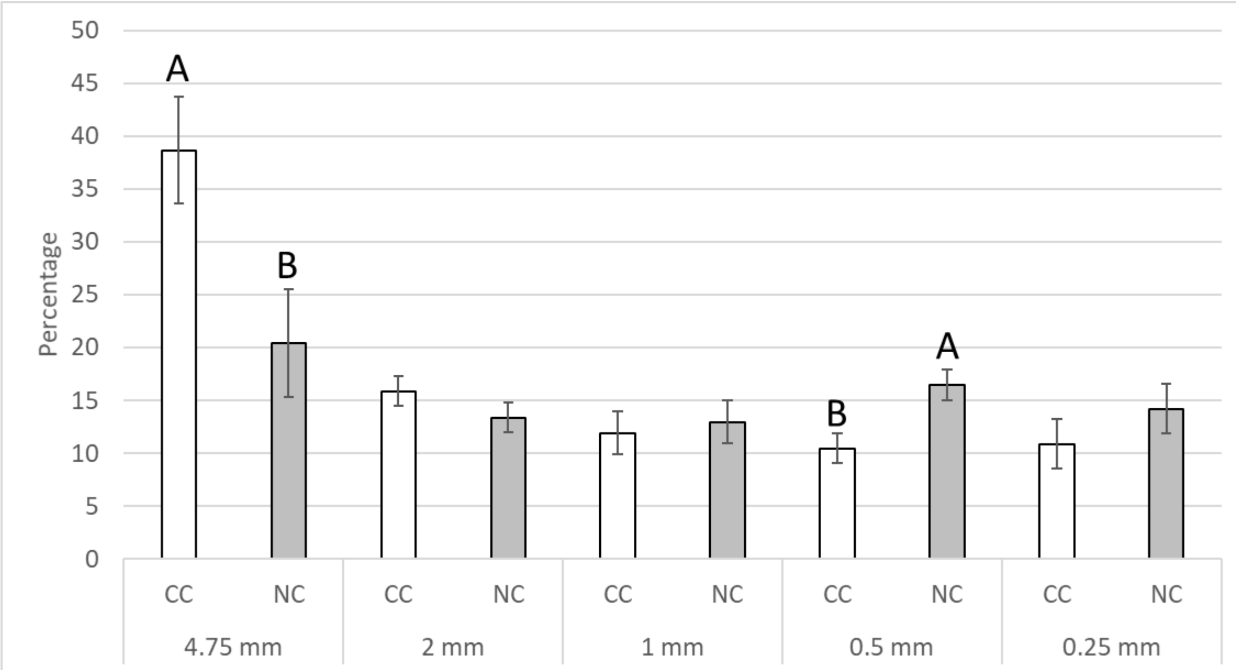


Figure 18. Percent sand free aggregate sizes in 2022 measured for cover crop (CC) and no cover crop (NC) plots at a 5 to 10 cm depth. This figure shows the percentage of soil left on each sieve. Each size was analyzed individually. Letters show statistical differences. No letters indicate no statistical difference. P=0.024, 0.1489, 0.7099, 0.014, and 0.0641 for fraction sizes 4.75 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm, respectively. Means separated at $p < 0.05$. Error bars are standard error from SAS. Values were determined by SAS.

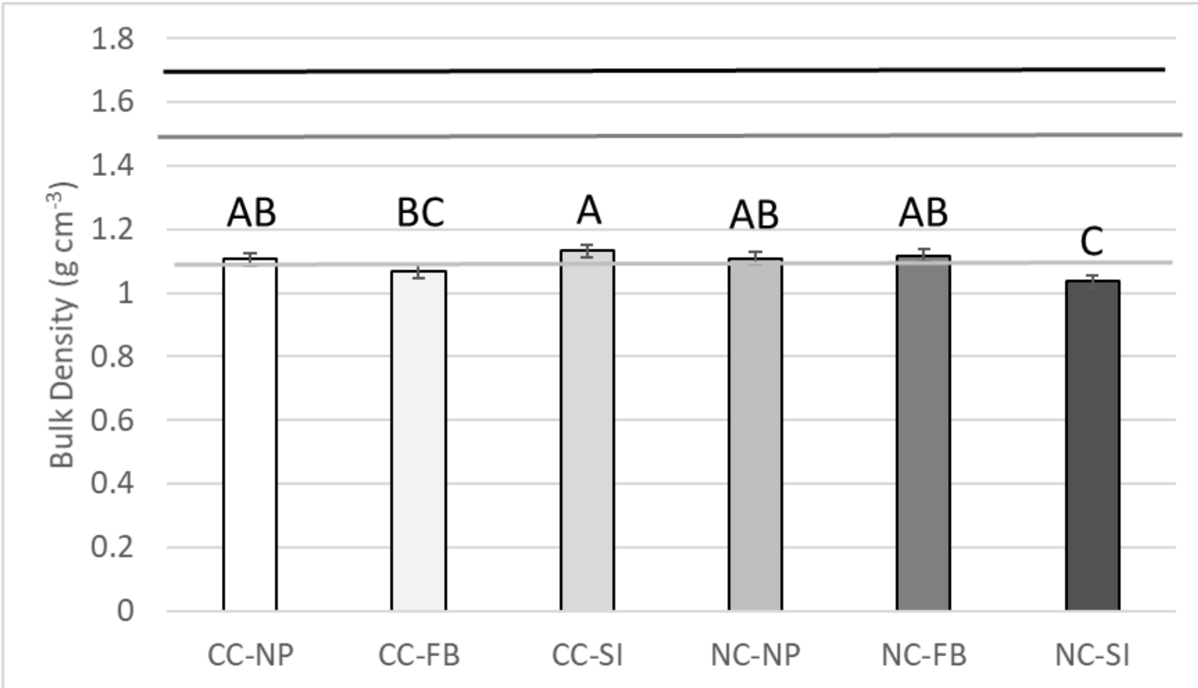


Figure 19. Bulk density results per cover crop treatment (CC, NC) and phosphorus treatment (NP, SUF, BAM) at 0 to 5 cm. Field soil texture is a silty clay loam. Ideal levels are from Dallas (2003) for this specific soil texture. Light gray line at 1.1 g cm^{-3} that shows the ideal bulk density for a silty clay loam. Gray line at 1.5 g cm^{-3} shows the density that may affect root growth in a silty clay loam. Black line at 1.65 g cm^{-3} indicates that the densities here and above would restrict root growth in a silty clay loam. Means separated at $p < 0.05$. P=0.0102. Letters indicate significance, no letters indicate no significance. Error bars are standard error from SAS. Values were determined by SAS.

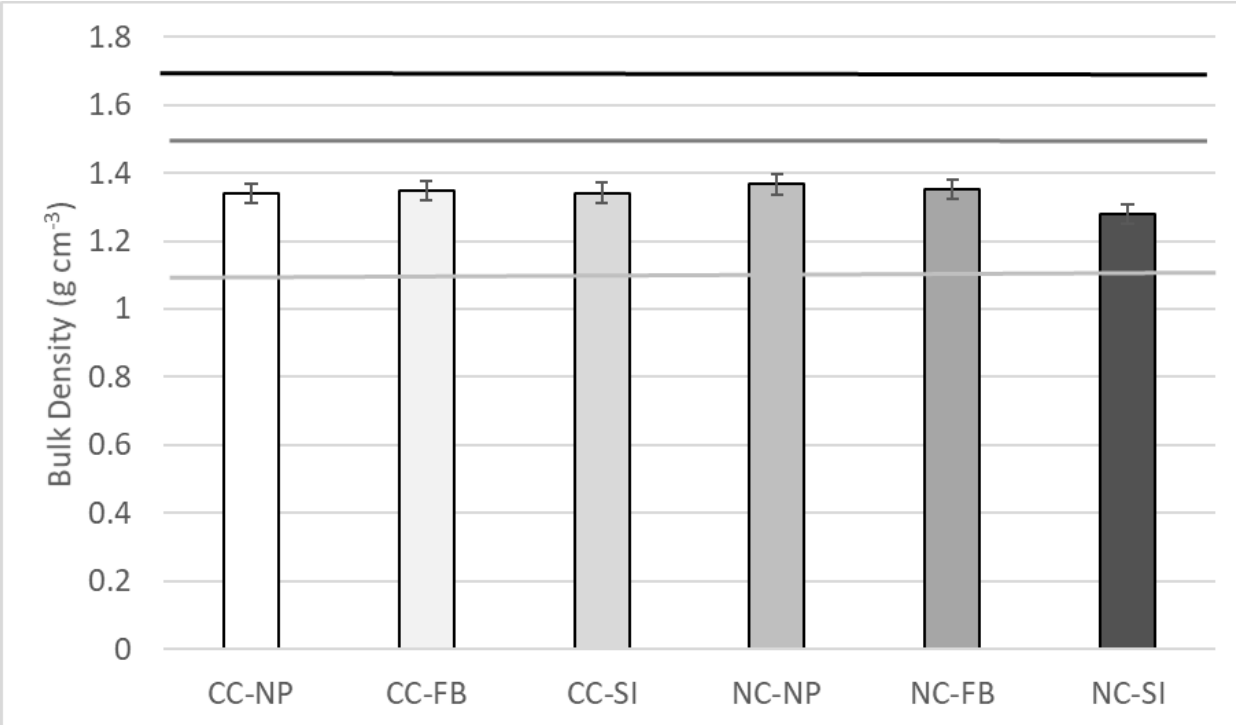


Figure 20. Bulk density results per cover crop treatment (CC, NC) and phosphorus treatment (NP, SUF, BAM) at 5 to 10 cm. Field soil texture is a silty clay loam. Ideal levels are from Dallas (2003) for this specific soil texture. Light gray line at 1.1 g cm^{-3} that shows the ideal bulk density for a silty clay loam. Gray line at 1.5 g cm^{-3} shows the density that may affect root growth in a silty clay loam. Black line at 1.65 g cm^{-3} indicates that the densities here and above would restrict root growth in a silty clay loam. Means separated at $p < 0.05$. P=0.2201. Letters indicate significance, no letters indicate no significance. Error bars are standard error from SAS. Values were determined by SAS.

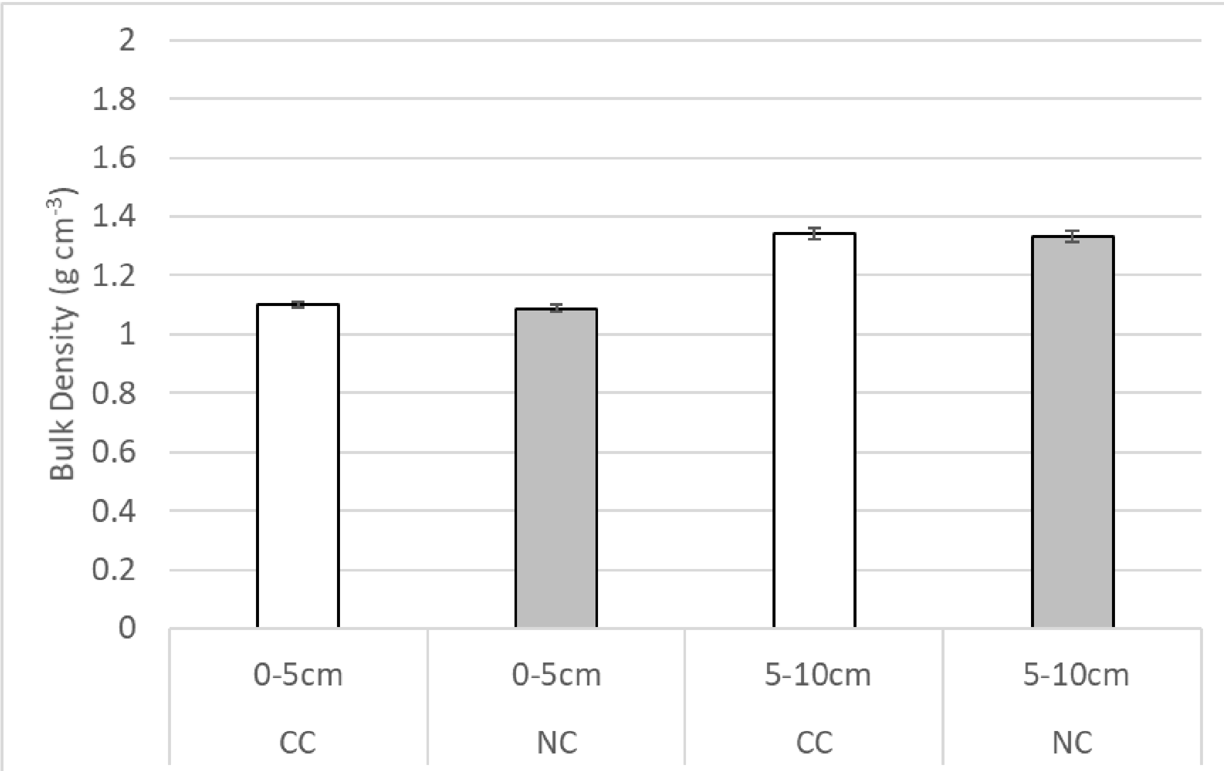


Figure 21. Bulk density results per cover crop treatments (cover crop (CC) and no cover crop (NC)) at 0 to 5 cm and 5 to 10 cm depths. Means separated at $p < 0.05$. P = 0.3993 at 0 to 5 cm and p = 0.6172 at 5 to 10 cm. Error bars are standard error from SAS. Letters indicate no statistical difference. Results were analyzed by depth. Values were determined by SAS.

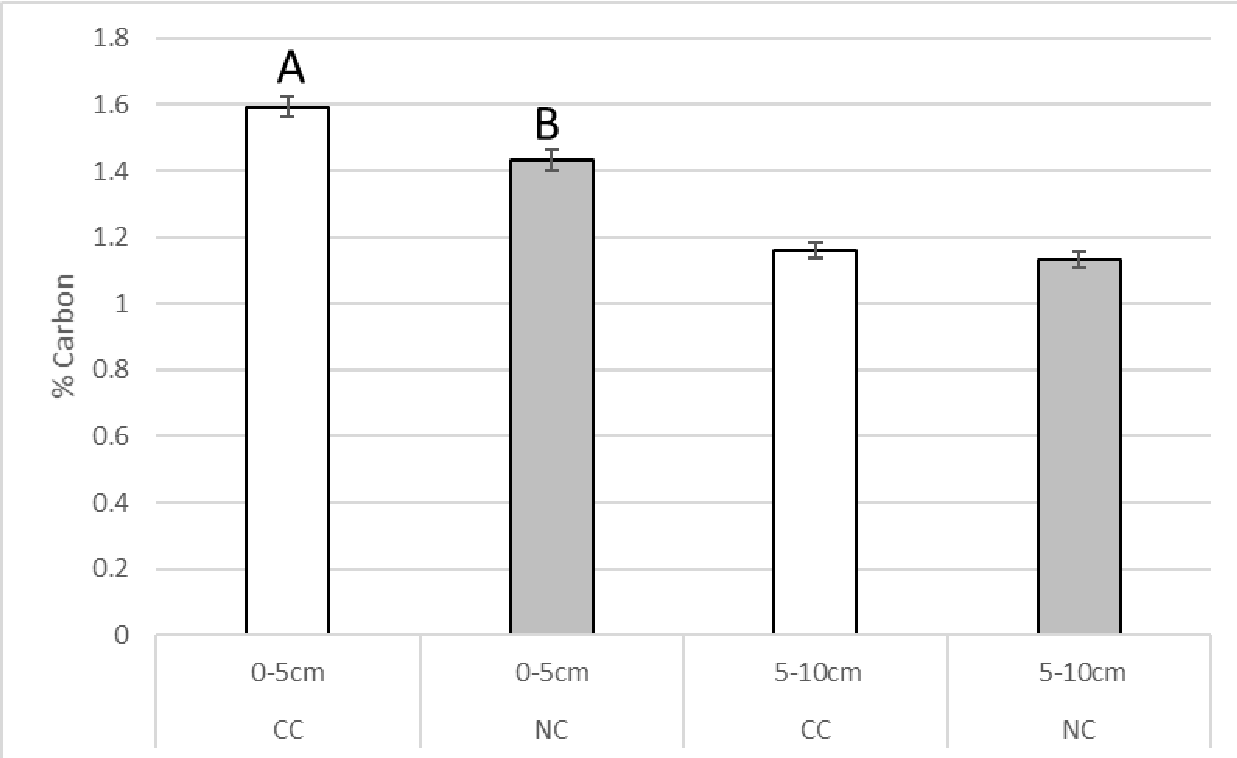


Figure 22. Percent soil organic carbon results per cover crop treatment (cover crop (CC) and no cover crop (NC) at 0 to 5 cm and 5 to 10 cm depths in 2022. Means separated at $p < 0.05$. P = 0.0019 at 0 to 5 cm and p = 0.3627 at 5 to 10 cm. Error bars are standard error from SAS. Letters indicate statistical differences. No letters indicate no statistical differences. Results were analyzed individually by depth. Values were determined by SAS.

