Texture Analyses of Grid Samples Under a Center Pivot

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Introduction and Objectives

Intensive grid sampling is a widely used approach for assessing soil fertility, but it often focuses primarily on macronutrient analyses such as nitrogen (N), phosphorus (P), and potassium (K). While this provides valuable insights for nutrient management, it overlooks other critical soil characteristics that can influence crop growth and yield. Micronutrient concentrations, soil texture, and other physical and chemical properties play essential roles in soil health and plant nutrient uptake, yet they are frequently omitted from standard grid sampling protocols.

A previously created ¼-acre grid of the Warrington Irrigation Research Farm provided a detailed view of macronutrient distribution across the field. Interestingly, micronutrient maps generated from the same sampling effort revealed patterns that were just as striking as those of macronutrients. However, the spatial variability observed in micronutrient concentrations did not clearly align with management history or expected soil fertility gradients. This suggests that underlying factors, such as differences in parent material, may be driving these variations.

To further investigate these patterns, a subset of soil samples was be analyzed for texture to explore potential relationships between particle size distribution and micronutrient concentrations. Soil texture influences numerous soil properties, including cation exchange capacity, nutrient availability, and water retention. Understanding these relationships can provide valuable insights into the farm's soil characteristics and may also help predict areas of higher or lower susceptibility to nematode infestations. By incorporating soil texture analysis into the existing grid sampling framework, this study aims to improve interpretations of nutrient distribution and enhance precision management strategies for the research farm.

Methods

Soil sampling was conducted in 2022 and again in 2024 on a ¼-acre grid at the Warrington Irrigation Research Farm in Harbeson, DE, to assess soil nutrient and physical properties across the field. From these datasets, a subset of soil samples was selected for textural analysis and sent to the Penn State Soil Testing Lab, where sand, silt, and clay fractions were quantified. This analysis provided a more detailed understanding of soil physical characteristics that may influence nutrient distribution and water dynamics.

Once the soil texture data were obtained, they were integrated into ArcGIS for spatial analysis. The data were interpolated using kriging to generate high-resolution raster maps of sand, silt, and clay content across the research farm. These maps were then compared to existing macronutrient and micronutrient datasets, as well as soil pH measurements, to identify potential correlations between soil texture and nutrient availability. Additionally, a digital elevation model (DEM) was incorporated into the analysis to assess how topography influenced the distribution of soil texture and nutrient patterns.

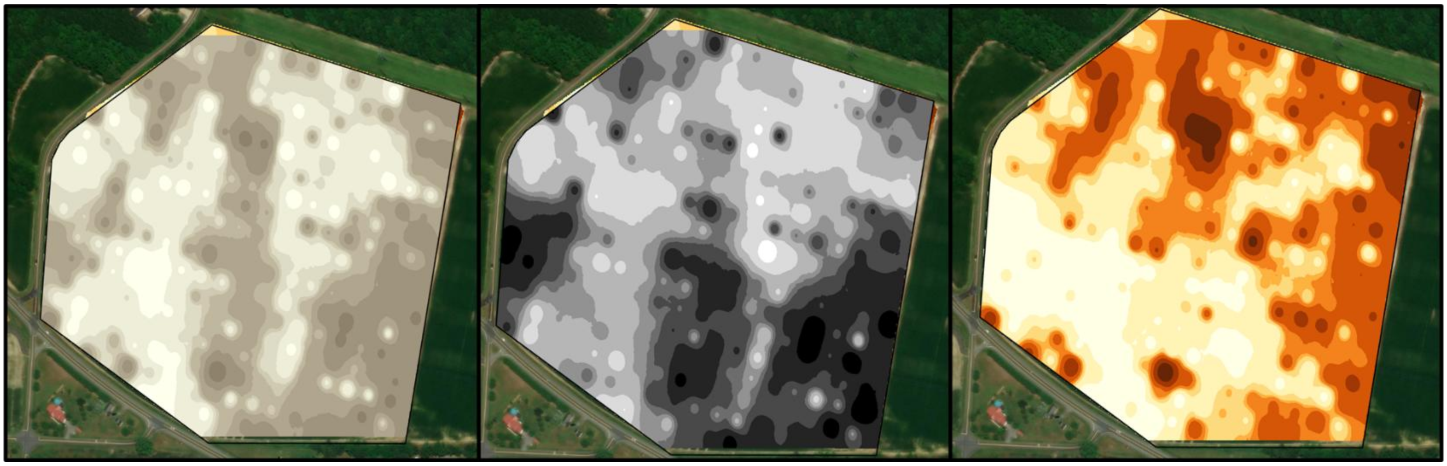

Figure 1: Sand, silt, and clay content mapped across the Warrington Irrigation Research Farm. Light colors are more sand, while dark black is higher silt, and dark red is greater clay.