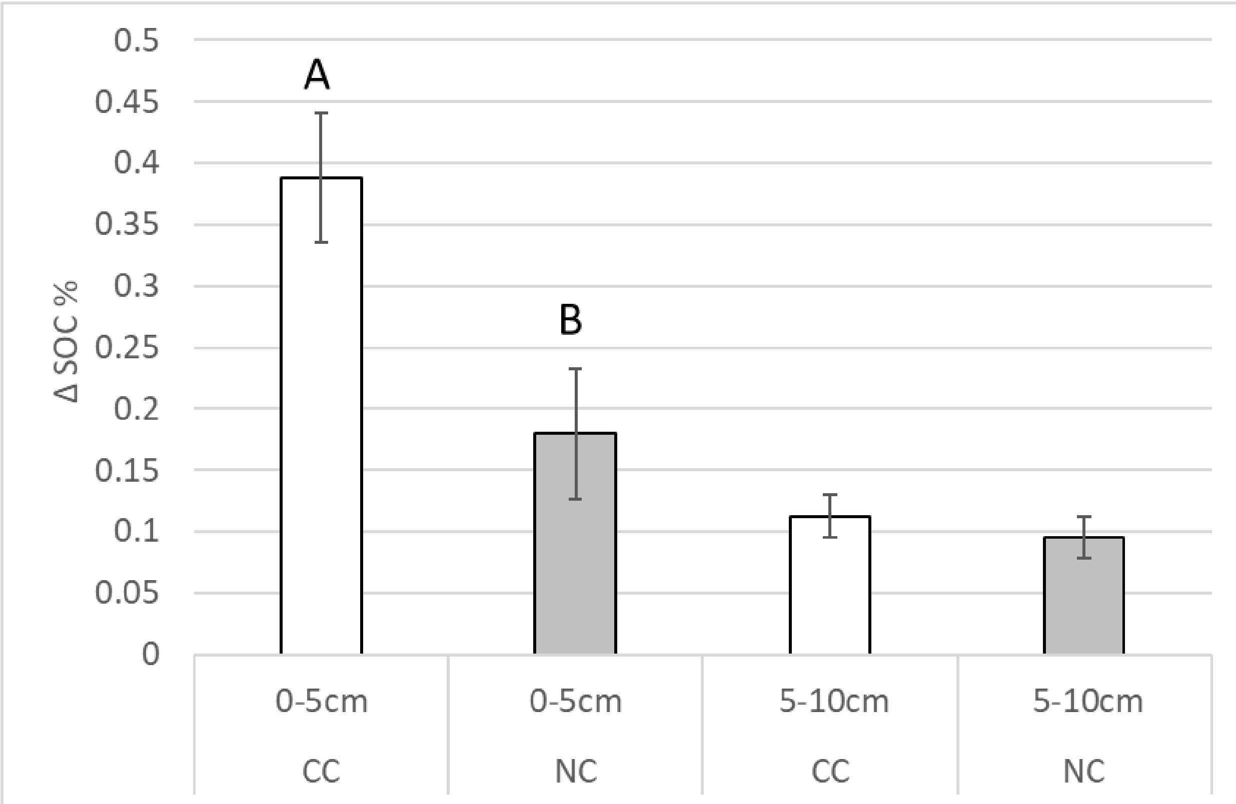


Figure 23. Percent ΔSOC results per cover crop treatment (cover crop (CC), and no cover crop (NC)) at both depths (0 to 5 cm and 5 to 10 cm). Means separated at $p < 0.05$. P = 0.0017 at 0 to 5 cm and p = 0.4946 at 5 to 10 cm. Error bars are standard error from SAS. Letters indicate statistical differences. No letters indicate no statistical difference. Results were analyzed individually by depth. Values were determined by SAS.

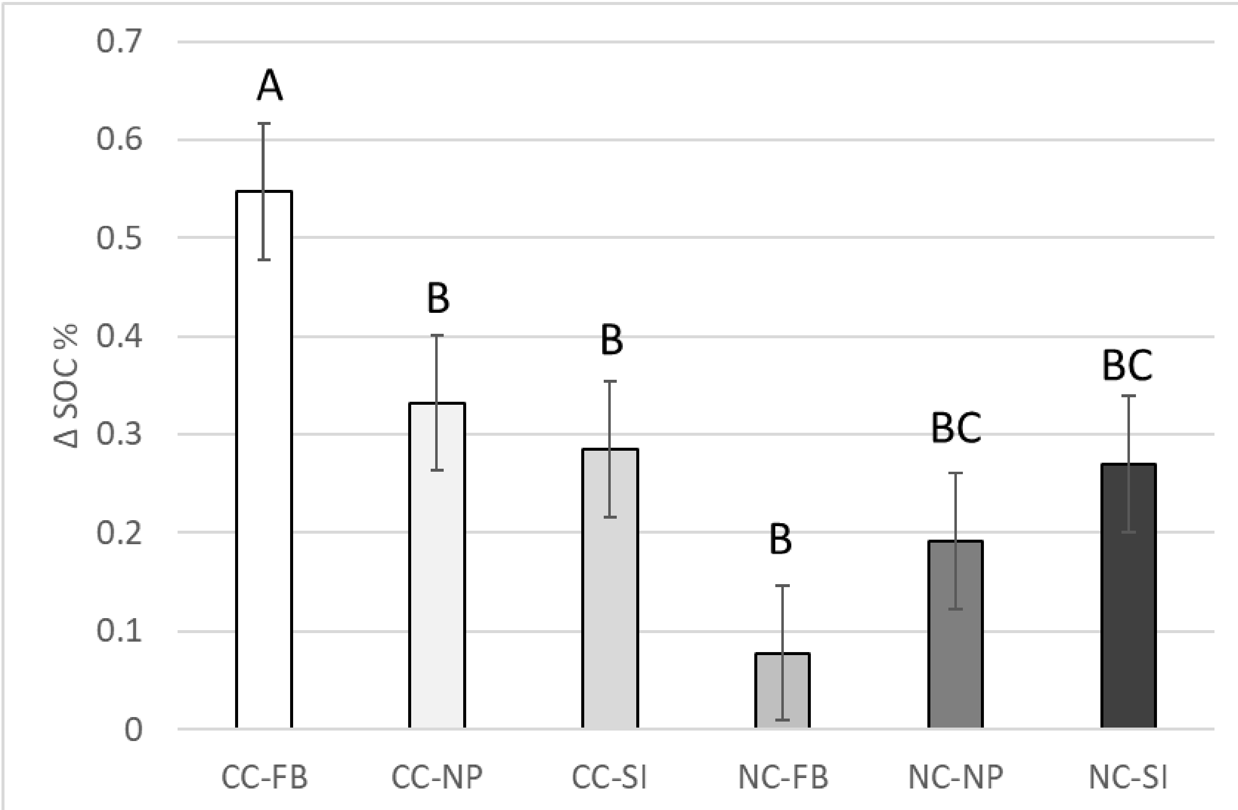


Figure 24. Percent ΔSOC interaction of cover (cover crop (CC) and no cover crop (NC)) by fertilizer (No Phosphorus (NP), Fall Broadcast (FB), and Spring Injection (SI)) in the 0 to 5 cm depth. Means separated at $p < 0.05$. P = 0.0049. Error bars are standard error from SAS. Letters indicate statistical differences. No letters indicate no statistical difference. Values were determined by SAS.

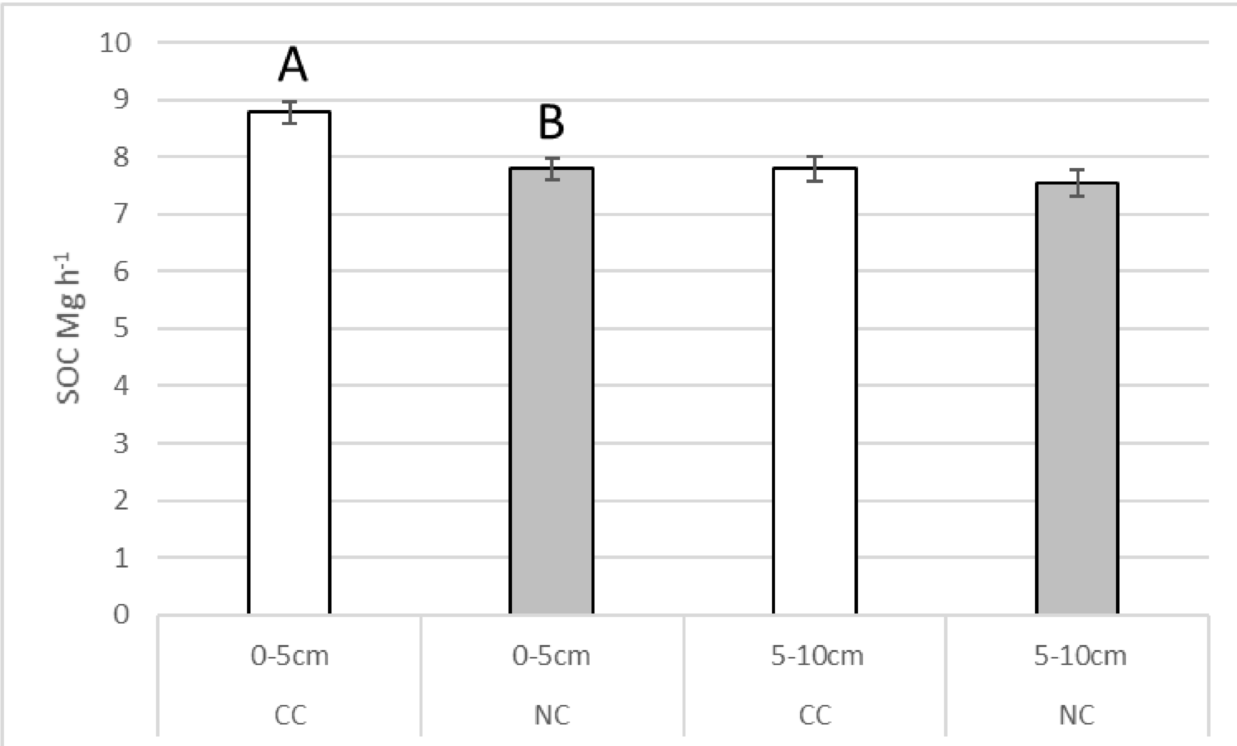


Figure 25. Soil organic carbon (Mg ha-1) results per cover crop treatment (cover crop (CC) and no cover crop ((NC)) at 0 to 5 cm and 5 to 10 cm depths in 2022. Means separated at p < 0.05. P = 0.0017 at 0 to 5 cm and p = 0.3301 at 5 to 10 cm. Error bars are standard error from SAS. Letters indicate statistical differences. No letters indicate no significant difference. Results were analyzed individually by depth. Values were determined by SAS.

Chapter 4 - Conclusions

This study's purpose was to determine if P management strategies and cover crops impact soil physical properties and soil organic carbon, and to examine if differences of soil organic carbon in cover crop or no cover crop treatments. The results of this study vary. It was found that P management strategies had minor effects on soil physical properties. Good soil physical properties are important because they dictate how well plants grow in the soil, the stability of the soil and how it can resist erosive forces, how dense the soil is, and how much water the soil can hold, infiltration rates, and other factors.

The mean weight diameter calculation was found to have a significant effect of cover where there was a greater effect of cover crops compared to the plots without cover crops in all years at both the 0 to 5 cm depth and the 5 to 10 cm depth. The results of the cover crop biomass (above and below ground biomass) and the previous crop residue shows that there would be plenty of residue on the soil surface during the winter months for the aggregates to have protection. The year 2019 is a good example of what happens when there is insufficient cover on the field and how the previous crop can affect aggregation; in this year the previous crop was corn, but cover crop biomass production was extremely low and is thus potentially similar to having no cover crops at all. The overall results of the MWD show that cover keeps the soil safe from external forces, and the importance of having protection.

The total aggregation calculation shows that the external factors of that year will play a part in the effect of cover at both depths. The 0 to 5 cm depth shows that there was only one year which did not have a significant effect of cover on TA (2017). This year had low precipitation and higher heat, which caused stress on the cover crop and the crop of that year, meaning there was less protection on the soil surface, and not a lot of SOC in the soil to bind aggregates together. The 5 to 10 cm depth shows that only two out of the four years had a significant effect of cover on TA. The years which did not have a significant effect of cover were 2017 and 2019, while 2018 and 2022 had significant effects. Again, this shows how important the previous crop and the external forces are to aggregation.

The aggregate size fraction data showed an overall trend of cover crop treatments increasing aggregation compared to no cover treatments. The size fractions between each year show an increase in sizes over time under cover crops. Under no cover treatments there was a greater amount of smaller sized aggregate fractions compared to cover treatments in some years.

The results of bulk density indicate no significant main effect of cover or fertilizer but there was an interaction of cover by fertilizer in the 0 to 5 cm depth, but not the 5 to 10 cm depth. Bulk density was found to be at the ideal level (1.10g cm^{-3}) in the surface depth, while the subsurface depth is denser, yet still less than 1.55 g cm^{-3}, a density that is considered root-restrictive for silty clay loam soil textures. Overall, the 0 to 5 cm depth was less dense compared to the 5 to 10 cm depth, with no significant differences between treatments.

The 2022 total carbon percentage results show that there was a significant effect of cover on the surface depth where CC was greater than NC and no effect in the subsurface depth. When looking at the residual SOC percentage there is an effect of cover on the 0 to 5 cm depth, but not the 5 to 10 cm depth. Showing that over time and with cover crops the SOC percentage increases. When converting SOC to SOC Mg ha^{-1}, the surface depth had a significant of cover where cover crops were greater than no cover crop plots. These results show how cover crops can increase the amount of SOC in the soil.

The soil texture across the landscape of this field showed points where the clay content differed by ±15%. Clay content was found to significantly correlate and positively correlate with

MWD, TA, the 1 m, 0.5 mm, and 0.25 mm size fractions in the 0 to 5 cm depth. It was concluded that clay content was significant to influence aggregation, particularly for small aggregates. After a correlation was ran between clay content and soil organic carbon, it was concluded that these two variables are not correlated with each other.

The hypotheses have different results. One hypothesis was that P management strategies will not affect soil physical properties or organic carbon. We fail to reject this hypothesis because our results indicate that P management strategies did not impact soil physical properties or soil organic carbon. A second hypothesis was that cover crops will have higher aggregation, lower bulk density, and a higher amount of soil organic carbon. We fail to reject this hypothesis due to the results showing that over time cover crops had an improved amount of aggregation, a lower bulk density, and there was a significant increase of SOC in the surface depth in the results. The final hypothesis was that clay content will increase aggregate stability and increase bulk density. We would fail to reject the part of this hypothesis due to the results showing that clay content does influence aggregate stability, but we would reject the part that states clay content would increase bulk density since the results show it does not.

Overall, we conclude that cover cropping is the main factor responsible for enhancing soil physical properties at the KAW field laboratory. Further research could be warranted from the results of this study. One immediate outcome that could be explored is whether or not there is a correlation between the results of the physical properties and the water quality data being collected by other graduate students in the KAW cohort, such as impacts on runoff volume, sediment mass, or P loss.

References

Adetunji, A. T., Ncube, B., Mulidzi, R., & Lewu, F. B. (2020). Management impact and benefit of cover crops on Soil Quality: A Review. *Soil and Tillage Research*, *204*, 1–11. https://doi.org/10.1016/j.still.2020.104717

Amézketa, E. (1999). Soil Aggregate Stability: A Review. *Journal of Sustainable Agriculture*, *14*(2-3), 83–151. https://doi.org/10.1300/j064v14n02_08

Bagnall, D. K., Morgan, C. L., Bean, G. M., Liptzin, D., Cappellazzi, S. B., Cope, M., Greub, K. L., Rieke, E. L., Norris, C. E., Tracy, P. W., Aberle, E., Ashworth, A., Tavarez, O. B., Bary, A. I., Baumhardt, R. L., Gracia, A. B., Brainard, D. C., Brennan, J. R., Reyes, D. B., … Honeycutt, C. W. (2022). Selecting soil hydraulic properties as indicators of Soil Health: Measurement Response to management and site characteristics. *Soil Science Society of America Journal*, *86*(5), 1206–1226. https://doi.org/10.1002/saj2.20428

Besalatpour, A. A., Ayoubi, S., Hajabbasi, M. A., Mosaddeghi, M. R., & Schulin, R. (2013). Estimating wet soil aggregate stability from easily available properties in a highly mountainous watershed. *Catena*, *111*, 72–79. https://doi.org/10.1016/j.catena.2013.07.001

Bissonnais, Y. (1996). Aggregate stability and assessment of soil crustability and erodibility: I. Theory and methodology. *European Journal of Soil Science*, *47*(4), 425–437. https://doi.org/10.1111/j.1365-2389.1996.tb01843.x

Blake, G. R., & Hartge, K. H. (1986). Bulk density. *Methods of Soil Analysis: Part 1 Physical and Mineralogical Methods*, *5.1, Second Edition*, 363–375. https://doi.org/10.2136/sssabookser5.1.2ed.c13

Blanco-Canqui, H., Mikha, M. M., Presley, D. A. R., & Claassen, M. M. (2011). Addition of cover crops enhances no-till potential for improving soil physical properties. *Soil Science Society of America Journal*, *75*(4), 1471–1482. https://doi.org/10.2136/sssaj2010.0430

Blanco-Canqui, H., Shapiro, C. A., Wortmann, C. S., Drijber, R. A., Mamo, M., Shaver, T. M., & Ferguson, R. B. (2013). Soil Organic Carbon: The value to soil properties. *Journal of Soil and Water Conservation*, *68*(5), 129A–134A. https://doi.org/10.2489/jswc.68.5.129a

Blanco-Canqui, H., Shaver, T. M., Lindquist, J. L., Shapiro, C. A., Elmore, R. W., Francis, C. A., & Hergert, G. W. (2015). Cover crops and ecosystem services: Insights from studies in temperate soils. *Agronomy Journal*, *107*(6), 2449–2474. https://doi.org/10.2134/agronj15.0086

Blanco-Canqui, H., & Ruis, S. J. (2020). Cover crop impacts on soil physical properties: A Review. *Soil Science Society of America Journal*, *84*(5), 1527–1576. https://doi.org/10.1002/saj2.20129

Blanco-Canqui, H. (2022). Cover crops and carbon sequestration: Lessons from U.S. studies. *Soil Science Society of America Journal*, *86*(3), 501–519. https://doi.org/10.1002/saj2.20378

Bronick, C. J., & Lal, R. (2004). Soil Structure and management: A Review. *Geoderma*, *124*(1-2), 3–22. https://doi.org/10.1016/j.geoderma.2004.03.005

Büchi, L., Walder, F., Banerjee, S., Colombi, T., van der Heijden, M. G. A., Keller, T., Charles, R., & Six, J. (2022). Pedoclimatic factors and management determine soil organic carbon and aggregation in farmer fields at a regional scale. *Geoderma*, *409*, 1–12. https://doi.org/10.1016/j.geoderma.2021.115632

Buck, H. J., & Palumbo-Compton, A. (2022). Soil Carbon Sequestration as a climate strategy: What do farmers think? *Biogeochemistry*, 1–12. https://doi.org/10.1007/s10533-022-00948-2

Cai, A., Han, T., Ren, T., Sanderman, J., Rui, Y., Wang, B., Smith, P., Xu, M., & Li, Y. (2022). Declines in soil carbon storage under no tillage can be alleviated in the long run. *Geoderma*, *425*, 1–3. https://doi.org/10.1016/j.geoderma.2022.116028

Carver, R. E., Nelson, N. O., Roozeboom, K. L., Kluitenberg, G. J., Tomlinson, P. J., Kang, Q., & Abel, D. S. (2022). Cover crop and phosphorus fertilizer management impacts on surface water quality from a no-till corn-soybean rotation. *Journal of Environmental Management*, *301*, 1–11. https://doi.org/10.1016/j.jenvman.2021.113818

Chaplot, V., & Cooper, M. (2015). Soil aggregate stability to predict organic carbon outputs from soils. *Geoderma*, *243-244*, 205–213. https://doi.org/10.1016/j.geoderma.2014.12.013

Cotrufo, M. F., Soong, J. L., Horton, A. J., Campbell, E. E., Haddix, M. L., Wall, D. H., & Parton, W. J. (2015). Formation of soil organic matter via biochemical and physical pathways of litter mass loss. *Nature Geoscience*, *8*(10), 776–779. https://doi.org/10.1038/ngeo2520

Dallas. (2003). Protecting Urban Soil Quality: Examples for Landscape Codes and Specifications. 1–20.

Davis, C. J., Presley, D. A. R., Rivard, C. L., Griffin, J. J., & Tomlinson, P. J. (2022). Conservation systems influence on soil properties in pumpkin production. *Soil Science Society of America Journal*, *86*(2), 435–449. https://doi.org/10.1002/saj2.20365

Ellert, B. H., Janzen, H. H., & McConkey, B. G. (2019). Measuring and Comparing Soil Carbon Storage. In R. Lal, J. M. Kimble, R. F. Follett, & B. A. Stewart (Eds.), *Assessment Methods for Soil Carbon* (pp. 131–146). essay, CRC Press.

Elliott, E. T. (1986). Aggregate structure and carbon, nitrogen, and phosphorus in native and cultivated soils. *Soil Science Society of America Journal*, *50*(3), 627–633. https://doi.org/10.2136/sssaj1986.03615995005000030017x

Fernández-Ugalde, O., Barré, P., Hubert, F., Virto, I., Girardin, C., Ferrage, E., Caner, L., & Chenu, C. (2013). Clay mineralogy differs qualitatively in aggregate-size classes: Clay-mineral-based evidence for aggregate hierarchy in temperate soils. *European Journal of Soil Science*, *64*(4), 410–422. https://doi.org/10.1111/ejss.12046

Hartmann, M., & Six, J. (2022). Soil structure and microbiome functions in Agroecosystems. *Nature Reviews Earth & Environment*, 1–11. https://doi.org/10.1038/s43017-022-00366-w

Haruna, S. I., Anderson, S. H., Udawatta, R. P., Gantzer, C. J., Phillips, N. C., Cui, S., & Gao, Y. (2020). Improving soil physical properties through the use of cover crops: A review. *Agrosystems, Geosciences & Environment*, *3*(1), 1–18. https://doi.org/10.1002/agg2.20105

Kemper, W. D., & Rosenau, R. C. (1986). Aggregate Stability and Size Distribution. In *Methods of soil analysis, part 1: Physical and mineralogical methods* (2nd ed., Vol. 9, pp. 425–442). essay, Soil Science Society of America

Kilmer, V. J., & Alexander, L. T. (1949). Methods of making mechanical analyses of soils. *Soil Science*, *68*(1), 15–24. https://doi.org/10.1097/00010694-194907000-00003

Lazicki, P., Mazza Rodrigues, J. L., & Geisseler, D. (2021). Sensitivity and variability of soil health indicators in a California cropping system. *Soil Science Society of America Journal*, *85*(5), 1827–1842. https://doi.org/10.1002/saj2.20278

LECO Corp. (2005) Carbon and Nitrogen in Soil and Sediment. Organic Application Note: TruSpec CN (Form No. 203-821-275). St. Joseph.

LECO Corp. (2006) LECO TruSpec CN Carbon/Nitrogen Determinator Instruction Manual. St. Joseph.

Lehmann, J., and Kleber, M. (2015). The contentious nature of soil organic matter. *Nature, (528)*, 60-68.

McVay, K. A., Budde, J. A., Fabrizzi, K., Mikha, M. M., Rice, C. W., Schlegel, A. J., Peterson, D. E., Sweeney, D. W., & Thompson, C. (2006). Management effects on soil physical properties in long-term tillage studies in Kansas. *Soil Science Society of America Journal*, *70*(2), 434–438. https://doi.org/10.2136/sssaj2005.0249

Mikha, M. M., & Rice, C. W. (2004). Tillage and manure effects on soil and aggregate-associated carbon and nitrogen. *Soil Science Society of America Journal*, *68*(3), 809–816. https://doi.org/10.2136/sssaj2004.0809

Nelson, N. O., Roozeboom, K. L., Yeager, E. A., Williams, J. R., Zerger, S. E., Kluitenberg, G. J., Tomlinson, P. J., Abel, D. S., & Carver, R. E. (2022). Agronomic and economic implications of cover crop and phosphorus fertilizer management practices for water quality improvement. *Journal of Environmental Quality*, *52*(1), 113–125. https://doi.org/10.1002/jeq2.20427

Nimmo, J. R., & Perkins, K. S. (2002). Aggregate Stability and Size Distribution. In *Methods of soil analysis: Part 4: Physical methods* (Vol. 5, Ser. 4, pp. 317–328). essay, Soil Science Society of America.

NRCS. (2019, May). *Soil Bulk Density / Moisture / Aeration*. Soil Health - Guides for Educators. Retrieved July 16, 2022, from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_050936.pdf

Ozlu, E., & Arriaga, F. J. (2021). The role of carbon stabilization and minerals on soil aggregation in different ecosystems. *CATENA*, *202*, 1–11. https://doi.org/10.1016/j.catena.2021.105303

Portella, C. M., Guimarães, M. de, Feller, C., Fonseca, I. C., & Tavares Filho, J. (2012). Soil aggregation under different management systems. *Revista Brasileira De Ciência Do Solo*, *36*(6), 1868–1877. https://doi.org/10.1590/s0100-06832012000600021

Presley, D. A. R., Sindelar, A. J., Buckley, M. E., & Mengel, D. B. (2012). Long-term nitrogen and tillage effects on soil physical properties under continuous grain sorghum. *Agronomy Journal*, *104*(3), 749–755. https://doi.org/10.2134/agronj2011.0311

Rabot, E., Wiesmeier, M., Schlüter, S., & Vogel, H.-J. (2018). Soil structure as an indicator of soil functions: A Review. *Geoderma*, *314*, 122–137. https://doi.org/10.1016/j.geoderma.2017.11.009

Shaw, J. N., Reeves, D. W., & Truman, C. C. (2003). Clay mineralogy and dispersibility of soil and sediment derived from Rhodic Paleudults. *Soil Science*, *168*(3), 209–217. https://doi.org/10.1097/01.ss.0000058893.60072.a7

Simon, L. M., Obour, A. K., Holman, J. D., & Roozeboom, K. L. (2022). Long-term cover crop management effects on soil properties in dryland cropping systems. *Agriculture, Ecosystems & Environment*, *328*, 107852. https://doi.org/10.1016/j.agee.2022.107852

Six, J., Bossuyt, H., Degryze, S., & Denef, K. (2004). A history of research on the link between (micro)aggregates, soil biota, and Soil Organic Matter Dynamics. *Soil and Tillage Research*, *79*(1), 7–31. https://doi.org/10.1016/j.still.2004.03.008

Soil Survey Laboratory Staff. 1996. Soil survey laboratory methods manual. Soil Survey Investigation Report No. 42 version 3.0. National Soil Survey Center, Lincoln, NE.

Stewart, C. E., Paustian, K., Conant, R. T., Plante, A. F., & Six, J. (2007). Soil Carbon Saturation: Concept, evidence and evaluation. *Biogeochemistry*, *86*(1), 19–31. https://doi.org/10.1007/s10533-007-9140-0

Stone, L. R., & Schlegel, A. J. (2010). Tillage and crop rotation phase effects on soil physical properties in the west-central great plains. *Agronomy Journal*, *102*(2), 483–491. https://doi.org/10.2134/agronj2009.0123

Tautges, N. E., Chiartas, J. L., Gaudin, A. C., O'Geen, A. T., Herrera, I., & Scow, K. M. (2019). Deep soil inventories reveal that impacts of cover crops and compost on soil carbon sequestration differ in surface and subsurface soils. *Global Change Biology*, *25*(11), 3753–3766. https://doi.org/10.1111/gcb.14762

Tisdall, J. M., & Oades, J. M. (1982). Organic matter and water-stable aggregates in soils. *Journal of Soil Science*, *33*(2), 141–163. https://doi.org/10.1111/j.1365-2389.1982.tb01755.x

Totsche, K. U., Amelung, W., Gerzabek, M. H., Guggenberger, G., Klumpp, E., Knief, C., Lehndorff, E., Mikutta, R., Peth, S., Prechtel, A., Ray, N., & Kögel-Knabner, I. (2017). Microaggregates in soils. *Journal of Plant Nutrition and Soil Science*, *181*(1), 104–136. https://doi.org/10.1002/jpln.201600451

Trivedi, P., Delgado-Baquerizo, M., Jeffries, T. C., Trivedi, C., Anderson, I. C., Lai, K., McNee, M., Flower, K., Pal Singh, B., Minkey, D., & Singh, B. K. (2017). Soil aggregation and associated microbial communities modify the impact of agricultural management on carbon content. *Environmental Microbiology*, *19*(8), 3070–3086. https://doi.org/10.1111/1462-2920.13779

Tucker, M. R., Clay minerals: Their importance and function in soils. 1–2 (1999). Raleigh, NC; NCDA & CS Agronomic Division.

USDA Natural Resources Conservation Service. (1996, April). *Soil Quality Indicators: Aggregate Stability*. Retrieved April 22, 2022, from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052820.pdf

USDA Natural Resources Conservation Service. (2008, June). *Bulk Density*. Soil Quality Indicators. Retrieved August 13, 2022, from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053256.pdf

van Bavel, C. H. (1950). Mean weight-diameter of soil aggregates as a statistical index of aggregation. *Soil Science Society of America Journal*, *14*(C), 20–23. https://doi.org/10.2136/sssaj1950.036159950014000c0005x

Van Eerd, L. L., DeBruyn, A. H., Ouellette, L., Hooker, D. C., & Robinson, D. E. (2018). Quantitative and qualitative comparison of three wet aggregate stability methods using a long-term tillage system and crop rotation experiment. *Canadian Journal of Soil Science*, *98*(4), 738–742. https://doi.org/10.1139/cjss-2018-0101

Villamil, M. B., Bollero, G. A., Darmody, R. G., Simmons, F. W., & Bullock, D. G. (2006). No-till corn/soybean systems including winter cover crops. *Soil Science Society of America Journal*, *70*(6), 1936–1944. https://doi.org/10.2136/sssaj2005.0350\

Wagner, S., Cattle, S. R., & Scholten, T. (2007). Soil-aggregate formation as influenced by Clay Content and organic-Matter Amendment. *Journal of Plant Nutrition and Soil Science*, *170*(1), 173–180. https://doi.org/10.1002/jpln.200521732

Wilpiszeski, R. L., Aufrecht, J. A., Retterer, S. T., Sullivan, M. B., Graham, D. E., Pierce, E. M., Zablocki, O. D., Palumbo, A. V., & Elias, D. A. (2019). Soil aggregate microbial communities: Towards understanding microbiome interactions at biologically relevant scales. *Applied and Environmental Microbiology*, *85*(14), 1–18. https://doi.org/10.1128/aem.00324-19

Appendix A - Statistical Codes

MWD, TA, and Aggregate Fraction Statistical Analysis Code

```
data aaa; input yr plot point rep cover$ fert$ depth$ A B C D E TA MWD;
label MWD='Mean Weight Diameter (mm)' TA='Total Aggregation (g)' A=' 4.75(mm)' B='
2(mm)' C=' 1(mm)' D=' 0.5(mm)' E=' 0.25(mm)';
label depth='depth (cm)';
cards;
.
.
.
proc sort data=aaa; by yr plot cover fert rep depth;
proc means data = aaa noprint;
  by yr plot cover fert rep depth;
  var MWD TA A B C D E;
  output out=ccc mean=MWD TA A B C D E;
  run;
proc sort data=ccc; by yr depth cover fert rep;
proc glimmix data = ccc noitprint; by yr depth;
class cover fert rep;
model GMD = cover|fert/ddfm = satterth;
random rep;
lsmeans cover|fert / lines
ods output Tests3=ANOVA2;
run;
```

Bulk Density, TC and SOC Statistical Analysis Code

```
data aaa; input yr plot point rep cover$ fert$ ID$ depth$ BD TC SOC;

label BD='Oven-Dry Bulk Density (g/cm3)' TC='Total Carbon (%)'  SOC='Mg/ha)';

label depth='depth (cm)';

cards;
.
.
.
proc sort data=aaa; by plot cover fert rep depth;

proc means data = aaa noprint;

  by plot cover fert rep depth;

  var BD TC SOC;

  output out=ccc mean=BD TC SOC;

  run;

proc sort data=ccc; by depth cover fert rep;

proc glimmix data = ccc noitprint; by depth;

class cover fert rep;

model bd = cover|fert/ddfm = satterth;

random rep;

lsmeans cover|fert / lines ;

run;

quit;
```

Residual Total Carbon Statistical Code

```
OPTIONS ps=4000;
data aaa; input plot point rep cover$ fert$ depth$ TC;
label TC='Total Carbon (%)';
```

```
label depth='depth (cm)';
cards;
.
.
.
*/*Average data from each point for variables of interst;
proc sort data=aaa; by plot cover fert rep depth;
proc means data = aaa noprint;
  by plot cover fert rep depth;
  var TC;
  output out=ccc mean=TC;
  run;
*/* Run ANOVA and output the ANOVA results to a new dataset;
proc sort data=ccc; by depth cover fert rep;
proc glimmix data =ccc noitprint; by depth;
class cover fert rep;
model tc = cover|fert/ddfm = satterth;
random rep;
lsmeans cover|fert / lines ;
run;
quit;
```

Soil Organic Carbon and Clay Correlation Code

```
data ;
input soc clay;
datalines;
.
.
.
;
proc corr;
var soc clay;
run;
```

Appendix B - Raw Data Results

2017 Raw Data Tables

Plot	Depth	4.75mm %	2mm %	1mm %	0.5mm %	0.25mm %
101-1	0-5cm	7.85	5.31	0.3	9.49	20.75
101-2	0-5cm	11.71	7.19	9.18	14.16	15.32
101-3	0-5cm	11.29	18.68	13.08	14.23	14.23
102-1	0-5cm	15.96	15.26	14.16	18.52	14.28
102-2	0-5cm	7.91	11.63	12.07	15.35	15.56
102-3	0-5cm	4.74	7.66	6.29	11.95	17.35
103-1	0-5cm	8.15	14.44	2.42	18.71	17.01
103-2	0-5cm	17.74	9.66	6.72	13.48	15.22
103-3	0-5cm	23.54	10.42	7.04	10.84	13.27
104-1	0-5cm	0.91	4.96	7.25	12.68	24.27
104-2	0-5cm	1.65	5.31	5.84	17.02	19.24
104-3	0-5cm	8.24	6.75	8.27	19.48	21.92
105-1	0-5cm	20.16	16	14.06	15.4	12.48
105-2	0-5cm	20.74	17.89	14.32	15.28	15.41
105-3	0-5cm	14.96	9.5	4.46	10.63	15.13
106-1	0-5cm	5.01	17.3	14.67	16.59	17.65
106-2	0-5cm	7.54	11.63	10.07	14.68	16.82
106-3	0-5cm	3.54	8.58	11.38	19	26.64
201-1	0-5cm	23.33	7.85	4.2	6.14	10.09
201-2	0-5cm	11.04	6.7	3.98	6.29	10.85
201-3	0-5cm	5.42	8.21	4.5	8.06	13.19
202-1	0-5cm	5.15	0.79	8.73	13.44	13.3
202-2	0-5cm	5.43	1.05	7.91	11.87	13.28
202-3	0-5cm	4.44	10.33	7.2	9.68	11.75
203-1	0-5cm	5.67	4.66	5.08	13.47	19.79
203-2	0-5cm	3.83	6.13	5.72	12.38	18.2
203-3	0-5cm	2.07	4.59	6.37	10.85	14.62
204-1	0-5cm	3.43	6.66	5.06	7.44	11.64
204-2	0-5cm	1.2	6.43	3.77	5.52	10.47
204-3	0-5cm	4.06	12.02	10.53	12.49	10.33
205-1	0-5cm	4.29	7.5	5.01	6.64	2.09
205-2	0-5cm	5.06	9.09	6.01	7.1	11.69
205-3	0-5cm	.	.	.	.	.
206-1	0-5cm	.	.	.	.	.