Results and Discussion

Texture vs Nutrient Comparisons

The analysis of soil texture correlations with various nutrients and elements in coastal plain soils provides significant insights into the interactions between particle size and nutrient availability. In sandy soils, there were several notable negative correlations with essential nutrients. For instance, potassium (K, -0.50), calcium (Ca, -0.33), and magnesium (Mg, -0.47) exhibited negative correlations with sand content, indicating that sandy soils have a reduced capacity to retain these vital nutrients. This is likely due to their inherently lower cation exchange capacity (CEC) compared to finer-textured soils, which are more capable of holding onto positively charged nutrients. Similarly, manganese (Mn, -0.31) and sulfur (S, -0.16) also showed negative correlations with sand content, suggesting that these micronutrients may be less available in sandy soils. Furthermore, aluminum (Al, -0.22) had a negative correlation with sand, which could be indicative of lower aluminum levels in sandy soils, but in certain conditions, especially in acidic soils, aluminum can become toxic to plants.

Table 1: Correlation Table of Nutrient Availability with Sand, Silt, and Clay Content: pH, Phosphorus, Potassium, Calcium, Magnesium, Manganese, Zinc, Copper, Iron, Boron, Sulfur, Sodium, and Aluminum.

	pH	**Phos**	**K**	**Ca**	**Mg**	**Mn**	**Zn**	**Cu**	**Fe**	**B**	**S**	**Na**	**Al**
Sand	**-**	-	-0.50	-0.33	-0.47	-0.31	-	-	-0.23	-0.29	-0.16	0.13	-0.22
Silt	0.29	-0.14	0.41	0.37	0.34	0.18	-	0.21	0.22	0.35	-	0.02	-0.14
Clay	-0.26	-	0.35	0.13	0.38	0.30	-	-0.22	0.13	-	0.35	-0.23	0.52

In contrast, finer-textured soils, such as those with higher silt content, demonstrated stronger correlations with nutrient retention. Silt showed positive correlations with several key nutrients, including phosphorus (Phos, 0.29), potassium (K, 0.41), calcium (Ca, 0.37), magnesium (Mg, 0.34), and manganese (Mn, 0.18), reflecting the greater ability of silt to retain these elements due to its higher CEC and surface area. This finding suggests that silt-rich soils are better at holding onto and providing access to essential macronutrients and micronutrients for plant growth. Copper (Cu, 0.21) and iron (Fe, 0.22) also showed positive correlations with silt, highlighting that these micronutrients are more available in finer soils, or are part of the original parent material.

Clay soils, known for their higher CEC, demonstrated positive correlations with several nutrients as well, further confirming that finer soils generally retain more nutrients. For example, magnesium (Mg, 0.38), manganese (Mn, 0.30), and sulfur (S, 0.35) all exhibited positive correlations with clay content, which is consistent with the notion that clay particles, with their greater surface area, hold onto nutrients more effectively. However, not all nutrients exhibited such positive correlations in clay soils. For example, potassium (K, 0.35) and phosphorus (P, -0.14) showed weaker or negative correlations with clay, indicating that while clay may retain some nutrients more effectively, its impact on others could be less pronounced. For micronutrients, it is likely that the clay may also be the source ad reason Mn is higher in those textures.

These findings underscore the important role that soil texture plays in determining nutrient availability. Sandy soils, with their lower nutrient retention capacity, may require more frequent fertilization to maintain nutrient availability, while finer soils like those with higher silt and clay content are better equipped to hold and release nutrients to plants over time. These insights are critical for designing effective soil fertility management strategies in coastal plain soils, especially in areas where nutrient leaching can be a concern. Additionally, understanding these correlations can help optimize the use of fertilizers and lime in these environments, ensuring that crops receive the nutrients they need while minimizing environmental impacts.