206-2	0-5cm	24.12	7.24	5.54	11.11	14.86
206-3	0-5cm	7.61	3.6	15.62	14.6	8.83
301-1	0-5cm	7.5	1.08	3.9	5.23	13.39
301-2	0-5cm	5.21	9.66	5	6.65	13.17
301-3	0-5cm	6.25	10.89	4.93	6.13	11.63
302-1	0-5cm	1.36	6.41	4.55	5.14	9.64
302-2	0-5cm	1.28	7.41	3.96	5.07	8.39
302-3	0-5cm	1.87	5.04	4.03	6.21	9.83
303-1	0-5cm	7.07	6.96	5.35	8.83	17.15
303-2	0-5cm	1.59	6.37	5.81	10.27	16.34
303-3	0-5cm	10.76	4.8	7.07	16.89	22.23
304-1	0-5cm	3.12	10.4	5.48	5.31	11.2
304-2	0-5cm	10.41	4.69	1.97	3.88	10.08
304-3	0-5cm	7.32	10.95	6.15	6.19	14.26
305-1	0-5cm	14.87	7.77	4.4	5.87	14.31
305-2	0-5cm	4.44	8.99	5.28	6.43	17.38
305-3	0-5cm	3.9	7.26	7.26	10.88	13.03
306-1	0-5cm	.	.	.	.	.
306-2	0-5cm	4.23	5.88	5.59	7.36	16.81
306-3	0-5cm	14.69	10.94	4.71	6.72	11.95

Plot	Depth	4.75mm %	2mm %	1mm %	0.5mm %	0.25mm %
101-1	5-10cm	11.88	11.07	9.57	13	16.87
101-2	5-10cm	4.27	15.77	14.68	17.1	16.47
101-3	5-10cm	16.12	2.71	10.51	17.69	13.86
102-1	5-10cm	16.11	14.14	12.28	16.38	13.5
102-2	5-10cm	23.97	16.07	13.37	3.92	14.74
102-3	5-10cm	7.27	7.87	13.91	22.69	20.38
103-1	5-10cm	29.51	11.23	2.34	11.83	3.74
103-2	5-10cm	5.87	8.21	11.19	25.76	19.8
103-3	5-10cm	43.05	8.09	8.26	12.55	10.12
104-1	5-10cm	3.89	7.91	7.7	13.67	19.96
104-2	5-10cm	3.51	2.64	11.96	15.15	15.7
104-3	5-10cm	3.88	10.48	10.71	19.19	23.16
105-1	5-10cm	21.52	13.2	10.78	14.22	15.31
105-2	5-10cm	42.98	9.74	10.25	12.92	11.3
105-3	5-10cm	10.61	9.94	12.58	31.59	13.75
106-1	5-10cm	3.32	8.68	10.67	14.75	20.07
106-2	5-10cm	5.5	8.91	7.14	13.4	19.41
106-3	5-10cm	2.21	9.94	14.6	25.87	19.7
201-1	5-10cm	24.87	9.35	5.52	8.29	14.5

201-2	5-10cm	9.44	10.05	4.56	6.28	12.56
201-3	5-10cm	1.02	8.03	5.47	7.53	12.36
202-1	5-10cm	5.57	4.02	9.22	12.13	16.82
202-2	5-10cm	12.51	11.67	15	18.08	4.82
202-3	5-10cm	4.1	12.72	9.08	10.38	15.2
203-1	5-10cm	7.41	6.47	7.15	14.33	16.99
203-2	5-10cm	1.72	11.39	12.15	18.06	19.74
203-3	5-10cm	1.09	10.11	11.61	17.25	18.79
204-1	5-10cm	5.64	8.45	7.15	10.83	17.62
204-2	5-10cm	6.38	13.94	8.67	14.06	17.84
204-3	5-10cm	0.11	5.55	6.21	8.44	17.27
205-1	5-10cm	2.59	9.59	1.93	5.68	10.89
205-2	5-10cm	0.82	11.31	7.59	8.11	13.41
205-3	5-10cm	.	.	.	.	.
206-1	5-10cm	.	.	.	.	.
206-2	5-10cm	0.63	10.36	11.49	21.17	21.24
206-3	5-10cm	8.17	12.87	9.33	12.06	15.38
301-1	5-10cm	4.69	8.61	4.88	6.85	16.44
301-2	5-10cm	17.9	7.36	4.23	5.29	9.64
301-3	5-10cm	.	.	.	.	.
302-1	5-10cm	5.58	9.29	4.08	5.33	13.6
302-2	5-10cm	15.32	2.03	3.73	7.24	14.88
302-3	5-10cm	0.5	4.59	0.52	4.61	11.41
303-1	5-10cm	2.27	8.79	10.65	21.71	20.94
303-2	5-10cm	4.69	7.08	7.42	10.25	17.04
303-3	5-10cm	12.59	9.86	9.5	19.04	15.49
304-1	5-10cm	5.18	5.88	4.87	4.5	11.83
304-2	5-10cm	.	.	.	.	.
304-3	5-10cm	.	.	.	.	.
305-1	5-10cm	6.57	11	4.15	6.54	15.03
305-2	5-10cm	4.23	5.88	5.59	7.36	16.81
305-3	5-10cm	.	.	.	.	.
306-1	5-10cm	.	.	.	.	.
306-2	5-10cm	35.74	8.49	5.01	7.79	10.99
306-3	5-10cm	17.69	7.1	5.1	8.45	16.16

Plot	Depth	Total Aggregation (%)	MWD (mm)
101-1	0-5cm	43.39	0.903192
101-2	0-5cm	57.38	1.343549
101-3	0-5cm	71.34	1.742014
102-1	0-5cm	78.04	1.964474
102-2	0-5cm	62.4	1.298362
102-3	0-5cm	47.77	0.874538
103-1	0-5cm	60.66	1.296239
103-2	0-5cm	62.54	1.762728
103-3	0-5cm	64.71	2.13285
104-1	0-5cm	49.8	0.582663
104-2	0-5cm	48.88	0.63538
104-3	0-5cm	64.41	1.149861
105-1	0-5cm	77.61	2.225835
105-2	0-5cm	83.24	2.333868
105-3	0-5cm	54.35	1.534589
106-1	0-5cm	71.1	1.35006
106-2	0-5cm	60.66	1.246211
106-3	0-5cm	68.75	0.967198
201-1	0-5cm	51.49	1.959832
201-2	0-5cm	38.52	1.153745
201-3	0-5cm	39.1	0.875491
202-1	0-5cm	41.34	0.70989
202-2	0-5cm	39.14	0.714539
202-3	0-5cm	43.29	0.927356
203-1	0-5cm	48.35	0.834686
203-2	0-5cm	45.93	0.765195
203-3	0-5cm	38.19	0.595782
204-1	0-5cm	33.99	0.701054
204-2	0-5cm	27.14	0.521565
204-3	0-5cm	49.08	1.018308
205-1	0-5cm	25.35	0.752634
205-2	0-5cm	38.68	0.892737
205-3	0-5cm	.	.
206-1	0-5cm	.	.
206-2	0-5cm	62.55	2.050844
206-3	0-5cm	50.02	1.045528
301-1	0-5cm	30.84	0.74848
301-2	0-5cm	39.33	0.907843
301-3	0-5cm	39.54	1.004584
302-1	0-5cm	26.77	0.53737

302-2	0-5cm	25.88	0.552701
302-3	0-5cm	26.91	0.524659
303-1	0-5cm	44.78	0.964389
303-2	0-5cm	39.69	0.616119
303-3	0-5cm	61.69	1.211649
304-1	0-5cm	35.1	0.794376
304-2	0-5cm	30.94	1.004457
304-3	0-5cm	44.54	1.097308
305-1	0-5cm	46.8	1.440231
305-2	0-5cm	42.29	0.850794
305-3	0-5cm	42.21	0.804934
306-1	0-5cm	.	.
306-2	0-5cm	39.25	0.745654
306-3	0-5cm	48.84	1.535236

Plot	Depth	Total Aggregation (%)	MWD (mm)
101-1	5-10cm	62.09	1.482105
101-2	5-10cm	67.77	1.253994
101-3	5-10cm	60.58	1.509936
102-1	5-10cm	72.14	1.89649
102-2	5-10cm	71.9	2.390709
102-3	5-10cm	71.99	1.219351
103-1	5-10cm	58.58	2.449539
103-2	5-10cm	70.56	1.123027
103-3	5-10cm	81.82	3.295823
104-1	5-10cm	52.91	0.866704
104-2	5-10cm	48.68	0.728587
104-3	5-10cm	67.09	1.033345
105-1	5-10cm	74.44	2.174502
105-2	5-10cm	86.75	3.377729
105-3	5-10cm	77.99	1.51609
106-1	5-10cm	57.18	0.903844
106-2	5-10cm	54.07	0.988589
106-3	5-10cm	72.02	0.997532
201-1	5-10cm	62.39	2.147456
201-2	5-10cm	42.68	1.175191
201-3	5-10cm	34.22	0.603107
202-1	5-10cm	47.46	0.848346
202-2	5-10cm	61.79	1.617507
202-3	5-10cm	51.02	1.022182
203-1	5-10cm	51.87	1.028652

203-2	5-10cm	62.67	0.9319
203-3	5-10cm	58.52	0.836264
204-1	5-10cm	49.38	0.962355
204-2	5-10cm	60.71	1.228233
204-3	5-10cm	37.35	0.493328
205-1	5-10cm	30.44	0.68751
205-2	5-10cm	41.06	0.732414
205-3	5-10cm	.	.
206-1	5-10cm	.	.
206-2	5-10cm	64.58	0.844581
206-3	5-10cm	57.5	1.295956
301-1	5-10cm	41.2	0.849072
301-2	5-10cm	44.32	1.59846
301-3	5-10cm	.	.
302-1	5-10cm	37.52	0.899469
302-2	5-10cm	42.93	1.282156
302-3	5-10cm	21.43	0.369843
303-1	5-10cm	64.11	0.887117
303-2	5-10cm	46.07	0.856683
303-3	5-10cm	66.36	1.520671
304-1	5-10cm	32.11	0.764893
304-2	5-10cm	.	.
304-3	5-10cm	.	.
305-1	5-10cm	43.11	1.028498
305-2	5-10cm	39.25	0.745654
305-3	5-10cm	.	.
306-1	5-10cm	.	.
306-2	5-10cm	67.91	2.779913
306-3	5-10cm	54.19	1.624716

2018 Raw Data Tables

Plot	Depth	4.75mm %	2mm %	1mm %	0.5mm %	0.25mm %
101-1	0-5cm	27.21	4.45	6.73	9.54	9.56
101-2	0-5cm	.	.	.	.	.
101-3	0-5cm	68.78	6.14	4.21	4.72	2.44
102-1	0-5cm	10.61	13.09	7.85	9.26	8.16
102-2	0-5cm	2.52	9.16	11.05	12.58	9.04
102-3	0-5cm	3.64	11.44	11.26	13.61	13.3
103-1	0-5cm	.	.	.	.	.
103-2	0-5cm	37.46	16.34	11.36	10.85	5.73

103-3	0-5cm	27.62	8.22	6.37	11.11	7.06
104-1	0-5cm	4.81	11.45	8.38	9.93	12.87
104-2	0-5cm	15.02	8.67	6.05	9.38	10.8
104-3	0-5cm	15.8	14.13	11.34	13.56	9.86
105-1	0-5cm	20.2	16.38	7.11	12.88	7.15
105-2	0-5cm	10.02	8.97	10.1	13.4	12.99
105-3	0-5cm	53.47	7.9	2.23	2.79	5.07
106-1	0-5cm	22.51	7.23	4.07	10.04	12.32
106-2	0-5cm	7.39	10.7	11.64	17.45	12.98
106-3	0-5cm	2.29	11.86	8	12.86	13.92
201-1	0-5cm	24.69	3.72	4.25	4.46	8.94
201-2	0-5cm	25.87	7.96	3.67	7	9.65
201-3	0-5cm	.	.	.	.	.
202-1	0-5cm	38.44	12.78	4.5	11.56	6.52
202-2	0-5cm	15.01	9.8	4.92	5.49	8.03
202-3	0-5cm	54.63	4.99	2.99	4.93	4.05
203-1	0-5cm	10.64	12.69	10.14	8.28	5.69
203-2	0-5cm	11.9	9.94	6.39	11.92	7.93
203-3	0-5cm	3.24	5.89	7.94	11.66	14.46
204-1	0-5cm	0.75	5.84	4.7	6.19	7.68
204-2	0-5cm	2.14	5.4	5.44	7.32	10.27
204-3	0-5cm	16.01	12.76	8.62	11.55	10.48
205-1	0-5cm	5.73	9.09	4.18	5.71	6.22
205-2	0-5cm	21.81	5.93	3.95	7.66	10.61
205-3	0-5cm	8.59	10.56	7.75	8.33	9.41
206-1	0-5cm	12.23	13.11	6.12	9.92	9.06
206-2	0-5cm	60.46	2.93	2.59	5.56	5.62
206-3	0-5cm	19.2	10.96	5.2	5.67	7.31
301-1	0-5cm	15.1	13.85	8.58	11.89	15.42
301-2	0-5cm	22.95	15.06	7.24	9.87	13.87
301-3	0-5cm	16.76	10.7	5.96	6.72	10.94
302-1	0-5cm	6.99	10.71	6.71	8.62	15.32
302-2	0-5cm	7.2	9.16	4.94	9.74	17.74
302-3	0-5cm	5.21	9.69	6.71	10.22	16.53
303-1	0-5cm	2.55	9.09	14.06	17.78	19.81
303-2	0-5cm	3.61	11.37	10.4	12.43	17.01
303-3	0-5cm	5.52	7.72	7.12	10.4	15.36
304-1	0-5cm	6.64	25.94	8.69	10	15.54
304-2	0-5cm	1.37	7.26	9.18	11.95	18.06
304-3	0-5cm	7.78	16	5.08	7.54	17.06
305-1	0-5cm	20.13	21.62	7.82	10.69	14.62

305-2	0-5cm	13.58	17.8	8.84	12.43	14.23
305-3	0-5cm	9.5	14.95	7.33	9.09	13.19
306-1	0-5cm	15.75	16.78	9.18	8.69	10.96
306-2	0-5cm	18.44	16.13	12.27	11.72	15.42
306-3	0-5cm	7.2	20.24	7.69	10.24	16.24

Plot	Depth	4.75mm %	2mm %	1mm %	0.5mm %	0.25mm %
101-1	5-10cm	48.47	8.65	7.71	7.39	3.09
101-2	5-10cm	42.93	14.7	7.45	7.56	4.48
101-3	5-10cm	64.54	10.29	4.97	4.43	2.23
102-1	5-10cm	7.22	8.81	11.28	11.38	7.55
102-2	5-10cm	0.37	13.28	14.72	14.53	11.22
102-3	5-10cm	2.26	14.47	10.66	13.51	11.43
103-1	5-10cm	48.76	11.45	6.78	7.28	3.92
103-2	5-10cm	71.97	4.61	3.97	3.58	1.54
103-3	5-10cm	50.41	8.12	9.09	10.88	4.69
104-1	5-10cm	8.93	21.33	18.21	15.18	8.43
104-2	5-10cm	31.32	9.48	11.83	17.65	8.17
104-3	5-10cm	45.46	8.57	12.86	12.6	2.79
105-1	5-10cm	39.27	16.34	8.52	9.72	4.67
105-2	5-10cm	9	10.29	11.67	11.44	9.52
105-3	5-10cm	62.37	9.32	7.56	6.58	1.97
106-1	5-10cm	48.73	7.64	11.81	11.07	3.39
106-2	5-10cm	20.5	9.71	17.61	15.87	7.38
106-3	5-10cm	12.29	17.46	17.28	19.25	12.6
201-1	5-10cm	56.71	5.57	3.99	5.75	4.01
201-2	5-10cm	25.53	10.86	3.53	4.48	6.24
201-3	5-10cm	56.47	7.21	2.27	3.07	3.38
202-1	5-10cm	36.08	10.38	5.81	8.87	7.11
202-2	5-10cm	10.33	11.25	7.34	10.84	10.29
202-3	5-10cm	28.32	12.44	7.2	9.11	9.57
203-1	5-10cm	2.02	13.29	18.08	20.24	11.42
203-2	5-10cm	3.39	12.02	13.6	19.88	10.67
203-3	5-10cm	0.3	5.41	10.63	18.37	18.46
204-1	5-10cm	2.97	6.96	5.29	13.97	20.97
204-2	5-10cm	0	5.14	4.15	7.35	21.47
204-3	5-10cm	1.53	11.14	8.1	9.76	19.25
205-1	5-10cm	4.72	12.84	7.61	7.34	13.27
205-2	5-10cm	12.03	7.47	7.14	8.52	10.59
205-3	5-10cm	13.64	6.46	7.2	9.13	11.26
206-1	5-10cm	9.01	8.99	8.09	10.69	14.11

206-2	5-10cm	18.56	10.92	5.08	10.65	14.44
206-3	5-10cm	55.88	5.09	2.94	3.63	3.35
301-1	5-10cm	.	.	.	.	.
301-2	5-10cm	22.36	18.79	12.57	15.89	12.18
301-3	5-10cm	.	.	.	.	.
302-1	5-10cm	6.53	12.52	10.18	15.63	18.99
302-2	5-10cm	3.4	13.76	7.91	10.29	14.51
302-3	5-10cm	3.52	12.59	6.29	8.6	18.16
303-1	5-10cm	0.2	6.45	16.36	35.18	21.52
303-2	5-10cm	3.58	11.56	12.51	18.47	19.75
303-3	5-10cm	2.24	12.07	14.74	20.53	20.93
304-1	5-10cm	5.88	16	8.24	12.23	21.7
304-2	5-10cm	2.09	7.7	9.67	13.56	19.23
304-3	5-10cm	8.19	15.05	8.23	10.75	16.85
305-1	5-10cm	22.62	16.19	4.47	6.16	12.34
305-2	5-10cm	1.54	10.69	7.52	16.19	24.41
305-3	5-10cm	17.68	14.35	5.83	8.36	12.42
306-1	5-10cm	41.24	15.63	7.7	9.54	8.39
306-2	5-10cm	28.22	16.87	10.61	10.83	12.5
306-3	5-10cm	21.53	15.18	10.2	13.7	15.35

Plot	Depth	Total Aggregation (%)	MWD (mm)
101-1	0-5cm	57.44	2.146780207
101-2	0-5cm	.	.
101-3	0-5cm	85.81	4.716715294
102-1	0-5cm	48.97	1.399632954
102-2	0-5cm	44.28	0.833109459
102-3	0-5cm	53.17	0.997606432
103-1	0-5cm	.	.
103-2	0-5cm	81.59	3.23546
103-3	0-5cm	60.22	2.293297914
104-1	0-5cm	47.17	1.007500361
104-2	0-5cm	49.81	1.514554347
104-3	0-5cm	64.48	1.836625718
105-1	0-5cm	63.67	2.115843384
105-2	0-5cm	55.21	1.297619759
105-3	0-5cm	71.26	3.784712223
106-1	0-5cm	55.96	1.915932732
106-2	0-5cm	60.04	1.236334786
106-3	0-5cm	48.77	0.878749942
201-1	0-5cm	45.97	1.898032855

201-2	0-5cm	54.02	2.118564458
201-3	0-5cm	.	.
202-1	0-5cm	73.59	3.093555275
202-2	0-5cm	43.15	1.503988331
202-3	0-5cm	71.08	3.783793415
203-1	0-5cm	47.22	1.407695531
203-2	0-5cm	47.99	1.373886415
203-3	0-5cm	43.06	0.736923785
204-1	0-5cm	25.11	0.483820346
204-2	0-5cm	30.51	0.580599321
204-3	0-5cm	59.09	1.757514713
205-1	0-5cm	30.84	0.887326864
205-2	0-5cm	49.81	1.809276244
205-3	0-5cm	44.48	1.187261244
206-1	0-5cm	50.2	1.484035254
206-2	0-5cm	77.12	4.083400342
206-3	0-5cm	48.22	1.806272434
301-1	0-5cm	64.46	1.749856337
301-2	0-5cm	68.77	2.244815213
301-3	0-5cm	50.9	1.67175837
302-1	0-5cm	48.24	1.094848944
302-2	0-5cm	48.71	1.045871541
302-3	0-5cm	48.19	0.963316969
303-1	0-5cm	63.07	0.933972295
303-2	0-5cm	54.61	0.983429464
303-3	0-5cm	45.88	0.922508331
304-1	0-5cm	66.62	1.603902519
304-2	0-5cm	47.65	0.692497327
304-3	0-5cm	53.34	1.290861093
305-1	0-5cm	74.13	2.296477797
305-2	0-5cm	66.39	1.78689092
305-3	0-5cm	53.48	1.395165932
306-1	0-5cm	60.94	1.862387498
306-2	0-5cm	73.77	2.082480725
306-3	0-5cm	61.44	1.443464263

Plot	Depth	Total Aggregation (%)	MWD (mm)
101-1	5-10cm	75.23	3.595533
101-2	5-10cm	76.95	3.446344
101-3	5-10cm	86.28	4.594651
102-1	5-10cm	46.21	1.107495

102-2	5-10cm	54.11	0.901351
102-3	5-10cm	52.17	0.995992
103-1	5-10cm	78.12	3.693223
103-2	5-10cm	85.58	4.853595
103-3	5-10cm	83.13	3.744412
104-1	5-10cm	71.96	1.742958
104-2	5-10cm	78.37	2.684318
104-3	5-10cm	82.25	3.50754
105-1	5-10cm	78.43	3.299603
105-2	5-10cm	51.76	1.277759
105-3	5-10cm	87.75	4.476253
106-1	5-10cm	82.56	3.658823
106-2	5-10cm	71	2.081705
106-3	5-10cm	78.71	1.849786
201-1	5-10cm	75.87	3.951301
201-2	5-10cm	50.55	2.165602
201-3	5-10cm	72.26	3.947575
202-1	5-10cm	67.98	2.870379
202-2	5-10cm	49.87	1.330549
202-3	5-10cm	66.43	2.478877
203-1	5-10cm	64.89	1.08687
203-2	5-10cm	59.42	1.065442
203-3	5-10cm	53.01	0.626898
204-1	5-10cm	49.92	0.749625
204-2	5-10cm	38.04	0.448816
204-3	5-10cm	49.59	0.803331
205-1	5-10cm	45.71	1.021439
205-2	5-10cm	45.66	1.29733
205-3	5-10cm	47.64	1.371394
206-1	5-10cm	50.75	1.194005
206-2	5-10cm	59.48	1.812455
206-3	5-10cm	70.79	3.854628
301-1	5-10cm	.	.
301-2	5-10cm	81.64	2.4359
301-3	5-10cm	.	.
302-1	5-10cm	63.68	1.225142
302-2	5-10cm	49.67	0.994323
302-3	5-10cm	49.06	0.93994
303-1	5-10cm	79.48	0.845879
303-2	5-10cm	65.69	1.06115
303-3	5-10cm	70.32	1.040564

304-1	5-10cm	63.82	1.256776
304-2	5-10cm	52.12	0.771943
304-3	5-10cm	58.98	1.348811
305-1	5-10cm	61.48	2.195791
305-2	5-10cm	59.69	0.834472
305-3	5-10cm	58.48	1.860057
306-1	5-10cm	82.39	3.396917
306-2	5-10cm	78.81	2.68192
306-3	5-10cm	75.83	2.228278

2018 Raw Data Tables

Plot	Depth	4.75mm %	2mm %	1mm %	0.5mm %	0.25mm %
101-1	0-5cm	10.01	15.5	15.5	19.73	14.94
101-2	0-5cm	4.05	6.75	8.5	18.39	19.48
101-3	0-5cm	4.05	6.75	8.5	18.39	19.48
102-1	0-5cm	3.44	4.51	2.9	8.76	16.35
102-2	0-5cm	7.23	4.15	9.68	16.74	21.44
102-3	0-5cm	9.05	8.65	7.14	12.06	15.81
103-1	0-5cm	20	7.05	6.82	16.79	18.87
103-2	0-5cm	14.79	7.73	12.47	22.52	18.91
103-3	0-5cm	1.64	19.47	21.21	23.1	14.16
104-1	0-5cm	0.58	4.12	8.26	14.6	20.47
104-2	0-5cm	5.08	4.97	5.18	12.27	21.57
104-3	0-5cm	8.12	5.89	7.93	21.08	18.24
105-1	0-5cm	13.53	8.5	11.4	20.55	20.22
105-2	0-5cm	5.51	7.13	9.53	15.85	15.21
105-3	0-5cm	4.54	9.8	15.8	20.1	19.28
106-1	0-5cm	5.69	6.32	7.86	15.62	16.86
106-2	0-5cm	1	5.61	8.16	13.48	18.99
106-3	0-5cm	1.43	2.53	2.72	9.82	16.21
201-1	0-5cm	8.29	6.34	5.19	11.02	19.53
201-2	0-5cm	10.91	4.73	4.69	10.52	15.44
201-3	0-5cm	14.29	8.67	8.36	14.6	16.13
202-1	0-5cm	2.82	4.8	5.67	10.7	17.12
202-2	0-5cm	9.61	7.66	11.38	17.84	17.28
202-3	0-5cm	10.51	7.52	8.27	15.83	14.25
203-1	0-5cm	5.36	4.56	7.03	10.64	16.9
203-2	0-5cm	9.26	9.75	13.89	24.52	19.18
203-3	0-5cm	14.87	7.82	7.15	13.68	18.45
204-1	0-5cm	0	0	1.55	4.55	16.17

204-2	0-5cm	5.29	4.3	3.61	6.87	15.19
204-3	0-5cm	2.67	3.5	4.12	8.24	16.49
205-1	0-5cm	2.14	5.64	6.4	12.29	14.31
205-2	0-5cm	1.28	3.29	4.34	8.44	16.96
205-3	0-5cm	3.13	3	3.65	7.17	15.19
206-1	0-5cm	7.18	6.41	5.6	12.26	17.06
206-2	0-5cm	5.67	3.73	3.63	7.92	12.21
206-3	0-5cm	2.78	4.02	5.46	12.05	18.32
301-1	0-5cm	2.27	4.34	3.78	9.72	16.63
301-2	0-5cm	16.35	13.28	12.08	15.8	15.94
301-3	0-5cm	7.47	5.81	5.95	12.5	18.6
302-1	0-5cm	1.33	2.4	3.36	6.69	12.94
302-2	0-5cm	3.08	4.49	4.68	9.4	17.74
302-3	0-5cm	3.9	4.08	4.63	11.36	15.5
303-1	0-5cm	6.39	7.2	9.08	14.56	20.38
303-2	0-5cm	2.93	3.45	2.66	7.64	12.1
303-3	0-5cm	8.55	6.6	4.5	11.11	18.75
304-1	0-5cm	5.48	5.85	5.68	10.85	19.52
304-2	0-5cm	0	2.13	3.52	6.61	12.5
304-3	0-5cm	11.03	8.53	5.83	10.86	18.04
305-1	0-5cm	8.19	8	8.35	11.71	18.14
305-2	0-5cm	1.7	10.48	11.1	32.09	13.67
305-3	0-5cm	7.74	6.9	7.27	10.76	16.93
306-1	0-5cm	.	.	.	.	.
306-2	0-5cm	7.87	4.48	7.19	12.14	18.09
306-3	0-5cm	3.57	7.65	8.54	12.58	19.32

Plot	Depth	4.75mm %	2mm %	1mm %	0.5mm %	0.25mm %
101-1	5-10cm	9.18	23.71	21.61	21.76	13.31
101-2	5-10cm	8.53	11.36	13.8	15.86	17.37
101-3	5-10cm	8.53	11.36	13.8	15.86	17.37
102-1	5-10cm	0.61	2.54	5.04	9.76	19.5
102-2	5-10cm	3.07	9.84	14.17	20.85	19.73
102-3	5-10cm	4.61	11.71	13.22	14.57	14.34
103-1	5-10cm	9.45	17.64	27.68	25.41	10.55
103-2	5-10cm	5.22	12.99	19.5	28.02	17.07
103-3	5-10cm	1.64	19.47	21.21	23.1	14.16
104-1	5-10cm	1.08	10.18	16.39	23.09	22.34
104-2	5-10cm	4.1	13.17	16.53	22.64	18.38
104-3	5-10cm	0	5.74	11.61	21.39	24.61
105-1	5-10cm	10.42	16.99	18.37	21.28	15.63

105-2	5-10cm	1.5	10.17	14.25	21.97	22.75
105-3	5-10cm	4.14	14.37	19.69	25.67	16.96
106-1	5-10cm	.	.	.	.	.
106-2	5-10cm	.	.	.	.	.
106-3	5-10cm	11.63	11.8	12.85	19.81	20.17
201-1	5-10cm	14.67	3.12	7.08	11.84	19.25
201-2	5-10cm	11.69	7.24	8.35	12.27	14.66
201-3	5-10cm	8.59	10.42	9.25	12.77	16.2
202-1	5-10cm	4.17	6.37	7.61	9.52	13.11
202-2	5-10cm	11.69	7.24	8.35	12.27	14.66
202-3	5-10cm	4.66	11.83	13.16	18.19	18.84
203-1	5-10cm	2.36	4.02	5.53	15.12	23.4
203-2	5-10cm	0.99	7.34	11.64	22.21	22.65
203-3	5-10cm	5.02	8.77	11.06	18.61	22.54
204-1	5-10cm	0.64	3.27	6.53	12.52	18.72
204-2	5-10cm	6.24	11.53	10.02	20.23	23.19
204-3	5-10cm	0.1	4.32	5.58	12.06	19.93
205-1	5-10cm	3	4.84	6.12	11.79	12.8
205-2	5-10cm	4.14	5.03	4.45	8.67	15.71
205-3	5-10cm	1	4.12	7.09	10.79	16.26
206-1	5-10cm	1.9	7.26	10.74	15.45	22.05
206-2	5-10cm	2.96	5.16	7.29	13.43	19.6
206-3	5-10cm	3.53	8.25	8.23	11.9	18.08
301-1	5-10cm	5.28	7.22	8.16	13.55	18.7
301-2	5-10cm	5.52	0.99	7.41	10.56	17.05
301-3	5-10cm	0	5.64	6.97	8.47	11.64
302-1	5-10cm	1.95	2.86	5.6	8.29	14.2
302-2	5-10cm	1.2	5.69	7.93	10.35	18.55
302-3	5-10cm	2.54	0	5.29	9.53	16.19
303-1	5-10cm	.	.	.	.	.
303-2	5-10cm	0.83	2.09	4.94	10.06	17.79
303-3	5-10cm	3.07	6.47	8.14	16.12	19.29
304-1	5-10cm	4.62	8.02	8.77	11.6	17.8
304-2	5-10cm	0	2.91	6.74	16.49	25.38
304-3	5-10cm	2.28	6.24	6.22	13.07	18.89
305-1	5-10cm	12.43	8.98	7.27	9.27	14.28
305-2	5-10cm	10.03	9.32	9.61	13.31	18.41
305-3	5-10cm	2.24	6.98	7.68	11.85	20.04
306-1	5-10cm	12.03	13.92	9.57	10.68	14.96
306-2	5-10cm	4.88	6.54	11.94	15.44	18.79
306-3	5-10cm	10.29	7.74	11.91	12.08	13.35