Soil Property Comparisons

The relationships between particle size and various soil properties showed distinct trends. Elevation was weakly correlated with both sand (0.19) and silt (0.17), while a stronger negative correlation was observed with clay (-0.51). This suggest clay is in lower landscape positions, potentially depressions. In terms of Veris-EC, sand exhibited a negative correlation (-0.30), indicating that sandy soils generally have lower electrical conductivity at shallower depths. On the other hand, silt displayed positive correlations (0.48 and 0.50, respectively), reflecting the ability of finer soils to retain more ions and therefore exhibit higher conductivity. Clay however, had no relationship.

Table 2: Correlation Table of Soil Properties and Nutrient Indicators: Elevation, Veris-EC, pH, Buffer pH, Soil Organic Matter (SOM), Cation Exchange Capacity (CEC), Base Saturation (BS), and Percent Saturation (Psat) with Sand, Silt, and Clay Content (Significance at p = 0.05**)**

	Elevation	**Veris-EC**	**pH**	**Buffer pH**	**SOM**	**CEC**	**BS**	**Psat**
Sand	0.19	-0.30	-	0.30	-0.37	-0.51	-	0.22
Silt	0.17	0.48	0.29	-	-	0.23	0.32	-0.12
Clay	-0.51	-	-0.26	-0.61	0.52	0.57	-0.34	-0.22

When examining pH, no significant correlation was found with sand, whereas clay had a negative correlation (-0.26), suggesting that clay-rich soils tend to have slightly lower pH values. This may be attributed to the greater retention of acidic compounds in these soils. The relationship between buffer pH and soil texture was more pronounced, with silt showing a positive correlation (0.29), indicating that finer soils are more effective at buffering pH levels over time. In contrast, clay exhibited a strong negative correlation (-0.61), which may reflect its tendency to retain more acidic compounds, resulting in lower buffer pH values.

For organic matter (OM), sand was negatively correlated (-0.51), consistent with the lower organic matter content typically found in sandy soils. Clay, however, showed a positive correlation (0.52), suggesting that clay-rich soils retain more organic material due to their higher cation exchange capacity. Cation exchange capacity (CEC) also followed a similar pattern, with sand showing a negative correlation (-0.51) and clay a positive correlation (0.57). This indicates that clay-rich soils have a higher ability to hold onto nutrients and other cations, improving their fertility.

For base saturation (BS), silt exhibited a positive correlation (0.23), while clay showed a negative correlation (-0.34). This suggests that silt-rich soils may have better base saturation, while clay-rich soils might retain more acidic cations, leading to lower base saturation. Finally, Psat was weakly positively correlated with sand (0.22), while both silt and clay showed negative correlations (-0.12 and -0.22, respectively). These patterns suggest that sandier soils may have slightly higher Psat values compared to their finer-textured counterparts. P-sat is calculated based on Al and Fe content, which are higher in clay soils.

The analysis reveals that soil texture significantly influences key soil properties in coastal plain environments. Sandy soils, with lower cation exchange capacity (CEC), showed negative correlations with Veris-EC (shallow and deep), organic matter (OM), and CEC, indicating their limited ability to retain nutrients and water. In contrast, finer soils, particularly those with higher silt and clay content, demonstrated positive correlations with these properties, suggesting better nutrient and moisture retention due to their higher surface area and CEC. Additionally, clay-rich soils exhibited stronger negative correlations with buffer pH, highlighting the need for careful management of soil amendments like lime to neutralize acidity. These findings emphasize the importance of soil texture in managing soil fertility, nutrient availability, and pH, especially in coastal plain areas where tailored fertilizer and lime applications can optimize plant growth.

Conclusions

The analysis of soil texture and nutrient interactions in coastal plain soils emphasizes the significant role that soil characteristics play in nutrient availability and retention. Sandy soils, with their lower cation exchange capacity (CEC), tend to have weaker nutrient retention, making them more susceptible to nutrient leaching. As a result, they may require more frequent fertilization to maintain optimal nutrient levels. On the other hand, soils with higher silt and clay content show a stronger ability to retain essential nutrients, as these finer-textured soils have higher CEC, which helps in holding onto and releasing nutrients more effectively. This makes finer soils better equipped to support plant growth by providing a more stable nutrient environment. Understanding these relationships is crucial for optimizing fertilization practices and improving soil health and crop productivity in coastal plain soils.