Plot	Depth	Total Aggregation (%)	MWD (mm)
101-1	0-5cm	75.23	1.629
101-2	0-5cm	56.73	0.878
101-3	0-5cm	56.73	0.878
102-1	0-5cm	35.63	0.622
102-2	0-5cm	59.18	1.003
102-3	0-5cm	52.43	1.185
103-1	0-5cm	69.11	1.850
103-2	0-5cm	76.25	1.660
103-3	0-5cm	79.52	1.331
104-1	0-5cm	47.79	0.551
104-2	0-5cm	48.47	0.806
104-3	0-5cm	60.75	1.110
105-1	0-5cm	73.64	1.583
105-2	0-5cm	52.96	5.926
105-3	0-5cm	68.71	1.118
106-1	0-5cm	52	0.934
106-2	0-5cm	47.11	0.614
106-3	0-5cm	32.53	0.436
201-1	0-5cm	50.03	1.038
201-2	0-5cm	45.97	1.130
201-3	0-5cm	61.54	1.547
202-1	0-5cm	40.58	0.645
202-2	0-5cm	63.42	1.286
202-3	0-5cm	55.96	1.275
203-1	0-5cm	44.23	0.813
203-2	0-5cm	75.78	1.413
203-3	0-5cm	61.55	1.538
204-1	0-5cm	20.2	0.101
204-2	0-5cm	35	0.726
204-3	0-5cm	34.67	0.555
205-1	0-5cm	40.67	0.643
205-2	0-5cm	33.99	0.467
205-3	0-5cm	31.72	0.551
206-1	0-5cm	48.12	0.978
206-2	0-5cm	32.91	0.731
206-3	0-5cm	42.15	0.626
301-1	0-5cm	36.39	0.563
301-2	0-5cm	72.95	1.883
301-3	0-5cm	49.8	0.987

302-1	0-5cm	26.56	0.406
302-2	0-5cm	38.85	0.631
302-3	0-5cm	39.14	0.675
303-1	0-5cm	57.12	1.025
303-2	0-5cm	28.62	0.535
303-3	0-5cm	48.98	1.052
304-1	0-5cm	46.5	0.852
304-2	0-5cm	24.68	0.315
304-3	0-5cm	53.96	1.285
305-1	0-5cm	53.59	1.130
305-2	0-5cm	68.76	0.959
305-3	0-5cm	49.35	1.043
306-1	0-5cm	.	.
306-2	0-5cm	49.51	0.982
306-3	0-5cm	51.14	0.841

Plot	Depth	Total Aggregation (%)	MWD (mm)
101-1	5-10cm	89.43	1.936
101-2	5-10cm	66.74	1.360
101-3	5-10cm	66.74	1.360
102-1	5-10cm	37.37	0.425
102-2	5-10cm	67.22	1.011
102-3	5-10cm	58.3	1.102
103-1	5-10cm	90.62	1.855
103-2	5-10cm	82.73	1.359
103-3	5-10cm	79.52	1.331
104-1	5-10cm	72.87	0.949
104-2	5-10cm	74.42	1.224
104-3	5-10cm	63.08	0.660
105-1	5-10cm	82.57	1.753
105-2	5-10cm	70.2	0.835
105-3	5-10cm	80.76	1.324
106-1	5-10cm		.
106-2	5-10cm	.	.
106-3	5-10cm	76.1	1.587
201-1	5-10cm	55.81	1.363
201-2	5-10cm	54.05	1.319
201-3	5-10cm	57	1.248
202-1	5-10cm	40.6	0.790
202-2	5-10cm	54.05	1.319
202-3	5-10cm	66.53	1.142

203-1	5-10cm	50.22	0.632
203-2	5-10cm	64.55	0.781
203-3	5-10cm	65.82	1.048
204-1	5-10cm	41.56	0.486
204-2	5-10cm	71.02	1.212
204-3	5-10cm	41.8	0.474
205-1	5-10cm	38.39	0.660
205-2	5-10cm	37.65	0.702
205-3	5-10cm	38.89	0.527
206-1	5-10cm	57.1	0.779
206-2	5-10cm	48.09	0.711
206-3	5-10cm	49.88	0.846
301-1	5-10cm	52.68	0.933
301-2	5-10cm	41.38	0.713
301-3	5-10cm	32.52	0.486
302-1	5-10cm	32.78	0.504
302-2	5-10cm	43.5	0.605
302-3	5-10cm	32.56	0.429
303-1	5-10cm	.	.
303-2	5-10cm	35.67	0.420
303-3	5-10cm	52.91	0.788
304-1	5-10cm	50.69	0.912
304-2	5-10cm	51.42	0.479
304-3	5-10cm	46.59	0.685
305-1	5-10cm	52.03	1.388
305-2	5-10cm	60.51	1.316
305-3	5-10cm	48.7	0.721
306-1	5-10cm	60.94	1.565
306-2	5-10cm	57.3	0.950
306-3	5-10cm	55.19	1.292

2022 Raw Data Tables

Plot	Depth	4.75mm %	2mm %	1mm %	0.5mm %	0.25mm %
101-1	0-5cm	39.72	29.74	15.95	8.56	3.01
101-2	0-5cm	35.56	21.41	14.15	12.96	6.91
101-3	0-5cm	42.77	24.54	15.88	9.13	3.87
102-1	0-5cm	22.4	19.55	15.46	16.18	12.57
102-2	0-5cm	16.14	23.36	21.17	-13.65	42.94
102-3	0-5cm	22.36	14.75	16.48	16.33	13.66
103-1	0-5cm	63.56	16.07	6.42	5.03	3.64

103-2	0-5cm	27.36	33.33	20.27	11.12	4.27
103-3	0-5cm	76.1	12.57	5.74	3.42	1.36
104-1	0-5cm	19.97	13.19	12.16	17.98	15.09
104-2	0-5cm	7.36	11.55	-0.85	17.2	21.14
104-3	0-5cm	6.38	19.17	24.54	23.92	13.42
105-1	0-5cm	20.69	17.29	17.57	16.85	12.41
105-2	0-5cm	58.78	22.39	8.73	5.29	2.4
105-3	0-5cm	15.57	27.38	22.68	19.33	9.4
106-1	0-5cm	20.26	19.45	16.6	19.55	14.18
106-2	0-5cm	21.08	17.53	19.54	19.82	11.62
106-3	0-5cm	18.9	25.64	21.1	16.47	8.87
201-1	0-5cm	75.8	10.57	3.37	3.35	3.12
201-2	0-5cm	32.09	21.06	9.31	11.11	11.59
201-3	0-5cm	26.01	20.6	9.47	8.08	9.36
202-1	0-5cm	38.22	21.1	11.32	9.88	7.52
202-2	0-5cm	21.27	21.31	18.72	16.4	10.09
202-3	0-5cm	74.49	12.47	4.09	3.73	2.06
203-1	0-5cm	24.89	12.41	12.95	17.21	15.76
203-2	0-5cm	13.25	14.04	18.46	25.74	16
203-3	0-5cm	25.18	20.7	16.52	16.26	10.05
204-1	0-5cm	13.56	12.79	9.74	12	15.72
204-2	0-5cm	7.22	8.22	4.69	9.97	17.92
204-3	0-5cm	19.92	16.18	11.2	14.24	16.13
205-1	0-5cm	26.8	21.42	11.2	10.86	9.29
205-2	0-5cm	21.21	20.86	12.28	11.55	10.25
205-3	0-5cm	15.7	18.79	12.21	13.17	12.48
206-1	0-5cm	29.32	24.41	15.87	13	8.39
206-2	0-5cm	18.97	20.54	18.08	20.82	11.95
206-3	0-5cm	21.4	17.2	13.05	16.36	14.09
301-1	0-5cm	57.82	10.8	5.93	6.83	8.18
301-2	0-5cm	55.62	22.6	6.77	5.8	4.13
301-3	0-5cm	65.64	10.19	2.63	3.22	5.29
302-1	0-5cm	16.58	23.13	9.23	11.46	13.08
302-2	0-5cm	36.49	15.44	7.35	9.69	13.06
302-3	0-5cm	15.35	17.05	11.74	12.29	15.1
303-1	0-5cm	9.65	13.72	12.95	16.43	17.51
303-2	0-5cm	15.47	9.42	8.72	13.09	16.36
303-3	0-5cm	21.9	14.98	12.45	14.3	14.05
304-1	0-5cm	11.98	8.83	5.94	10.37	16.99
304-2	0-5cm	22.65	12.46	10.09	12.99	13.77
304-3	0-5cm	14.02	10.6	7.78	12.92	18.02

305-1	0-5cm	47.18	14.37	5.83	6.4	9.09
305-2	0-5cm	63.18	11.82	3.98	6.32	6.53
305-3	0-5cm	54.4	22.24	4.49	5.61	6.73
306-1	0-5cm	42	17.14	9.8	11.39	7.63
306-2	0-5cm	16.81	23.44	17.25	17.41	13.61
306-3	0-5cm	38.59	17.52	11.41	12.14	9.41

Plot	Depth	4.75mm %	2mm %	1mm %	0.5mm %	0.25mm %
101-1	5-10cm	52.14	18.14	13.61	9.11	4.16
101-2	5-10cm	13.83	17.02	19.04	24.34	14.06
101-3	5-10cm	66.45	15.5	7.4	4.94	2.72
102-1	5-10cm	21.01	16.73	13.27	17.02	14.24
102-2	5-10cm	24.71	14.42	18.35	18.54	11.88
102-3	5-10cm	49.59	18	10.43	9.42	5.39
103-1	5-10cm	63.01	14.66	6.48	7.11	3.94
103-2	5-10cm	82.76	9.82	3	1.86	0.94
103-3	5-10cm	71.39	10.33	7.41	5.91	2.36
104-1	5-10cm	14.7	18.22	16.99	22.41	15.04
104-2	5-10cm	9.51	15.29	17.95	26.92	14.18
104-3	5-10cm	14.28	19.1	22.89	25.57	10.74
105-1	5-10cm	16.07	22.4	24.54	19.55	9.41
105-2	5-10cm	32.36	29.3	19.09	11.74	4.21
105-3	5-10cm	21.94	17.88	26.41	20.85	7.53
106-1	5-10cm	10.42	16.08	15.87	27.12	15.21
106-2	5-10cm	38.13	19.24	13.57	14.59	8.08
106-3	5-10cm	63.11	13.97	8.62	7.85	3.87
201-1	5-10cm	60.42	17.35	5.09	4.21	4.49
201-2	5-10cm	61.96	11.83	4.32	5.42	8.34
201-3	5-10cm	51.34	16.91	5.15	4.83	8.96
202-1	5-10cm	29.34	21.05	12.09	12.72	12.81
202-2	5-10cm	20.91	18.67	37.32	16.34	13.23
202-3	5-10cm	17.81	18.29	24.89	13.3	13.3
203-1	5-10cm	13.68	18.46	22.91	18.18	12.72
203-2	5-10cm	11.8	13.9	16.98	25.01	17.26
203-3	5-10cm	11.06	14.95	23.15	28.26	12.83
204-1	5-10cm	2.8	3.96	8.04	13.41	23.05
204-2	5-10cm	10.04	7.97	8.33	11.4	19.15
204-3	5-10cm	8.72	7.44	9.65	17.55	22.3
205-1	5-10cm	29.43	10.96	7.2	8.43	12.92
205-2	5-10cm	30.78	8.03	6.27	9.82	14.82
205-3	5-10cm	26.23	10.96	7.63	9.06	14.57

206-1	5-10cm	39.9	15.19	10.09	12	11.01
206-2	5-10cm	17.21	18.16	15.02	20.44	13.29
206-3	5-10cm	26.74	13.06	8.62	10.85	15.09
301-1	5-10cm	27.02	9.63	7.98	12.16	17.91
301-2	5-10cm	41.33	20.19	6.34	6.71	9.51
301-3	5-10cm	28.66	8.4	8.34	11.11	15.96
302-1	5-10cm	17.01	15.25	8.06	12.65	12.88
302-2	5-10cm	20.85	12.82	10.32	16.01	15.64
302-3	5-10cm	12.25	7.64	10.89	14.12	14.12
303-1	5-10cm	6.24	9.9	12.36	21.92	19.9
303-2	5-10cm	13.34	12.33	13.25	12.25	14.33
303-3	5-10cm	28.49	20.23	15.12	17.78	9
304-1	5-10cm	7.85	7.79	9.12	12.08	19.87
304-2	5-10cm	19.96	11.21	11.97	15.07	18.56
304-3	5-10cm	35.48	16.97	11.59	11.97	10.93
305-1	5-10cm	47.06	8.8	4.67	6.2	11.45
305-2	5-10cm	23.78	12.64	10.76	14.27	16.55
305-3	5-10cm	25.68	11.34	7.85	9.41	18.31
306-1	5-10cm	35.18	20.62	9.35	8.68	10.05
306-2	5-10cm	9.48	17.32	10.81	0.15	35.08
306-3	5-10cm	59.61	14.66	6.95	9.01	8.85

Plot	Depth	Total Aggregation (%)	MWD (mm)
101-1	0-5cm	96.89	3.854
101-2	0-5cm	90.78	3.336
101-3	0-5cm	95.94	3.881
102-1	0-5cm	85.99	2.505
102-2	0-5cm	89.88	2.206
102-3	0-5cm	83.25	2.364
103-1	0-5cm	94.66	4.749
103-2	0-5cm	96.3	3.277
103-3	0-5cm	99.15	5.393
104-1	0-5cm	78.1	2.119
104-2	0-5cm	55.86	1.109
104-3	0-5cm	86.95	1.667
105-1	0-5cm	84.47	2.358
105-2	0-5cm	97.45	4.686
105-3	0-5cm	94.27	2.444
106-1	0-5cm	89.93	2.409
106-2	0-5cm	89.19	2.434

106-3	0-5cm	90.69	2.555
201-1	0-5cm	96.1	5.281
201-2	0-5cm	84.91	3.041
201-3	0-5cm	73.27	2.624
202-1	0-5cm	87.84	3.436
202-2	0-5cm	87.34	2.532
202-3	0-5cm	96.6	5.271
203-1	0-5cm	83	2.409
203-2	0-5cm	87.34	1.864
203-3	0-5cm	88.54	2.725
204-1	0-5cm	63.64	1.636
204-2	0-5cm	47.73	1.015
204-3	0-5cm	77.32	2.179
205-1	0-5cm	79.35	2.741
205-2	0-5cm	76.07	2.395
205-3	0-5cm	72.11	1.998
206-1	0-5cm	90.76	3.071
206-2	0-5cm	90.11	2.387
206-3	0-5cm	81.58	2.338
301-1	0-5cm	89.48	4.234
301-2	0-5cm	94.85	4.475
301-3	0-5cm	86.91	4.628
302-1	0-5cm	73.2	2.144
302-2	0-5cm	81.67	3.102
302-3	0-5cm	71.38	1.915
303-1	0-5cm	70.13	1.499
303-2	0-5cm	62.74	1.640
303-3	0-5cm	77.15	2.276
304-1	0-5cm	53.87	1.350
304-2	0-5cm	71.73	2.200
304-3	0-5cm	63.17	1.578
305-1	0-5cm	82.72	3.684
305-2	0-5cm	91.77	4.569
305-3	0-5cm	93.39	4.361
306-1	0-5cm	87.64	3.532
306-2	0-5cm	88.41	2.318
306-3	0-5cm	88.74	3.363

Plot	Depth	Total Aggregation (%)	MWD (mm)
101-1	5-10cm	97.08	4.228
101-2	5-10cm	88.2	1.992
101-3	5-10cm	96.94	4.921
102-1	5-10cm	82.2	2.307
102-2	5-10cm	87.82	2.536
102-3	5-10cm	92.66	4.025
103-1	5-10cm	95.16	4.683
103-2	5-10cm	98.26	5.672
103-3	5-10cm	97.38	5.067
104-1	5-10cm	87.11	2.047
104-2	5-10cm	83.68	1.667
104-3	5-10cm	92.39	2.140
105-1	5-10cm	91.87	2.340
105-2	5-10cm	96.64	3.446
105-3	5-10cm	94.54	2.590
106-1	5-10cm	84.41	1.725
106-2	5-10cm	93.54	3.432
106-3	5-10cm	97.4	4.701
201-1	5-10cm	91.49	4.573
201-2	5-10cm	91.88	4.496
201-3	5-10cm	87.01	4.007
202-1	5-10cm	87.74	2.921
202-2	5-10cm	106.16	2.687
202-3	5-10cm	86.91	2.291
203-1	5-10cm	85.82	2.041
203-2	5-10cm	84.78	1.747
203-3	5-10cm	90.23	1.829
204-1	5-10cm	51.13	0.680
204-2	5-10cm	56.78	1.245
204-3	5-10cm	65.56	1.210
205-1	5-10cm	68.84	2.504
205-2	5-10cm	69.62	2.495
205-3	5-10cm	68.34	3.354
206-1	5-10cm	87.98	2.158
206-2	5-10cm	83.95	2.445
206-3	5-10cm	74.18	2.357
301-1	5-10cm	74.58	3.517
301-2	5-10cm	83.99	2.413
301-3	5-10cm	72.34	1.906
302-1	5-10cm	65.64	2.126

302-2	5-10cm	75.53	1.412
302-3	5-10cm	58.78	1.193
303-1	5-10cm	70.16	1.654
303-2	5-10cm	65.29	2.905
303-3	5-10cm	90.48	2.905
304-1	5-10cm	56.55	1.119
304-2	5-10cm	76.61	2.042
304-3	5-10cm	86.81	3.155
305-1	5-10cm	78.15	3.484
305-2	5-10cm	77.89	2.300
305-3	5-10cm	72.51	2.311
306-1	5-10cm	83.69	3.202
306-2	5-10cm	72.77	1.517
306-3	5-10cm	99.03	4.501

Bulk Density, Total Carbon and Soil Organic Carbon Raw Data Tables

Plot	Depth	Bulk Density (g cm^{-3})	Total C %	SOC (Mg h^{-1})
101-1	0-5cm	1.10	1.49	8.21
101-2	0-5cm	1.13	1.46	8.24
101-3	0-5cm	1.08	1.70	9.17
102-1	0-5cm	1.10	1.65	9.11
102-2	0-5cm	1.13	1.35	7.63
102-3	0-5cm	1.15	1.47	8.43
103-1	0-5cm	0.82	1.75	7.15
103-2	0-5cm	1.13	1.63	9.25
103-3	0-5cm	1.16	2.08	12.10
104-1	0-5cm	0.95	1.46	6.90
104-2	0-5cm	1.02	1.50	7.68
104-3	0-5cm	1.02	1.62	8.27
105-1	0-5cm	1.17	1.74	10.19
105-2	0-5cm	1.17	1.52	8.88
105-3	0-5cm	1.07	1.51	8.06
106-1	0-5cm	1.14	1.41	8.04
106-2	0-5cm	1.15	1.31	7.51
106-3	0-5cm	1.07	1.28	6.86
201-1	0-5cm	1.17	1.63	9.56
201-2	0-5cm	1.17	1.70	9.91
201-3	0-5cm	1.17	1.71	10.00

202-1	0-5cm	1.14	1.71	9.78
202-2	0-5cm	1.17	1.40	8.17
202-3	0-5cm	0.97	1.76	8.50
203-1	0-5cm	1.18	1.56	9.18
203-2	0-5cm	0.94	1.35	6.32
203-3	0-5cm	1.07	1.32	7.06
204-1	0-5cm	1.16	1.39	8.06
204-2	0-5cm	1.13	1.45	8.18
204-3	0-5cm	1.19	1.34	7.98
205-1	0-5cm	1.05	1.36	7.14
205-2	0-5cm	1.07	1.51	8.06
205-3	0-5cm	1.11	1.51	8.40
206-1	0-5cm	0.95	1.43	6.78
206-2	0-5cm	1.15	1.66	9.57
206-3	0-5cm	1.10	1.65	9.08
301-1	0-5cm	1.18	1.64	9.65
301-2	0-5cm	1.03	1.72	8.86
301-3	0-5cm	1.09	1.53	8.37
302-1	0-5cm	1.15	1.34	7.73
302-2	0-5cm	0.98	1.29	6.31
302-3	0-5cm	1.08	1.53	8.26
303-1	0-5cm	0.95	1.49	7.04
303-2	0-5cm	1.13	1.44	8.15
303-3	0-5cm	1.07	1.49	7.95
304-1	0-5cm	1.12	1.29	7.20
304-2	0-5cm	1.18	1.52	8.93
304-3	0-5cm	1.07	1.49	7.95
305-1	0-5cm	1.02	1.61	8.22
305-2	0-5cm	1.02	1.27	6.48
305-3	0-5cm	1.22	1.49	9.09
306-1	0-5cm	1.10	1.47	8.12
306-2	0-5cm	1.08	1.57	8.47
306-3	0-5cm	1.18	1.22	7.21

Plot	Depth	Bulk Density (g cm^{-3})	Total C %	SOC (Mg h^{-1})
101-1	5-10cm	1.33	1.01	6.70
101-2	5-10cm	1.33	1.10	7.30
101-3	5-10cm	1.28	1.15	7.36
102-1	5-10cm	1.21	1.26	7.62

102-2	5-10cm	1.37	0.88	6.02
102-3	5-10cm	1.35	1.25	8.43
103-1	5-10cm	1.28	1.12	7.17
103-2	5-10cm	1.36	1.27	8.66
103-3	5-10cm	1.38	0.96	6.64
104-1	5-10cm	1.27	1.10	6.99
104-2	5-10cm	1.33	1.22	8.12
104-3	5-10cm	1.37	1.18	8.11
105-1	5-10cm	1.24	1.21	7.51
105-2	5-10cm	1.32	1.19	7.86
105-3	5-10cm	1.28	1.14	7.30
106-1	5-10cm	1.23	1.12	6.88
106-2	5-10cm	1.26	1.21	7.61
106-3	5-10cm	1.31	1.10	7.18
201-1	5-10cm	1.42	1.28	9.11
201-2	5-10cm	1.32	1.19	7.85
201-3	5-10cm	1.36	1.39	9.43
202-1	5-10cm	1.39	1.29	8.98
202-2	5-10cm	1.38	1.11	7.65
202-3	5-10cm	1.34	1.25	8.40
203-1	5-10cm	1.32	1.27	8.36
203-2	5-10cm	1.37	1.06	7.27
203-3	5-10cm	1.14	1.09	6.21
204-1	5-10cm	1.43	1.15	8.23
204-2	5-10cm	1.39	1.12	7.77
204-3	5-10cm	1.33	1.08	7.17
205-1	5-10cm	1.43	1.12	8.02
205-2	5-10cm	1.42	1.21	8.61
205-3	5-10cm	1.40	1.22	8.57
206-1	5-10cm	1.21	1.08	6.54
206-2	5-10cm	1.39	1.17	8.11
206-3	5-10cm	1.43	1.21	8.64
301-1	5-10cm	1.35	1.17	7.91
301-2	5-10cm	1.40	1.30	9.12
301-3	5-10cm	1.34	1.21	8.10
302-1	5-10cm	1.40	1.17	8.17
302-2	5-10cm	1.41	1.06	7.48
302-3	5-10cm	1.42	1.07	7.61
303-1	5-10cm	1.16	1.04	6.05

303-2	5-10cm	1.16	1.14	6.62
303-3	5-10cm	1.38	1.00	6.88
304-1	5-10cm	1.37	1.08	7.40
304-2	5-10cm	1.43	1.09	7.78
304-3	5-10cm	1.32	1.29	8.51
305-1	5-10cm	1.39	1.16	8.03
305-2	5-10cm	1.37	0.98	6.70
305-3	5-10cm	1.38	1.10	7.59
306-1	5-10cm	1.40	1.13	7.92
306-2	5-10cm	1.16	1.10	6.36
306-3	5-10cm	1.44	1.02	7.35

Residual Total Carbon Raw Data Table

Plot	Depth	2014 TC%	2022 TC%	ΔSOC%
101-1	0-5cm	1.09	1.49	0.403
101-1	5-10cm	0.83	1.01	0.1829
101-2	0-5cm	1.18	1.46	0.277
101-2	5-10cm	1.02	1.10	0.079
101-3	0-5cm	1.25	1.70	0.454
101-3	5-10cm	0.97	1.15	0.1829
102-1	0-5cm	1.35	1.65	0.304
102-1	5-10cm	1.14	1.26	0.116
102-2	0-5cm	0.89	1.35	0.4614
102-2	5-10cm	0.75	0.88	0.1314
102-3	0-5cm	1.35	1.47	0.123
102-3	5-10cm	1.21	1.25	0.036
103-1	0-5cm	1.16	1.75	0.586
103-1	5-10cm	0.97	1.12	0.146
103-2	0-5cm	1.15	1.63	0.477
103-2	5-10cm	1.01	1.27	0.258
103-3	0-5cm	1.10	2.08	0.984
103-3	5-10cm	0.83	0.96	0.1329
104-1	0-5cm	1.06	1.46	0.401
104-1	5-10cm	0.89	1.10	0.206
104-2	0-5cm	1.28	1.50	0.217
104-2	5-10cm	1.07	1.22	0.147
104-3	0-5cm	1.15	1.62	0.475
104-3	5-10cm	0.98	1.18	0.1951
105-1	0-5cm	1.27	1.74	0.473
105-1	5-10cm	1.13	1.21	0.085
105-2	0-5cm	1.28	1.52	0.244

105-2	5-10cm	1.18	1.19	0.015
105-3	0-5cm	1.19	1.51	0.319
105-3	5-10cm	1.16	1.14	-0.019
106-1	0-5cm	1.24	1.41	0.166
106-1	5-10cm	1.02	1.12	0.104
106-2	0-5cm	1.31	1.31	0.003
106-2	5-10cm	1.17	1.21	0.041
106-3	0-5cm	1.31	1.28	-0.028
106-3	5-10cm	1.04	1.10	0.061
201-1	0-5cm	1.38	1.63	0.253
201-1	5-10cm	1.13	1.28	0.15
201-2	0-5cm	1.36	1.70	0.336
201-2	5-10cm	1.08	1.19	0.107
201-3	0-5cm	1.39	1.71	0.322
201-3	5-10cm	1.25	1.39	0.145
202-1	0-5cm	1.34	1.71	0.366
202-1	5-10cm	1.14	1.29	0.147
202-2	0-5cm	1.12	1.40	0.285
202-2	5-10cm	1.04	1.11	0.069
202-3	0-5cm	1.34	1.76	0.419
202-3	5-10cm	1.06	1.25	0.188
203-1	0-5cm	1.12	1.56	0.437
203-1	5-10cm	0.94	1.27	0.3343
203-2	0-5cm	1.26	1.35	0.086
203-2	5-10cm	1.02	1.06	0.045
203-3	0-5cm	1.16	1.32	0.157
203-3	5-10cm	0.89	1.09	0.2032
204-1	0-5cm	1.26	1.39	0.127
204-1	5-10cm	1.12	1.15	0.032
204-2	0-5cm	1.12	1.45	0.335
204-2	5-10cm	1.01	1.12	0.114
204-3	0-5cm	1.28	1.34	0.062
204-3	5-10cm	1.03	1.08	0.048
205-1	0-5cm	1.31	1.36	0.05
205-1	5-10cm	1.10	1.12	0.022
205-2	0-5cm	1.34	1.51	0.174
205-2	5-10cm	1.22	1.21	-0.006
205-3	0-5cm	1.40	1.51	0.107
205-3	5-10cm	1.13	1.22	0.09
206-1	0-5cm	.	1.43	1.43
206-1	5-10cm	1.04	1.08	0.036
206-2	0-5cm	1.30	1.66	0.365
206-2	5-10cm	1.09	1.17	0.084

206-3	0-5cm	1.41	1.65	0.239
206-3	5-10cm	1.12	1.21	0.094
301-1	0-5cm	1.34	1.64	0.301
301-1	5-10cm	1.10	1.17	0.066
301-2	0-5cm	1.34	1.72	0.381
301-2	5-10cm	1.20	1.30	0.097
301-3	0-5cm	1.37	1.53	0.161
301-3	5-10cm	1.04	1.21	0.166
302-1	0-5cm	1.37	1.34	-0.032
302-1	5-10cm	1.03	1.17	0.143
302-2	0-5cm	1.49	1.29	-0.202
302-2	5-10cm	1.09	1.06	-0.025
302-3	0-5cm	1.26	1.53	0.266
302-3	5-10cm	1.00	1.07	0.069
303-1	0-5cm	1.23	1.49	0.259
303-1	5-10cm	1.00	1.04	0.037
303-2	0-5cm	1.32	1.44	0.117
303-2	5-10cm	1.14	1.14	-0.004
303-3	0-5cm	1.21	1.49	0.28
303-3	5-10cm	0.93	1.00	0.0666
304-1	0-5cm	1.25	1.29	0.041
304-1	5-10cm	1.01	1.08	0.07
304-2	0-5cm	1.24	1.52	0.277
304-2	5-10cm	0.98	1.09	0.1081
304-3	0-5cm	1.31	1.49	0.185
304-3	5-10cm	1.11	1.29	0.185
305-1	0-5cm	1.35	1.61	0.257
305-1	5-10cm	1.03	1.16	0.129
305-2	0-5cm	1.13	1.27	0.144
305-2	5-10cm	0.96	0.98	0.0188
305-3	0-5cm	1.27	1.49	0.218
305-3	5-10cm	1.04	1.10	0.062
306-1	0-5cm	1.25	1.47	0.216
306-1	5-10cm	1.00	1.13	0.126
306-2	0-5cm	1.12	1.57	0.454
306-2	5-10cm	0.92	1.10	0.1756
306-3	0-5cm	1.10	1.22	0.117
306-3	5-10cm	0.91	1.02	0.1086

2022 Slakes Raw Data Table

Slakes were only measured for the 0 to 5 cm depth. The smaller the number, the more stable the aggregate (stable 0-3, moderate 3-7, unstable 7+).

Plot	Slakes Score	Cover Crop	Phosphorus Application
101-1	0.8	CC	No Application
101-2	0.7	CC	No Application
101-3	1.2	CC	No Application
102-1	1.3	NC	No Application
102-2	1.1	NC	No Application
102-3	0.6	NC	No Application
103-1	0.5	CC	Fall Broadcast
103-2	0.7	CC	Fall Broadcast
103-3	0.6	CC	Fall Broadcast
104-1	0.8	NC	Spring Injected
104-2	0.4	NC	Spring Injected
104-3	3.8	NC	Spring Injected
105-1	0.6	CC	Spring Injected
105-2	0.7	CC	Spring Injected
105-3	1	CC	Spring Injected
106-1	0.9	NC	Fall Broadcast
106-2	0.8	NC	Fall Broadcast
106-3	0.5	NC	Fall Broadcast
201-1	0.4	CC	Spring Injected
201-2	0.8	CC	Spring Injected
201-3	0.7	CC	Spring Injected
202-1	0.3	CC	No Application
202-2	0.6	CC	No Application
202-3	0.3	CC	No Application
203-1	1.6	NC	Spring Injected
203-2	0.7	NC	Spring Injected
203-3	1.4	NC	Spring Injected
204-1	0.6	NC	Fall Broadcast
204-2	2	NC	Fall Broadcast
204-3	3.9	NC	Fall Broadcast
205-1	0.6	NC	No Application
205-2	0.9	NC	No Application
205-3	0.7	NC	No Application
206-1	0.4	CC	Fall Broadcast
206-2	0.5	CC	Fall Broadcast
206-3	1	CC	Fall Broadcast
301-1	0.3	CC	Fall Broadcast
301-2	0.7	CC	Fall Broadcast

301-3	4.7	CC	Fall Broadcast
302-1	0.9	NC	Fall Broadcast
302-2	1.9	NC	Fall Broadcast
302-3	0.8	NC	Fall Broadcast
303-1	2	NC	Spring Injected
303-2	0.2	NC	Spring Injected
303-3	0.7	NC	Spring Injected
304-1	5.3	NC	No Application
304-2	1.9	NC	No Application
304-3	1.6	NC	No Application
305-1	0.8	CC	Spring Injected
305-2	1.4	CC	Spring Injected
305-3	0.3	CC	Spring Injected
306-1	0.6	CC	No Application
306-2	2.6	CC	No Application
306-3	2.1	CC	No Application

Appendix C - Geometric Mean Diameter

Methods and Materials

Using the calculation from Kemper & Rosenau (1986) the geometric mean diameter (GMD) was calculated as shown below:

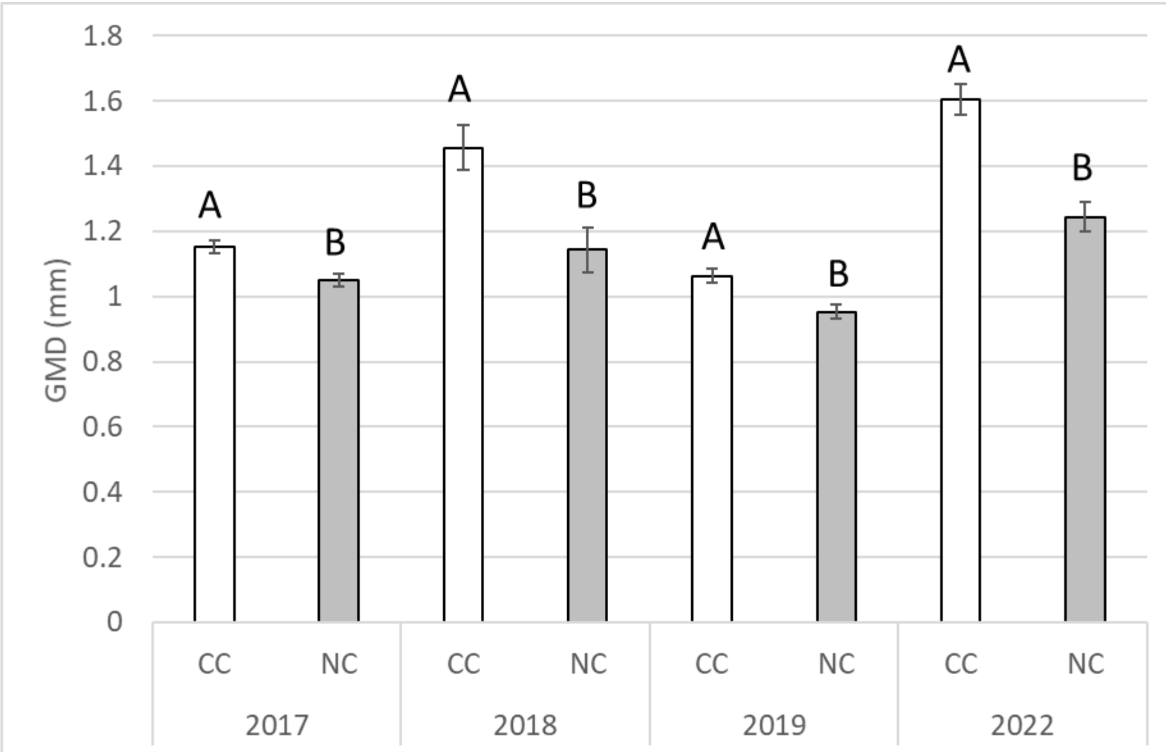
$$GMD = \exp [\Sigma_{(i=1, n)} w_i \log x_i / \Sigma_{(i=1, n)} w_i]$$

where w_i is the weight of aggregates in a size class with an average diameter x_i and $\Sigma_{(i=1, n)} w_i$ is the total weight of the sample.

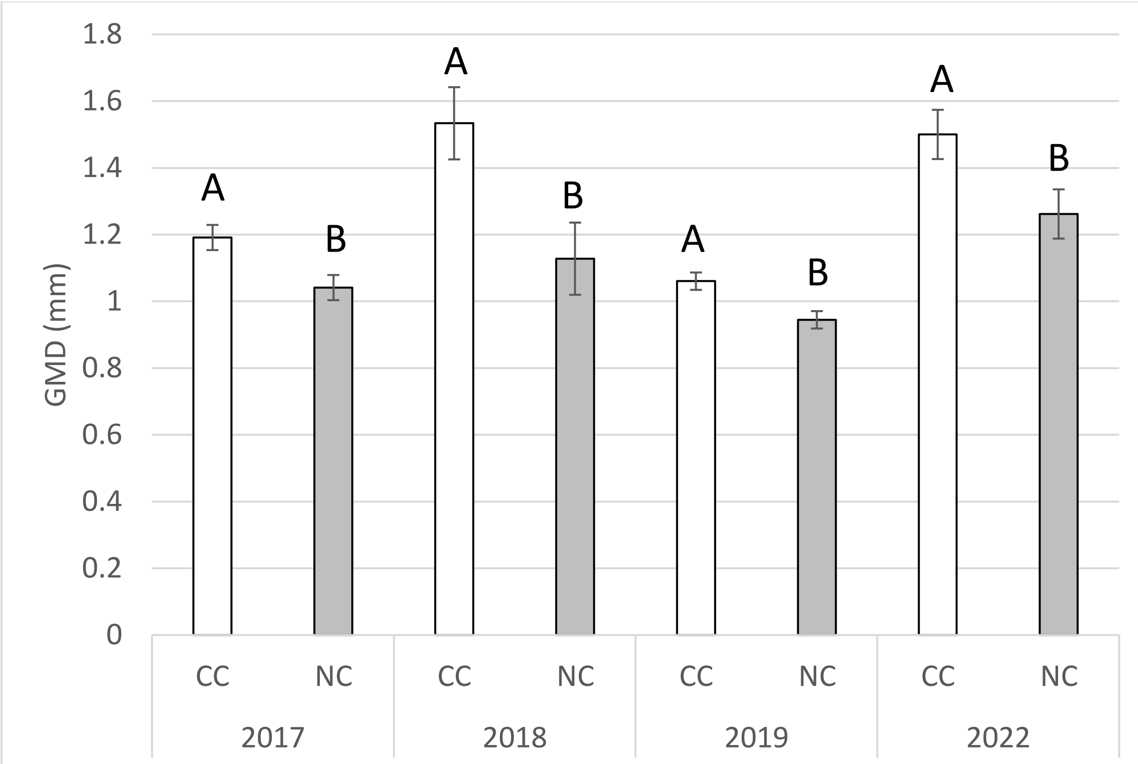
Results

Geometric mean diameter had a significant effect of cover in all years analyzed at both depths. In the 0 to 5 cm depth in 2017 there was a difference in means of approximately 0.1 mm, while in 2018 there was a difference in means of approximately 0.3 mm. The difference in means in 2019 was approximately 0.1 mm and in 2022 the difference in means was approximately 0.36 mm. In the 5 to 10 cm depth 2017 had a difference in means of approximately 0.15 mm, in 2018 the difference was approximately 0.4 mm. The difference in means in 2019 was 0.11 mm, while 2022 had a difference of approximately 0.2 mm. The GMD is as susceptible to influence from the cover crop and previous crop. Similar to MWD, in the GMD results 2017 and 2019 have a smaller effect of cover compared to 2018 and 2022. These results are again attributed to the amount of CC biomass previous crop residue, and how wet or dry the growing season of the CC or cash crop was. Blanco-Canqui & Ruis (2020) found GMD to be higher under CC than NC, showing that cover crops often increase aggregation in soils.

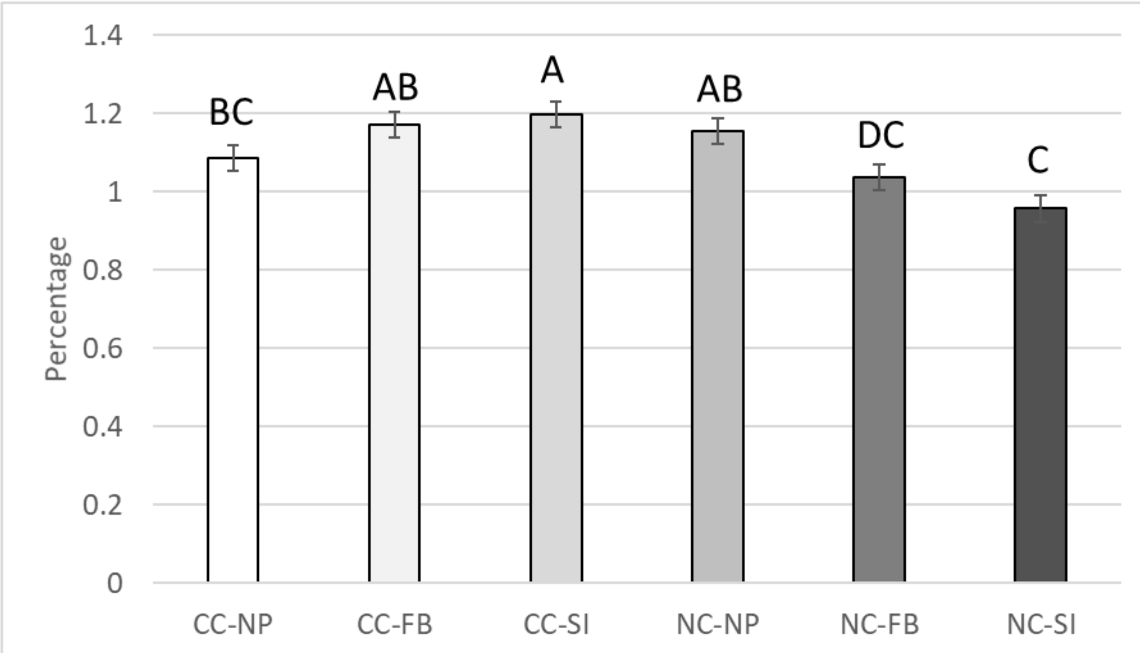
There was one interaction found of cover by fertilizer found for GMD in the 0 to 5 mm size fraction. The results of this interaction were not expected since NC-NP is statistically different from the other treatments which have both cover crops and a P treatment.



Geometric Mean Diameter (GMD) measured for cover crop (CC) and no cover crop (NC) plots in 2017, 2018, 2019, and 2022 at a 0 to 5 cm depth. The GMD was analyzed separately by year. Letters show statistical differences. No letters indicate no statistical difference. P= 0.0027 in 2017, p=<0.0001 in 2018, p= 0.0032 in 2019, and p=0.0001 in 2022. Error bars are standard error from SAS. Values were determined by SAS .



Geometric Mean Diameter (GMD) measured for cover crop (CC) and no cover crop (NC) plots in 2017, 2018, 2019, and 2022 at a 5-to 10 cm depth. The GMD was analyzed separately by year. Letters show statistical differences. No letters indicate no statistical difference. P=0.0141 in 2017, p=0.0004 in 2018, p=0.0007 in 2019, and p=0.0331 in 2022. Means separated at $p < 0.05$. Error bars are standard error from SAS. Values were determined by SAS.



Cover by fertilizer interaction for Geometric Mean Diameter (GMD) at the 0 to 5 cm depth in 2017. Letters show statistical differences. Means separated at $p < 0.05$. P= 0.0017. Treatment cover crop and spring injected (CC-SI) P management strategy is statistically different from the other treatments. Error bars are standard error from SAS. Values were determined by SAS.

Conclusions

In the geometric mean diameter calculation, it was found that cover crops were consistently higher than treatments without cover crops. In both depths all years analyzed had a significant effect of cover. Since GMD is a different calculation but essentially shows the same results, e.g., cover crops are greater than no cover crop plots in relation to aggregation. The greater effect of cover on GMD over time shows that cover crops increase aggregation.

Raw Data Tables

Plot	Depth	2017	2018	2019	2022
101-1	0-5cm	0.980663	1.42002	1.143	1.643
101-2	0-5cm	1.120413	.	0.961	1.516
101-3	0-5cm	1.206301	1.95144	0.961	1.637
102-1	0-5cm	1.211404	1.28293	0.935	1.317
102-2	0-5cm	1.102378	1.07943	0.975	1.149

102-3	0-5cm	1.001747	1.0697	1.097	1.283
103-1	0-5cm	1.086289	.	1.169	1.856
103-2	0-5cm	1.218034	1.572	1.1	1.514
103-3	0-5cm	1.332225	1.47061	1.084	1.982
104-1	0-5cm	0.864432	1.10358	0.874	1.234
104-2	0-5cm	0.900074	1.2707	0.939	1.013
104-3	0-5cm	0.998247	1.28608	1.01	1.132
105-1	0-5cm	1.290315	1.40129	1.087	1.288
105-2	0-5cm	1.273001	1.14199	1.628	1.83
105-3	0-5cm	1.202158	1.879	1.013	1.297
106-1	0-5cm	1.090388	1.33288	1.003	1.263
106-2	0-5cm	1.085484	1.10377	0.908	1.282
106-3	0-5cm	0.939243	1.04133	0.854	1.34
201-1	0-5cm	1.433834	1.48519	1.025	1.974
201-2	0-5cm	1.21958	1.46503	1.095	1.461
201-3	0-5cm	1.075247	.	1.153	1.473
202-1	0-5cm	0.970393	1.59052	0.933	1.565
202-2	0-5cm	0.979427	1.38254	1.068	1.334
202-3	0-5cm	1.098723	1.86901	1.109	1.975
203-1	0-5cm	0.956008	1.33179	0.987	1.272
203-2	0-5cm	0.958225	1.25925	1.051	1.138
203-3	0-5cm	0.940342	0.98848	1.134	1.368
204-1	0-5cm	1.038151	1.01871	0.651	1.192
204-2	0-5cm	0.99556	1.00802	0.995	1.045
204-3	0-5cm	1.117993	1.29232	0.909	1.259
205-1	0-5cm	1.293751	1.24517	0.957	1.449
205-2	0-5cm	1.109938	1.37469	0.871	1.378
205-3	0-5cm	.	1.21807	0.922	1.278
206-1	0-5cm	.	1.2873	1.028	1.454
206-2	0-5cm	1.299854	1.85198	1.03	1.27
206-3	0-5cm	1.108677	1.46098	0.911	1.285
301-1	0-5cm	1.030329	1.22051	0.909	1.727
301-2	0-5cm	1.098757	1.34713	1.202	1.792
301-3	0-5cm	1.160491	1.33315	1.013	1.904
302-1	0-5cm	1.020001	1.10589	0.88	1.316
302-2	0-5cm	1.056319	1.05746	0.925	1.478
302-3	0-5cm	0.996812	1.04609	0.953	1.241
303-1	0-5cm	1.042663	0.97926	1.001	1.117
303-2	0-5cm	0.938122	1.03612	0.951	1.178
303-3	0-5cm	1.013958	1.04279	1.037	1.293

304-1	0-5cm	1.104598	1.20949	0.976	1.134
304-2	0-5cm	1.229807	0.94642	0.837	1.304
304-3	0-5cm	1.140861	1.14848	1.104	1.152
305-1	0-5cm	1.236366	1.33135	1.058	1.658
305-2	0-5cm	1.024758	1.23782	0.986	1.804
305-3	0-5cm	1.032093	1.20492	1.054	1.758
306-1	0-5cm	.	1.32769	.	1.574
306-2	0-5cm	0.985485	1.26666	1.015	1.267
306-3	0-5cm	1.290453	1.16942	0.974	1.511

Plot	Depth	2017	2018	2019	2022
101-1	5-10cm	1.141886	1.762654	1.187	1.691
101-2	5-10cm	1.079056	1.696434	1.092	1.178
101-3	5-10cm	1.142929	1.927378	1.092	1.879
102-1	5-10cm	1.226754	1.183971	0.834	1.273
102-2	5-10cm	1.382853	1.063163	0.987	1.304
102-3	5-10cm	1.013151	1.0957	1.076	1.673
103-1	5-10cm	1.585111	1.752898	1.168	1.82
103-2	5-10cm	0.991254	2.012728	1.046	2.072
103-3	5-10cm	1.522277	1.678476	1.084	1.899
104-1	5-10cm	0.971372	1.251573	0.956	1.191
104-2	5-10cm	0.954938	1.403734	1.034	1.12
104-3	5-10cm	0.974856	1.637984	0.879	1.213
105-1	5-10cm	1.269214	1.633239	1.146	1.279
105-2	5-10cm	1.495619	1.194926	0.959	1.538
105-3	5-10cm	1.082238	1.866029	1.05	1.315
106-1	5-10cm	0.978425	1.672172	.	1.123
106-2	5-10cm	1.008162	1.317469	.	1.5
106-3	5-10cm	0.972346	1.200013	1.093	1.796
201-1	5-10cm	1.348798	1.851662	1.094	1.848
201-2	5-10cm	1.193072	1.596192	1.136	1.773
201-3	5-10cm	0.994814	1.935806	1.102	1.709
202-1	5-10cm	0.990556	1.584053	1.032	1.403
202-2	5-10cm	1.264361	1.216512	1.136	1.272
202-3	5-10cm	1.077532	1.464109	1.031	1.272
203-1	5-10cm	1.031228	1.070627	0.873	1.22
203-2	5-10cm	0.982349	1.077441	0.916	1.116
203-3	5-10cm	0.96829	0.907116	0.98	1.141
204-1	5-10cm	1.028613	0.929349	0.863	0.894
204-2	5-10cm	1.079658	0.840612	1.007	1.076

204-3	5-10cm	0.891867	0.982611	0.854	1.015
205-1	5-10cm	1.072169	1.124042	0.977	1.42
205-2	5-10cm	1.030619	1.225469	0.974	1.382
205-3	5-10cm	.	1.225946	0.902	1.499
206-1	5-10cm	.	1.126955	0.932	1.237
206-2	5-10cm	0.944751	1.267014	0.928	1.347
206-3	5-10cm	1.127843	1.921105	0.989	1.291
301-1	5-10cm	1.032466	.	0.997	1.612
301-2	5-10cm	1.37874	1.324059	0.946	1.332
301-3	5-10cm	.	.	0.946	1.277
302-1	5-10cm	1.101344	1.058295	0.912	1.247
302-2	5-10cm	1.170753	1.082019	0.916	1.146
302-3	5-10cm	0.890135	1.036909	0.844	1.017
303-1	5-10cm	0.950243	0.914678	.	1.2
303-2	5-10cm	1.00597	1.007144	0.841	1.396
303-3	5-10cm	1.128449	0.990016	0.947	1.396
304-1	5-10cm	1.081686	1.062196	1.009	1.037
304-2	5-10cm	.	0.954549	0.821	1.205
304-3	5-10cm	.	1.134778	0.929	1.468
305-1	5-10cm	1.11225	1.416609	1.183	1.619
305-2	5-10cm	0.985485	0.932687	1.089	1.274
305-3	5-10cm	.	1.324931	0.937	1.3
306-1	5-10cm	.	1.585462	1.197	1.526
306-2	5-10cm	1.519742	1.403838	0.992	1.052
306-3	5-10cm	1.222393	1.282244	1.140	1.691